A STUDY ON THE ENVIRONMENT AND TRANSPORTATION WITH THE RAPID ECONOMIC DEVELOPMENT IN THE SOUTH CHINA

Chunlu Liu* and Yoshito Itoh**

* Department of Civil Engineering, Nagoya University, Nagoya 464-8603
** Center for Integrated Research in Science and Engineering, Nagoya University, Nagoya 464-8603

ABSTRACT: The transportation sector is a principal source of the greenhouse gas emission, in particular CO_2, and is therefore a main contributor to the potential climate change. In the developing countries, the rapid economic development usually accompanies with their rapid urbanization, industrialization and mobilization, which result in the increase of passenger transportation, freight transportation, and number of vehicles although the transportation sectors in such developing regions may not have been the dominant sector of CO_2 emissions. The rapid development of some developing regions such as the Guangdong province in the south China has drawn much attention from various fields such as sustainable development and global environment. A comprehensive study on the economic development, transportation demand, energy consumption, and environment effect is very profitable for the global and local environment as well as to the local economic development. This research aims to study the environmental and transportation problems due to the rapid economic development in the southern China by means of the energy consumption. The findings from this research are helpful for the government decision-makers to develop the economy and transportation policies by incorporating the environmental effects and energy consumption.

KEYWORDS: Economic Development, Energy Consumption, Global Environment, and Transportation Activities

1. INTRODUCTION

The transportation sector is a principal source of the greenhouse gas emission, in particular CO_2, and is therefore a main contributor to the potential climate change. In the world wide, transportation has been a center of focus in the policy debate surrounding climate change as mentioned in the publication made by the European Conference of Ministers of Transport (1997). What to do about transportation-related emissions has been difficult for policy makers to come to terms with. Rapidly rising demand for mobility around the world, especially for the road transportation, has rendered strong policy action difficult to take. Transportation accounted for 27.7% and 29.1% of CO_2 emissions of all OECD countries in 1990 and 1994, respectively, and is rapidly becoming the dominant source of CO_2 emissions worldwide. This trend is corresponding to the increase in noxious emissions such as NO_X, CO, volatile organic compounds and particulate matter, which may be only partially offset by the introduction of catalytic converters. Figure 1 shows the percentages of CO_2 emissions from the transportation sector of several countries in 1990 and 1994 according to the publication made by the European Conference of Ministers of Transport (1997). The environmental effects of this trend are becoming manifest, particularly in the urban areas, with noxious emission levels exceeding prescribed health limits. According to the atmospheric emission inventory in London (Ackerman and Jefferson 1998), the road transportation sector is now the only major source of urban air pollution in London, which causes 75% of NO_X, 83% of Benzene, 77% of particulate, 97% of CO and 53% of volatile organic compounds, and 29% of CO_2 emissions on the top of all sectors.

In the developing countries, the rapid economic development usually accompanies with their urbanization, industrialization and mobilization, which result in the increase of passenger transportation, freight transportation, and number of vehicles although the transportation sector in such developing countries may not have been the dominant sector in CO_2 emissions. For example, the CO_2 emission from the transportation sector in China is relatively low, which is only about 4% in 1995 (Johnson et al. 1996). However, attention has to be paid to the environmental problems

induced from the transportation sector in these countries due to its possible rapid increase. The Guangdong province in the South China as shown in Fig. 2 has been achieving rapid economic growth since the early 1980s because of its proximity to Hong Kong and Macao, and has been designed as a window of showing the reform and open-door policies in China. It has drawn much attention from various fields such as sustainable development and global environment (Eng 1997, Liu and Itoh 1999, Wu 1998). This research aims to study the environmental and transportation problems due to the rapid economic development in the southern China by means of the energy consumption. Such a study is profitable for the global and local environment as well as to the local economic development.

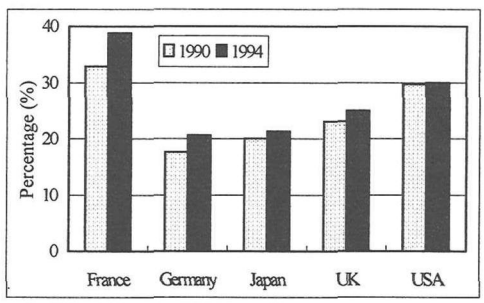

Figure 1: Percentages of CO_2 Emission in Transportation Sector

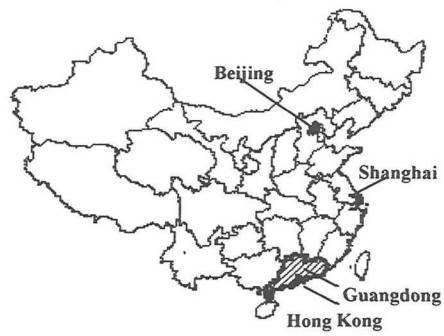

Figure 2: Location of the Guangdong Province in China

2. AIR POLLUTION PROBLEMS IN CHINA

2.1 Worldwide Comparison of CO_2 Emissions

In 1995, the total CO_2 emissions from fossil fuel burning and cement manufacturing were around 22.7 billion tons, of which China accounted for about 14% and was the second largest CO_2 emitter following the United States of America that accounted for 24% of CO_2 emission in the world (World Resources Institute 1998). Per capita CO_2 emission from China was 2.7 metric tons, compared with 20.5 tons of the United States of America, 9.0 tons of Japan, and 12.2 tons of the former Soviet Union. Figure 3 shows the comparison per capita CO_2 among several countries in four years including 1989, 1991, 1992 and 1995. Compared to other countries, the per capita CO_2 is still rather low in China. However, since China will continue to depend on coal as a main energy source, it is likely to become the world's largest emitter early in the next century (Eliasson and Xue 1997).

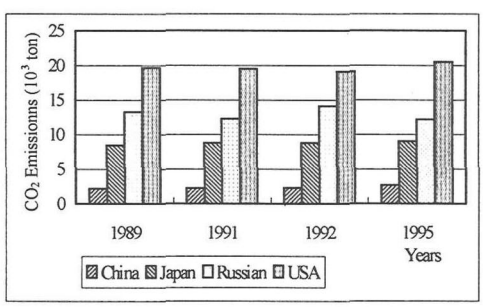

Figure 3: Changes of Per Capita CO_2

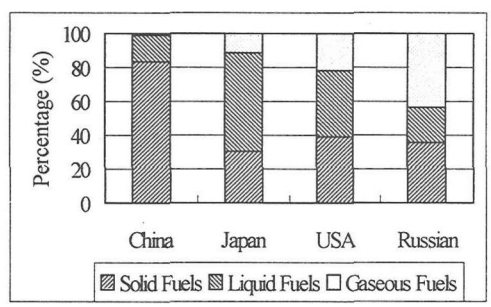

Figure 4: CO_2 Emission from Various Types of Fossil Fuels

The burning of fossil fuels and other human activities are changing the balance of CO_2 and other heat-trapping gases in the atmosphere. The greenhouse effect has the potential to alter the climate of the earth in a relatively short span of time dramatically. At current emission rates, global atmospheric CO_2 concentrations will double by the middle of the twenty-first century (Johnson et al. 1996). According to the Intergovernmental Panel on Climate Change (IPCC), this will result in a warming of the atmosphere of the earth by 1.5 to 4.5 degrees C and cause global mean sea levels to rise by 0.25 to 0.50 meters. Figure 4 shows the distribution of carbon dioxide from three dominant sources of fuels in several countries in 1995. The representative of these types of fossil fuels are coal, oil and natural gas, respectively. In China, the widespread use of coal and the fact that coal has a higher carbon content than oil or gas create large emissions of carbon dioxide. The combustion of fossil fuel was responsible for 95% of the carbon dioxide emissions, of which 80% originated from the use of coal.

It has been mentioned that the energy use varies with GDP (Proops et al. 1993). This assertion is also valid for China and the Guangdong province of the south China in the previous development procedure (Liu and Itoh 1999). While China has enjoyed a great success in energy conservation, its energy use per unit of GDP is still among the highest in the world. According to the World Resources Institute (1998), the energy intensity in various countries measured as energy consumption per unit of GDP is shown in Fig. 5. In 1995, the energy intensity in China (49.18 million joules per US$) is 8.35 times that (5.89 million joules per US$) of France, 8.79 times that (5.59 million joules per US$) of Germany, 13.43 times that (3.66 million joules per US$) of Japan, 5.99 times that (8.21 million joules per US$) of United Kingdom, and 3.71 times that (13.27 million joules per US$) of the United States of America.

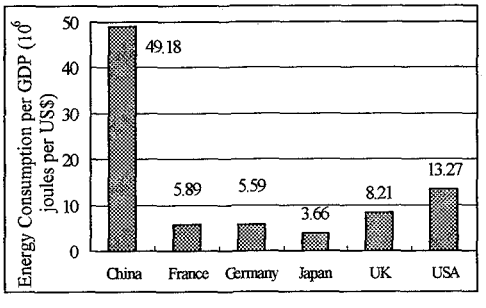

Figure 5: Comparison of Energy Consumption in Various Countries in 1995

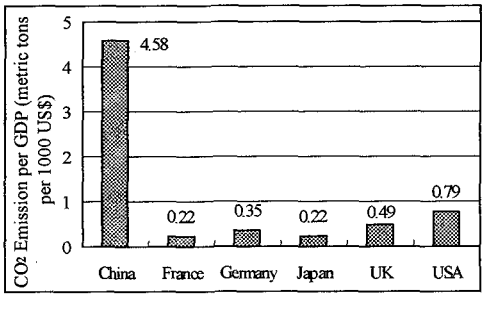

Figure 6: Comparison of CO_2 Emission in Various Countries in 1995

Due to the difference of energy efficiency in the GDP generation, the CO_2 emission per unit of GDP is also quite different in such countries as shown in Fig. 6. In China, France, Germany, Japan, UK, and USA, the generation of 1000 US$ equivalent GDP will cope with the CO_2 emission of 4.58, 0.22, 0.35, 0.22, 0.49, and 0.79 metric tons in 1995, respectively. The CO_2 emission in China is 20.67 times that of France, 13.24 times that of Germany, 20.75 times that of Japan, 9.33 times that of United Kingdom, and 5.82 times that of the United States of America. Therefore, a great effort is still quite necessary to conserve the energy consumption and reduce the CO_2 emission with the increase process of GDP in China.

It is obvious that the difference of the CO_2 emission per unit of GDP between China and the developed countries as shown in Fig. 6 is even much larger than the corresponding difference of the energy consumption per unit of GDP as shown in Fig. 5. This implied that more CO_2 emission is generated due to the consumption per unit of energy in China than in the developed countries. The numerical comparison in these countries is shown in Fig. 7. One main reason of higher CO_2 emission is that the dominant energy supply in China is the solid fuel that generates more CO_2 emission. Figure 8 compares the distribution of energy supplies in several countries in 1995 according to the World Resources Institute (1998). The main solid fuel, liquid fuel and gaseous fuel are coal, crude petroleum, and natural gas, respectively. The primary electricity refers to electricity generated by noncombustible energy sources and includes nuclear, wind, tidal, wave, solar, geothermal, and hydroelectric power sources. The primary electricity is as low as about 2% of the

total energy consumption in China in 1995, which were however more than 90% of energy in both France and Japan.

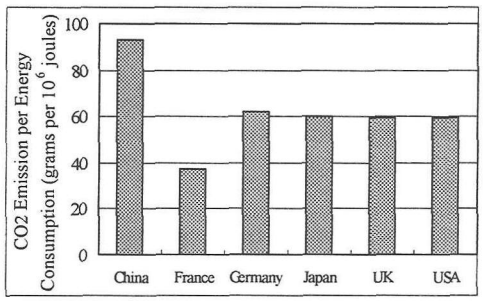

Figure 7: Comparison of Energy Consumption in Various Countries in 1995

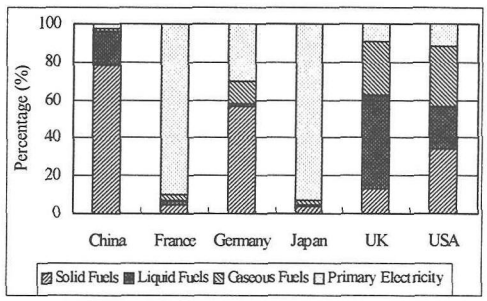

Figure 8: Energy Supply Pattern in Various Countries in 1995

It can be noticed that in the previous years the solid fossil fuel coal supplies the main energy. It may be the fundamental strategy for China to decrease the greenhouse gas emissions by reducing the proportion of carbon-intensive energy source in the energy mix. However, over the short term, there are limits to the extent of substitution for coal because of the long period needed to develop alternative technologies, the abundance of low-cost coal in China, and the magnitude of the energy supply that will be needed to fuel the economic expansion in China. Further, the primary energy demand in China is expected to grow at 3.6% per year by 2020 as per the International Energy Agency (1998). This increase is lower than the historical growth rate of 5.5% from 1971 to 1995 because the economic growth will not be so high as before. As a result, the current share of solid fuel will decline by about 10% to be 67% by 2020. However, the solid fuel still remains the dominant. The main driver of solid fuel demand is power generation.

2.2 Distribution of SO_2 Emissions

Further, the average sulfur content of consumed coal in China is 1.35% by weight. In 1996, the total sulfur dioxide emission is 13.6 millions tons, which increased from 12.93 millions tons in 1993. Responsible for such large sulfur dioxide (SO_2) emission is not only the high sulfur content of the coal, and the fact that coal plays such a dominant role in the energy supply but also the inefficiency of the majority of power plants in China. Since a large number of Chinese power plants are located on the east coast, 45% of sulfur dioxide emissions originated on only 8% of the total land surface. In addition, many homes in the northern half of China are heated by coal for several months of the year, which creates additional sulfur dioxide emissions. Figure 9 shows the sulfur dioxide emissions by sector in China in 1996 according to the China Statistical Yearbook (1997). Among these sectors, the electric utilities are the largest emitter accounting for about 53 % of the total sulfur dioxide emissions in China.

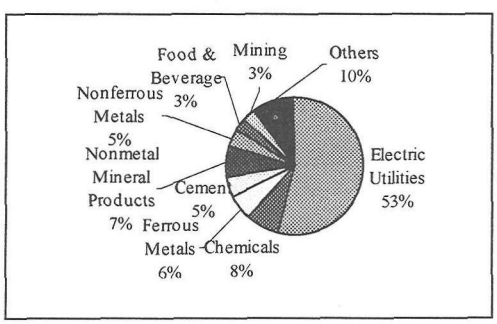

Figure 9: SO_2 Emissions by Sectors in China in 1996 (Total: 13.6 millions tons)

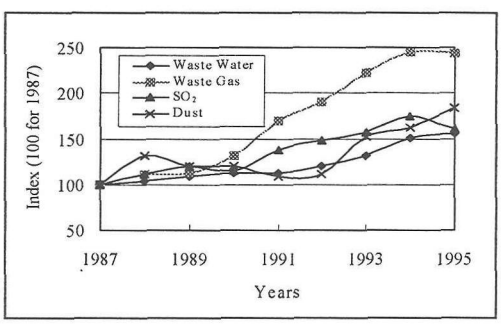

Figure 10: Changes of Waste Emissions in the Guangdong Province

The industrial air and water pollution in China has been major concerns for the past two decades. A recent assessment by the Chinese Research Academy of Environmental Science has identified industrial pollution as the source of approximately 70% of China's total environmental pollution. Current estimates of human health damage from urban air pollution are very high for some areas. Such high levels of damage are primarily due to the rapid growth of pollution-intensive industries. The pollution intensity of output in certain key emission categories has dropped sharply since 1985, at least in factories, which are regulated by the environmental agencies. Continued rapid decline in pollution intensity will be necessary just to stay even with the pace of industrial growth. Moreover, recent findings on pollution related health damage suggest that considerable improvement in ambient quality would be necessary. In fact, it is very difficult to face with the simultaneous need to reduce pollution and increase industrial output and employment, especially in the developing regions due to the limitation of the fund, equipment, labor capacity, and technology, and so on. Figure 10 shows the changes of the related indices of several types of industrial wastes including the waste water, waste gas, SO_2, and dust by taking the values in 1987 as 100 in the Guangdong province. Among them, the waste gas increased fastest and the transportation sector is further the main source of the waste gas.

3. TRANSPORTATION DEMAND AND SUPPLY ANALYSES IN THE SOUTH CHINA

In most developed countries, although the industrial use has reached the saturation point or is declining, the transportation demand has been continuing to increase (Hayashi and Roy 1996). Therefore, the CO_2 emission from the transportation takes an increasing percentage in such countries. In major developing countries, the transportation demand and supply also continue to increase in order to cope with the rapid economic growth although the percentage share of the CO_2 emission from the transportation may not be as high as in the developed countries. This is because the air pollution from both the industry and power generation sectors is huge in the developing countries.

3.1 Demands of Various Transportation Modes

In the Guangdong province, the components of transportation infrastructure construction investment in the railways, highways, waterways, and airways are 14.4%, 47.7%, 24.4%, and 13.5% respectively in 1992. These percent rates changed to 11.7%, 56.5%, 8.5%, and 23.3% in 1996. As a result, the length of civil aviation routes increased by as much as five times from 1989 to 1996 in the Guangdong province. Figures 11 and 12 show the changes indices of passengers and freights in various transportation modes including the airway, railway, highway and waterway in the Guangdong province from 1989 and 1996.

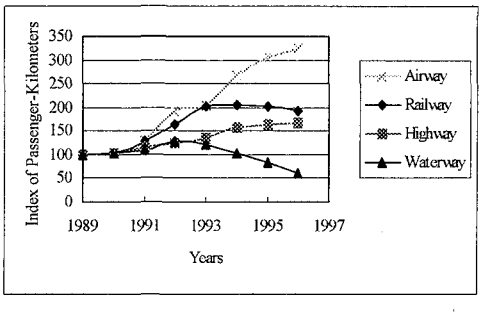

Figure 11: Change of Passengers of Various Transportation Modes in Guangdong Province

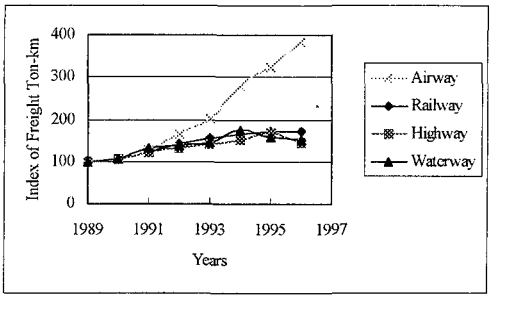

Figure 12: Change of Freights of Various Transportation Modes in Guangdong Province

The values of passengers and freights in various transportation modes in 1989 are designated to be 100 in Figs. 11 and 12 respectively. High increasing freight intensity and a low increasing passenger intensity happened as 113.6% and 86.3% respectively between 1989 and 1996. Air

transport increased faster than the other three ways in both the freight traffic turnover volume and passenger traffic. In terms of the turnover volume of freight traffic, the volume of water transportation decreased from 1992. The increasing speeds of the freight and passengers are near in railways and highways in 1996. It should be noticed that the railway and waterway are still the highly dominant modes to transport freights although they took effects of less than 30% in transporting passengers in 1996. It can be predicted that the highways and airways will become more and more important for the movement of passengers as the economy in the Guangdong province continues to grow. The high demands in these transportation modes are accompanied with the present high increase speeds of construction of highways and will lead high effects on the economic development.

3.2 Comparisons of Vehicles

In the Guangdong province in 1996, there are 17 vehicles per 1000 persons that is the highest amount of vehicle among 27 provinces in China except the three central cities Beijing, Shanghai, and Tianjin according to the Statistical Yearbook of China (1997). However, in most developed countries, every thousands of persons owned more than 400 vehicles in 1996. Compared to developed countries, the vehicle amount in the Guangdong province is still very low and further construction of transportation infrastructure is also needed as described in detail in Liu et al. (1998). However, the increasing speeds of vehicles in both China and the Guangdong province are rather high compared to the developed countries such as Japan, Germany, UK, France, and USA. Based on the statistical reports of International Road Federation (1986-1997) and Statistical Yearbook of China (1986-1997), comparisons have been done on the basis of the increasing speeds of vehicles among these countries and region.

Figure 13 shows a historical comparison of the numbers of vehicles per kilometer of roads among several countries and the Guangdong province by designating the number of vehicles in 1985 as 100. The relative increasing rate of vehicles versus road length in the Guangdong province is obviously higher than the average in China from 1987, and much higher than the developed countries. Further, the increasing speed is very stable in China although is fluctuated in the Guangdong province from 1993 to 1996. The vehicles per unit of road length in these developed countries are also increasing, however the rates are relatively low.

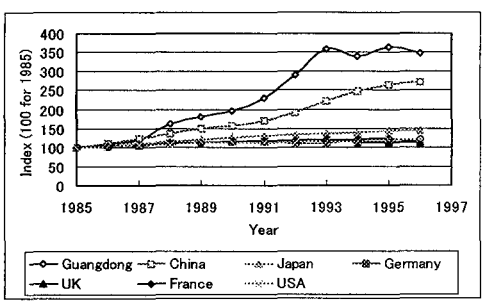

Figure 13: Comparison of Number of Vehicles according to Road Length

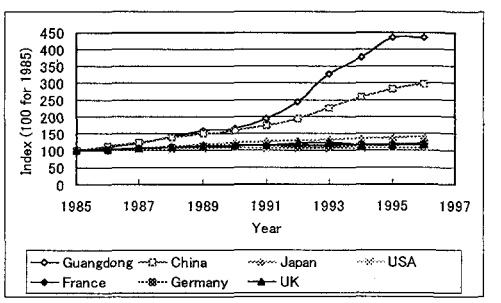

Figure 14: Comparison of Number of Vehicles according to Population

On the other hand, Figure 14 represents a comparison of the increasing indices of vehicles owned by per 1000 persons in such countries and region from 1985 to 1996. Similar results can concluded that the increasing rates of the Guangdong provinces in these years are higher than the average of China and those in the developed countries. However, it should be stated that the popularization of vehicles in China is still not enough to compare with the other developed countries as mentioned in the above. It can thus be predicted that a continuous increase of demand will endure for many years from now on although the increases in the previous years were very rapid in both China and the Guangdong province. This scenario certainly challenges the civil engineers for the transportation infrastructure construction and management.

4. ENVIRONMENTAL CHALLENGE FROM TRANSPORTATION

4.1 Energy Consumption and Economic Output of Each Economic Sector

With the development of economics, the energy consumption in the Guangdong province has increased drastically. As shown in Fig. 15, the yearly energy consumption in the agriculture, industry and service increased 109%, 74% and 184% respectively within the seven years from 1989 to 1996. Contained in the service sector, the energy demand in the transportation and communication sector increased from 3.11 millions tons of standard coals in 1989 to 6.12 millions tons of standard coals in 1996, which are more than half of the total energy consumption in the service sector. Figure 16 shows the GDP per energy consumption in the above-mentioned four economic sectors from 1989 to 1996. The economic efficiencies of energy consumption in the industry and transportation sectors are quite low compared to the agriculture sector and the service sector in average. This figure also implies that the elasticity of energy demand increase to GDP growth may change in different years.

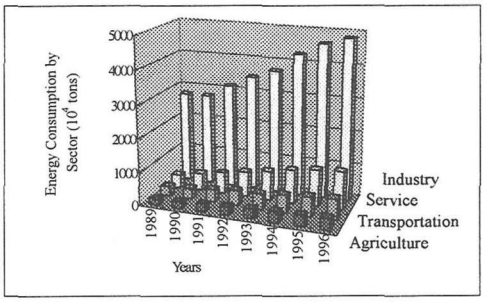

Figure 15: Increase of Energy Consumption in Each Sector in Guangdong Province

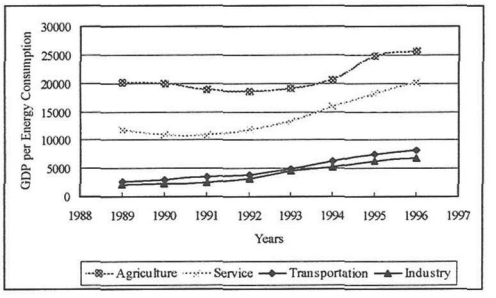

Figure 16: GDP per Energy Consumption Sector in Guangdong Province (unit: Yuan)

4.2 CO_2 Emissions of Each Economic Sector

China has an abundance of coal and a relative lack of petroleum and natural gas reserves. Therefore, coal is the major source of carbon dioxide emissions in China. Unlike developed countries, where coal is used mainly in power generation, in China the power sector accounts for only about a quarter of total coal consumption as shown in Fig. 17 for 1995 (Johnson et al. 1996). Most coal is consumed directly by industry for steam generation and by the residential sector for cooking and heating. This situation is expected to change a little bit with the development of power plants in the following years. Figure 18 shows the estimated distribution of CO_2 emission from energy consumption in China by 2020. The power sector will increase to 31% and the industrial sector decreases by 46%.

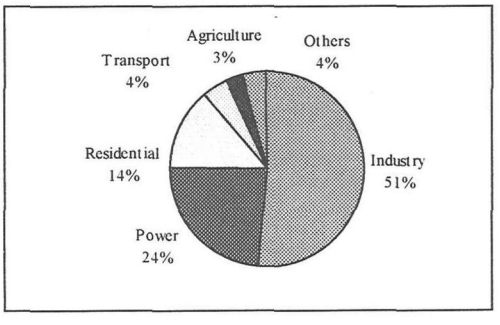

Figure 17: CO_2 Emission from Energy Consumption by Sector in China in 1995

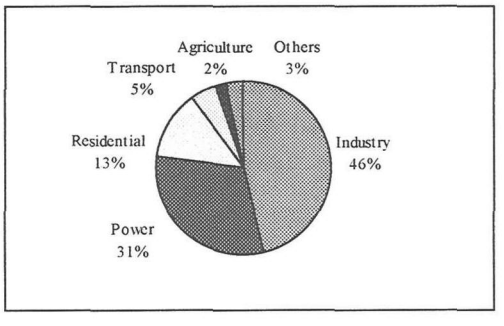

Figure 18: Predicted CO_2 Emission from Energy Consumption by Sector in China in 2020

5. CONCLUSIONS

This research aims to study the global environmental problems and the transportation problems due to the economic development in the developing countries and regions by means of the energy consumption. The following conclusions can be stated from this paper:

1) Both the energy consumption and the CO_2 emission per unit of GDP in China are higher than those in the developed countries, which are about 13.43 times and 20.75 times them of Japan in 1995. Further, more energy is needed to generate a unit of GDP in both the transportation and industry sectors compared to the agriculture and service sectors.

2) In the past decade, the numbers of vehicles per kilometer of road and per thousand persons increased more than 3 times in both China and the Guangdong province, which induced the environmental problems in addition to the traffic safety and the traffic congestion.

3) At present, more than 14% of CO_2 emissions of the world is generated in China, of which about more than 80% is due to the burning of coal. About 90% of coal is used for industrial production, power generation, and residential. The use of non-fossil fuels should be promoted for the sustainable development. The CO_2 emissions may increase in the following years because the solid fuel will still be the dominant energy source in China.

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