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Institute of Transport Studies
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Sustainability analysis of Chinese transport policy

Baohua Mao
School of Traffic and Transportation, Northern Jiaotong University,
Beijing 100044, P. R. China

Haibo Chen*
Institute for Transport Studies, University of Leeds, Leeds LS2 9JT, UK

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***Corresponding author**: Dr Haibo Chen,
Institute for Transport Studies, University of Leeds, Leeds LS2 9JT, UK
Tel: (+44) 0113 2335341, Fax: (+44) 0113 2335334

SUMMARY: Whilst the world economy is developed, the life and development of human beings have been threatened by the imbalance among environmental and ecological aspects. Thus sustainability is becoming increasingly the focus of various social fields. For most developing countries, a strategy with good sustainability for social development is of long-term significance to keep the economy in expansion. This paper first reviews the conceptual framework and up-to-date development of sustainability. Second, it reviews the current transport situation of China and its future demands. Third, the paper analyses transport policy from the viewpoints of energy consumption and environment pollution caused by transportation. It finally summarises suggestions for transport policy that China should consider in the future.

INTRODUCTION

Since the 1980s, many issues on environmental and economical fields have arisen with the expansion of world population and the development of the world economy, as it is important to maintain the quality of human life in social ecological and environmental aspects. Sustainability has certainly played an important role in decision making at national and even international levels (Masser *et al*, 1993; Ono, 1993; OECD/ECMT, 1995; Mao, 1996).

The Brundtland Commission (WECD, 1987) in *Our Common Future* defined sustainable development as 'development that meets the needs of the present without compromising the ability of future generations to meet their own needs'. The European Conference of Ministers of Transport pointed out in 1995 that road construction may make more people travel by car but with very limited improvement on the relaxation of peak-hour traffic congestion (OECD/ECMT, 1995). Transport is in nature an unsustainable activity for the following two reasons (Buchanan *et al.*, 1997). First, the infrastructure and many factors (such as land, architecture materials and petroleum) dealing with transport operations use non-renewable resources. Second, the transport process is responsible for great pollution, damages irreplaceable resources and also leads to long-term environmental change. It is believed that sustainability policy is far from being achieved, especially in developing countries. In most of these countries, sustainability has not been considered as an important issue either in transport or in transports planning (Mao, 1996). A sustainable transport policy may be achieved only when economic development and long-term environmental and ecological considerations have been combined in the transport decisions.

As the basis of global sustainable development, an agenda towards the twenty-first century was set up at the United Nations Conference on Environment and Development (UNCED) in June 1992, with the agreement of 150 countries. The overall objective for sustainable development was defined as 'improving the social, economic and environmental quality of human beings as well as the living and work environments of all people'. Obviously sustainability has been a world-wide problem. We will analyse the characteristics of transport sustainability, with a focus on Chinese transport and discuss possible policies to improve transport sustainability. Our main interest in this paper is to carry out a case study of China. Our conclusions on Chinese transport sustainability are given, together with suggestions for transport policy that China should take in the future.

ANALYSIS OF TRANSPORT SUSTAINABILITY

Traffic congestion

Traffic congestion is the most important target of all transport decisions to balance the relationship between the demand and supply in a transport system so as to relax the traffic congestion. Vehicle speed in the central urban areas of many Chinese cities has been decreased greatly over the past decades (Mao *et al.*, 1999). For example, the average speed of public vehicles fell to 12.9 km/h in Guangzhou in 1999. In many other big cities, vehicle speed is lower than 10 km/h during peak hours.

Air pollution

NO_x produced in combustion is harmful to human health and possibly leads to smog and acid rain. The World Health Organisation (1987) gave a density value of about 0.04 to 0.06 ppm for daily NO_2 in urban areas. However, this standard is not yet maintained in most Chinese cities. Statistics show that, in Beijing, the CO_2 emission from vehicles was over 50% of the total CO_2 emission in the 1980s (CTI, 1998). This figure continues to increase with the expansion of transport demand.

Traffic noise

Many populations near railway lines and trunk roads are exposed to an environment of worse than third level, with more than 65 decibels of noise in China (GBEPC, 1999). Much of the noise is generated by transport, including the tremors caused by heavy-loaded cars as well as loading and unloading operations at night.

Road safety

Currently, about 75 000 people die and more than 174 000 people are injured each year in traffic accidents in China. In the 15 EC countries, the annual deaths are 44

000, although the accident rates per car kilometre are high in Portugal and Greece.

Urban space and scenery

The construction of new transport infrastructure inevitably occupies urban space and also damages urban sightseeing. For future development, urban space has been a key problem as population density is increasing and space is reducing.

Land use

Land use has greatly changed car ownership and travelling patterns. At present, the motorization of China is not so high. However, the land available for each urban resident makes it more difficult to construct transport facilities such as roads and parking once car ownership increases.

Global warming

CO_2 is a very important and a contributing source to global warming. It is estimated that 25% of CO_2 in the world is produced by transport (Prades *et al.*, 1996). Many developed countries have been searching for management strategies to control the transport emissions. However, the situations in some developing and rapidly-motorising countries are not optimistic. Data in 1994 showed that the CO_2 emitted in China was 13.4% of the total emissions, whereas the number of vehicles in China accounted for only 1.7% of the total vehicles in the world (CTI, 1998).

Energy consumption

Energy consumption by industry has been reduced since the first petroleum crisis. However, energy consumed by transport has become greater with the development of highway transportation. For example, transport energy consumption is 30% of the total consumption among EC countries. Even though the oil crisis seems to have been relaxed since the second oil crisis in 1978, the demand of road transport from developing countries will increase the conflict between energy production and supply.

Urban deconcentration

The development of motorised transport has led to the expansion of travel distance and journey time that deconcentrates residents as well as their travel demands. Urban deconcentration reversibly increases the dependence of people on private cars and limits the development of public transport.

Experts have pointed that rail transit systems have better characteristics on energy consumption and pollution emissions (Gercek and Tekin, 1996). The efforts to improve transport sustainability may include these three aspects, namely technology, policy and city planning and landuse, as described below.

Technology

Transport sustainability can be improved by (1) reducing the environmental emissions of vehicles and (2) improving the efficiency on energy utility and transmission. China has speeded up the studies of substituent fuels for vehicles since 1990. One achievement of these studies was that a few thousand natural gas-fuelled public vehicles were manufactured and used for public transport services in Beijing (Yang and Zhang, 1993). However, many experts argue that the improvements in combustion efficiency and emission control would not help in finally solving the traffic congestion problem caused by increasing demand (OECD/ECMT, 1995; Buchanan *et al.*, 1997). In addition, tele-communications have also been regarded as a long-term way to reduce the amount of travels.

Policy

Government policies have significant effects on transport market share (Banister, 1994). There are indeed many ways for governments to implement their policies:

(1) Controlling the transport network by various transport investment schemes which would affect customers' choices.

(2) By taking account of some extra costs, such as traffic congestion and environmental pollution, governments may establish different taxes and price policies which would change the selections of customers.

(3) By subsidy, some transport modes may obtain priority to be developed.

(4) By restrictions to some infrastructure, such as city centre and car parking, governments may affect the choices of passengers.

Owens (1995) noticed a recent change of the role of transport policy on practice from 'prediction-supply' to 'prediction-protection'. The argument on how to include the whole social costs in customer price has become one of the most interesting topics. Policy for sustainable transport is, therefore, to maximise the accessibility within a network, subject to environmental constraints. Button and Verhoef (1998) advanced the concept of real transport price and pointed out the necessity of converting the extra price into the inner one. Bansiter (2000) pointed out that the common sense on un-sustainability caused by the increase of transport volume was achieved in European countries and most transport professionals have agreed that traffic congestion could not be solved completely by road investments. Many strategies have been proposed to discourage the use of private cars. It is difficult at this stage to coordinate the strategic inconsistency among political and public targets.

City Planning and Landuse

There is an interactive relationship between urban planning and transport. Transport influences the urban form during its development and urban style also has a great effect on transport performance, both on mode choices of users and transport network constructions. For example:

(1) Different land use itself may change private car use and be helpful to its transformation to public transport, cycling and walking.

(2) Encouragement and guidance to use public transport should be made for the public in their preferences. These measurements include separated bus lanes, car ban network with park and ride in city centres. The fuel consumption will be reduced by about 13% when 8% of private car passengers shift to other modes.

(3) Compact city planning may limit the land available so as to enlarge the density of landuse in present urban areas. Industrial and commercial houses may be established in those planning areas to form multi-purpose zones that make work and service more accessible to residents.

(4) It would lead to greater energy saving if the mid-level income group changes from low-rise buildings to high, efficient buildings and from private cars to public transport. This saving becomes less for the low income group. The high income group, however, can afford the additional fees additional for car use and would occupy larger and more luxurious houses.

CASE ANALYSIS OF CHINA

Sustainable transport issues in developing countries are not the same as those in developed countries (Muttagi, 1998; Chakravarty and Sachdeva, 1998). As a developing country, China has some special conditions that need to be considered in our analysis.

Economic growth

As a developing country with a population of more than 1300 millions, the Chinese government needs to pay more attention to economic development than sustainability to solve imminent living problems. The importance of industry may be revealed by it being 77% of the total gross domestic production in 1997. In China, about 75% of the total energy consumption results from industry. The situation has greatly affected government's consideration to set and implement sustainable targets.

Transport policy

Most policies aim to balance transport demand and supply. However, the traffic demand is so great compared to transport supply that there are not many opportunities available for transport users (Wang, 2000). This is a very important practice in considering transport problems in these developing regions. Some issues related to transport policies in China that need to be addressed are as follows:

(1) An integrated transport policy package is not available in China, making transport expansions confusing. For instance, there is no well-demonstrated transport planning based on demand forecast for all modes and their sustainability (Mao, 1996). Transport systems are not efficient because of the poor cooperation between different transport modes and the infrastructure. Public transport has been depressed for the past decade.

(2) Tests and examination of transport facilities need to be enhanced. Expired vehicles and locomotives can still be seen in operation, with increased transport emissions and accident risks (Yang and Zhang, 1993).

(3) Poor administration needs to be improved. There exist individual, group-owned and nation-owned transport enterprises on the transport market. These enterprises have poor administration and implementation systems. There are not comprehensive regulations available on price, services and insurance. Also fair competitive systems need to be established in many regions at the administration level.

Data collection and processing: There is, so far, no integrated system for collecting and processing observational and statistical data in China, which makes it difficult to get detailed research results (NBS, 1999). Many decisions are thus based only on experience with lack of scientific evidence.

Technology: The production and management of the transport industry are not advanced. For example, the traditional transport industry is still producing low standard vehicles with excessive emissions. In addition, there exist some difficulties in coordinating and managing multiple regional departments across the country.

Current transport market

The railway was the main form of land transport in China before the 1980s when transport demand and supply were basically in equilibrium, though its network was sparse. Entering the 1980s, rapid economic growth has led to a great increase of traffic volumes (Wang, 2000). Rail transport supply started to lag behind demand and consequently availability of train tickets fell short of the public's expectations and demands. Meanwhile, highways experienced high-speed development with support from central and local governments. The market share of highway transport was greatly augmented during the period. Figure 1 illustrates the development of passenger transport of China in the past twenty years.

It is noted that, while the population in China increased by 30%, highway transport achieved greater development of five times for passenger volume and eight times for passenger-kilometres in the past 20 years. Comparatively, the railway obtained an increase of only 7% for volume and 68% for its passenger-kilometres. Two conclusions may be drawn from these data. First, the development in transport was faster than the increase in population, which is consistent with economic growth and improvement of the average trip rate. Second, the development of highways was much quicker than that of the railway. This difference is due to the advantages of highways for short-distance transport. Figure 2 describes the development of economic and freight transport in China.

It is easy to see from Figure 2 that the Gross Domestic Product (GDP) has increased 4.9 times in the past 20 years. Highway freight volume has increased by 1.6 times and highway freight turnover has increased by 6.5 times during this period. Railway freight experienced only a 41% increase in volume and a 120% increase in turnover. It may be concluded from the above two figures that highways have played the principal part in transport since the 1990s.

The Chinese railway has been depressed since the middle of the 1990s in terms of both volume and market share. This may be because:

(1) Since the 1980s, the road construction and network have been greatly improved. Road transport has become competitive and changed the traditional transport market, dominated and manipulated by a monopolistic railway

operation.

(2) Traffic demand is being decentralised spatially due to the increase in population. Road transport is very suitable for short-distance trips, as it provides better accessibility and flexibility than railway transport.

(3) The aging infrastructure of railway transport failed to offer competitive services. For example, obsolete facilities lower the comfort of passenger transport. The travel speed of railway freight transport is very low at about 9 km/h from its acceptance of conveyance to delivery, resulting in a loss of market share.

(4) Poor railway management cannot cope with the changing environment. For example, there are too many staff serving customers. Transport services offered by railways are too simple to satisfy the requirements of different kinds of customers, etc.

For solving traffic congestion, the most common sense solution is the extension of transport capacity in time and space. There was an on-going argument between transport and industrial professionals at the beginning of the 1990s about the policy of private car ownership (Mao, 1995). However, the worsening traffic states in many city centres have displayed the after-effects of private car use in a developing country with a large population like China.

The increase in traffic volume and motor vehicles is 9% each year, nearly equal to that of the development of the gross national economy. Since 1990, the passenger volume of all transport modes has been increasing rapidly. The total volume reached 13.8 billion passengers, with a turnover of 1056 billion passenger-kilometres in 1998. The average travel distance for different modes has been changing since the 1980s. For example, the average travel distance of highway passenger transport increased from 35 km in 1978 to 47 km in 1998, for railways from 134 km to 395 km and for air from 1212 km to 1390 km during the same period. This directly reveals that railway market space has been greatly restricted by highway and air transport. A similar situation appears for freight transport. The average travel distance of highway goods increased from 32 km in 1978 to 56 km in 1998. Railways showed an increase from 485 km to 764 km and waterways from 873 km to 1771 km in the same time. Air transport changed from 1667 km to 2392 km (CATC, 1999). These changes have greatly altered the structure of the Chinese transport market.

Forecast of transport and economic development

In order to estimate the national transport demands of China, it is necessary to make a forecast of some important social and economic data. Table 1 lists several important indexes related to transport demand. Obviously, Gross National Product (GNP) and urban population have indexes which have increased fastest. They indicate more car ownership and more trips by motor vehicles in the near future.

Table 2 shows the forecast of transport demands to 2020. It is obvious that the passenger volume and its turnover would increase at an annual rate of 6.0-6.7% from 2000 to 2010. The freight volume increase will be from 3.4 to 4.8 % over the same time period. From 2010 to 2020, the expansion of transport demands is a little lower than highway and airline transport.

Sustainability analysis

Many aspects have been studied in the evaluation of transport sustainability, among which energy consumption and pollution emissions are the most important indicators of transport sustainability and need further analysis.

Transport energy consumption

There is a close relationship between the energy industry and transport, especially where the energy production of China is not so optimistic. The energy resource in China is less than 100 years for production, either of coal or petroleum (NBS, 1999). Figure 3 describes the structure of energy production of China in 1997.

Obviously, three quarters of the total energy is coal production. Oil production is less than one fifth. This balance is especially disadvantageous for a developing country wishing to expand road transport, and the solution would be to import oil and gas from elsewhere.

From the viewpoint of the balance of energy production and consumption, the average energy production increased from 650 km standard coal in 1980 to 1090 km in 1996. The average energy consumption, however, increased from 615 km to 1141 km during the same period. This means China has changed itself from an energy balanced to an energy insufficient state, a change that needs to be realised by all policy decision-makers. Figure 4 gives the statistic of data of energy consumption in 1997 for the whole country. It is easy to see that industry is the biggest state energy consumer of energy, as in most developing countries. China is still in her industrialising stage. It is necessary to note that there is a statistical difference in Figure 4. The energy used by transport facility manufacture, which is about 1.4% of total industrial energy consumption, is not included. Some other items related to transport such as energy consumption by some big mineral mills and private transport suppliers may also not be included in the statistics.

Though there are no official data about transport energy consumption in China, it is possible to give a n approximate calculation of total annual energy consumption of all transport modes according to their turnover and average unit consumption. Table 3 shows the energy consumption of different transport modes in 1995. Obviously, highways entail the most energy consumption though the turnover volumes are not so large. This means that highways consume more energy than other modes in carrying out the equivalent traffic. Table 4 lists the physical energy consumption of transport in 1985, 1990 and 1995. It is easy to see that coal consumption has decreased and oil consumption has become the main source of the energy consumption since 1990. This change may be due to the rapid increase of motor vehicles in the past decade.

As mentioned above, energy production in China is less than energy consumption. National Bureau of Statistics (1999) data show that the total energy production in 1997 is 1320 million ton standard coal, slightly less than the consumption of 1420 ton standard coal. Table 5 shows the unit energy consumption by different transport modes in 1995. For freight transport in 1995, the energy consumption of railways was 59.22 kcal per ton-km, whereas highways consumed 446.76 kcal per ton-km, 6.5 times more than railways. The energy consumption of railway passenger transport was about the same as that of railway freight transport and highway public transport was 116.74 kcal per pkm, based on diesel engines. It is easy to see that the energy efficiency of the railway is 97% higher than that of highways on passenger transport.

Table 6 gives the forecast for energy consumption of various transport modes based on the results of Table 2. As the energy consumption per pkm/tkm of highways is far greater than that of the railway, the corresponding energy consumption by highways in 2020 may possibly double the value of 2000. In urban areas, the increase is even greater according to the current policy of preference for private car ownership, though some big cities such as Beijing, Shanghai and Guangzhou have planned a large-scale rail transit network.

Table 7 lists the calculations of oil demands from 2000 to 2020 according to the energy consumption structure, based on Table 2, Table 5 and corresponding unit standards. The results show that the demand for liquid energy may show a rapid increase in the coming years. This demand will stimulate the conflict between oil consumption and production as petroleum only occupied 17.4% of total production as shown in Figure 3. It may also become one of the reasons for an unsustainable transport future for China.

The energy production is insufficient in China. Experiences in developed countries have shown that the development of transport will surely change the framework of the energy system.

Transport emissions analysis

Table 8 shows the calculated emissions by transport modes in 1995. The data warn that highways will become the biggest source of pollution contributing 88.4% of total emissions. Still worse, it is also the most rapidly developing form of transport in China.

Total suspended particles (TSP) has been one of the major resources of air pollution, especially in some big cities of the northern regions of China. The pollution of the atmosphere comes mainly from coal, the major energy resource in China. In some middle and small cities, the characteristic pollution is a mixture of combusted coal smog and vehicle emission gases. According to the statistical report by the Bureau of National Environment Protection, the total emission of exhaust gases, such as SO_2, NO_X, CO_X, HC, TSP etc., from industrial factories were over 53.44 million tons in 1997. Table 9 describes the forecast of the average emissions in 2020. Experience of developed countries has shown that road transport will contribute the most important emissions (Serageldin, 1993) if its market share becomes the largest.

The values of different emissions by road transport may be described as follows.

$$T_X = \frac{V_P}{S_V * \alpha_V}(1+\beta_V) * E_{V,X}$$

Where T_X is the emission of pollution X; $E_{V,X}$ is the unit emission of X per vehicle kilometre; V_P is the turnover of road passenger transport of the whole country; S_V is the average passengers per vehicle; α_V is the loading rate of a vehicle; and β_V is the additional running coefficient with consideration to the empty state. Table 10 shows the forecast of various transport emissions till 2020 according to the future demand and technological developments. The results are based on the improving structure of 2020. The emissions will be 1.7 times higher than for the current structure.

It is easy to see the total volume of harmful emission gases is more than 52.5 million tons each year, excluding the emissions from urban transport. Statistics also show that the total passenger kilometres of urban public transport is 25.13 billions in 1997, among which 90% is from bus transport. As the unit bus emission in urban areas is larger due to their lower operation speed, it is therefore reasonable to reckon that total gas emissions of transport would be greater than 70 million tons, including those from aircraft, railways, waterways and other private transport. This number is nearly equivalent to total industrial emissions, 53.4 million tons published officially, based on incomplete statistics in 1997. The further development of road transport will certainly worsen the situation.

On the other hand, China has also been confronted with great challenges of landuse and noise pollution. Statistics show that average area of land per capita is 0.777 ha, 1/3 of the world average value. The average ploughland per capita is 0.106 ha, less than half of the world average. Still worse, 60% ploughland has no guarantee of water resources and irrigation facilities, and 79% is low production status (NBS, 1999). The ploughland of the country is decreasing each year with industrialisation and poor administration of rural areas. In 1999, the loss of ploughland was as great as 8.42 million ha. The reasons include non-rural occupation, ecological reuse of farmland for other purposes and natural disasters.

Environmental deterioration has become a more and more serious problem in China due to the rapid economic development as well as the mass population, high density and sparse resources. Taking water pollution as an example, a sampling investigation in 1999 dealing with 141 Chinese inner rivers showed that the water quality of 63.8 % of the rivers had been reduced to No.4 or No.5 class standards. In some big cities, the emission of industrial liquid waste is just starting to be under limited control, but the emission of raw urban sewage has increased due to the continuing urbanisation in the past decades.

Policy analysis

Transport policy and its consequences have greatly influenced social development. It is easy to see from Table 2 that highway traffic will have a greater increase than other modes, and air traffic will also possibly show a great increase in the coming decades. The forecasts show that the turnover of airway passenger transport in China will be over 20% of total pkm in 2020, which is greater than 12.4% for the USA and 6.1% for the EU in 1994.This reveals the possible transport policy of China in the coming years. It is necessary to note that the above statistics do not take account of the traffic generated by industrial enterprises and private vehicles. The further development of individual private cars would affect the above consequences.

However, it has been recognised that the highway traffic increase is not sustainable (Banister, 2000). Some countries have put forward a series of integrated policies to achieve a sustainable output of society (Jakomin and Trupac, 2000; May, 1991). Rail transport should give priority to developing intercity and urban transport systems. That is why we appeal here for attention to the fact that a long-term and integrated policy is needed for future development.

CONCLUSIONS

(1) China has been at a crossroads in the choice of transport policies, among which the development of private transport tools is the most important. It is very important for the government to define a long-term sustainable transport policy that takes account of current and future situations in China.

(2) The highway network has been developed greatly in the past two decades. It has also been shown a great increase in both passenger and freight transport market shares. The development of highways is paramount in the land transport of China and also greatly improves the situation of transport in terms of both quantity and quality. Sustainability warns, however, that the inefficient railway transport system must be reformed to enable it to play an important role in the future as it is a sustainable resource.

(3) Railway departments fail to make the most of urban transport markets for two reasons. First, the railway management system is inflexible and difficult to coordinate with local authorities. This inflexibility hinders local railway development. Second, the railways have failed to develop urban rail transport, including the market development, demand analysis and technical revolution. This failure makes rail transport disadvantageous in competition with other forms of transports. All in all, this shrinkage of rail transport over middle and short distances is not conducive to the establishment of a united and sustainable transport system. The government should analyse in detail the demand for transport and a reasonable market of various modes based on the available resources so as to balance the transport supply and its demand as planned.

(4) The government should adopt policy favourable to the development of urban railways, especially in cities of big and middle scales. As mentioned above, urban railways have not developed as well as they would have. Most commuter and suburb railway transports are almost certain to fail. They lack an efficient and quick connection between long distance intercity railways and urban transport systems.

(5) It is necessary to prompt railways to speed up the development of railway technology and train organisation so as to meet the requirements of urban rail transport. For example, rail motor vehicles suitable for urban transport should be developed. On the other hand, a more flexible timetable appropriate for urban passenger transport is also necessary. The railway networks should be extended so as to improve the accessibility of passengers to urban areas. At the same time, better alternatives for the connection of passenger changes at

terminal stations, and better information and ticketing systems for passengers should be established.

(6) Government should organise an integrated study to better coordinate transport resources and develop policies as done in UK (May, 1991), including the prices of energy, land-use policy, car parking system and extra charges on some roads at peak hours, etc. This is beneficial as well as necessary for both transport users and a sustainable future.

(7) Motor manufacturing technologies need to be improved and advanced. Focuses should be on energy efficiency and pollution emissions. Although there are many regulations related to the emissions (NEPB, 1989a, b, c, 1995, 1999) in China, they still lack measures for their implementation and a regular emission monitoring system. This has become a major obstacle to a sustainable transport policy.

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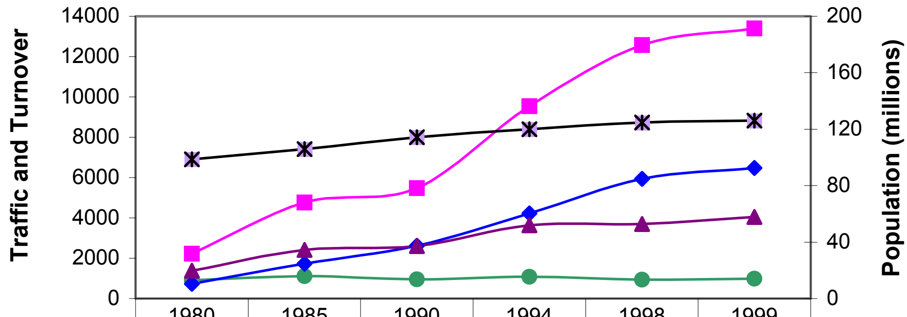
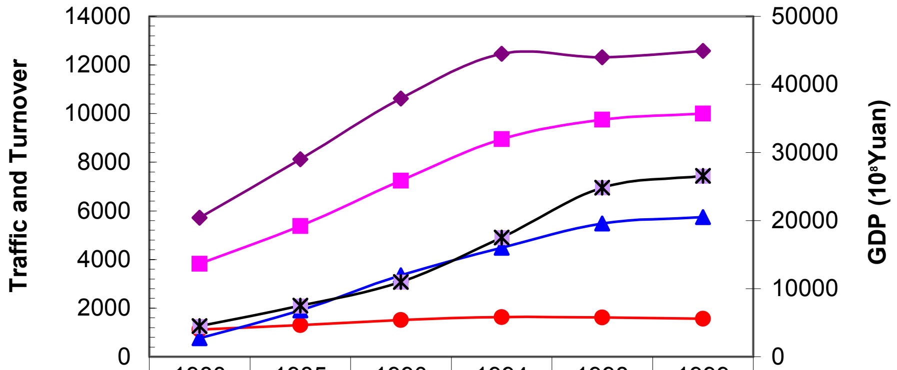


	1980	1985	1990	1994	1998	1999
Highway Traffic	2228	4765	5481	9539	12573	13400
Railway Traffic	912	1109	948	1087	936	977
Highway Turnover	730	1725	2621	4220	5943	6480
Railway Turnover	1380	2413	2610	3636	3696	4046
Population	98.7	105.9	114.3	119.9	124.8	126.1

Figure1 Statistics of Chinese highway and railway passenger transport. Traffic: in million passengers. Turnover: in10^8 passenger kilometres.



	1980	1985	1990	1994	1998	1999
Highway Traffic	3820	5381	7240	8949	9760	10000
Railway Traffic	1113	1307	1507	1631	1612	1569
Highway Turnover	764	1903	3358	4486	5483	5750
Railway Turnover	5717	8126	10622	12458	12312	12578
GDP	4518	7519	10980	17499	24856	26596

Figure 2 Developments of economy and freight transport in China. Traffic: in million tons. Turnover: in 10^8 ton kilometres. Data of GDP in 10^8 Yuan are based on the price in 1980.

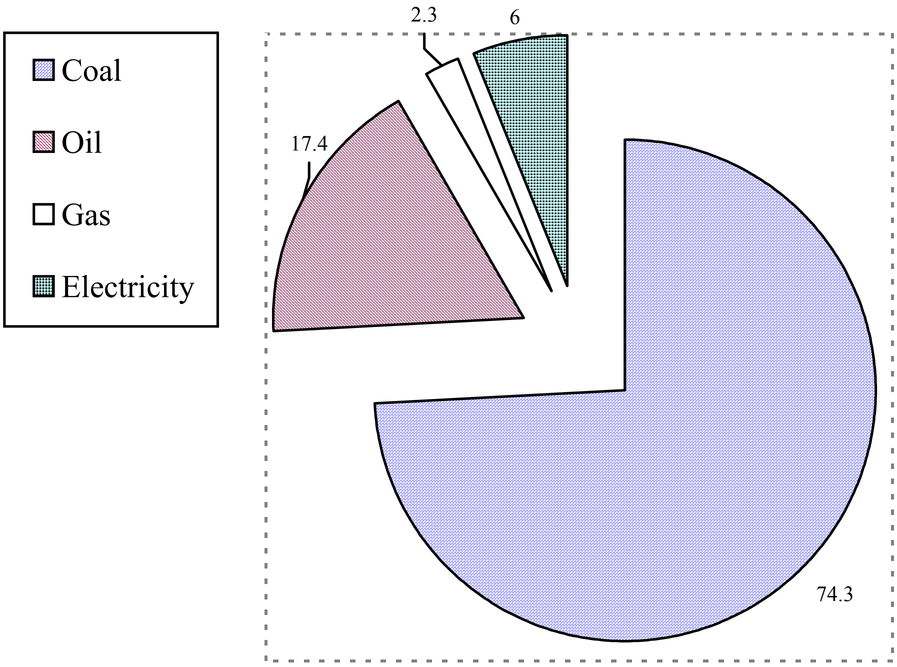


Figure 3 Structure of Energy Production of China in 1997.

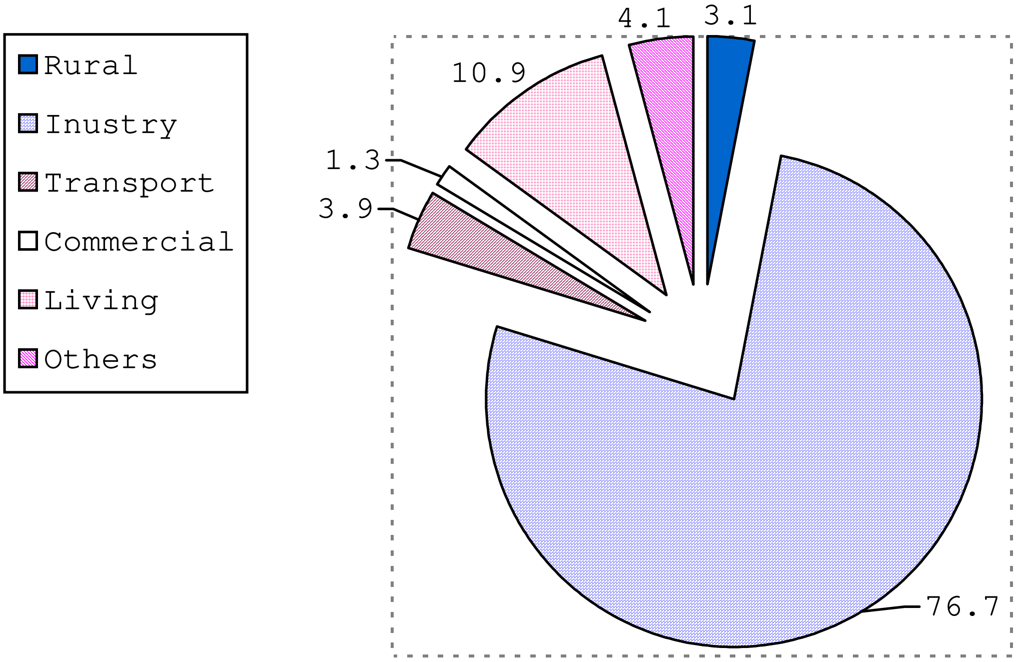


Figure 4 Energy Consumption of China in 1997.

Table 1 Forecast for Social and Economic Indexes of 2000-2020

Items	*Unit*	*1995 practical*	*2000*	*2010*	*2020*
Population	10^4 persons	121121	128000	140000	150000
GNP	10^8 Yuan	57277	85000	170000	310000
UPa	10^8passengers	1489	1745	2067	2437
UPo	10^8 persons	5.0	5.9	7.0	8.25

Source: CTI (2000); UPa: **U**rban **Pa**ssengers, UPo: **U**rban **Po**pulation.

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Table 2 Forecast for transport demands in 2010-2020

Items		*1998 practical*		*2000*		*2010*		*2020*	
		Turn-over	(%)	*Turn-over*	(%)	*Turn-over*	(%)	*Turn-over*	(%)
Railway	**Pa**	3696	35.0	4150	34.3	6580	29.1	10000	25.1
	Fr	12312	32.5	12700	30.4	16100	28.9	19200	27.2
Highway	**Pa**	5943	56.3	6860	56.8	13500	59.7	24500	61.5
	Fr	5483	14.5	6150	14.7	9100	16.3	12000	17.0
Waterway	**Pa**	120	1.1	125	1.0	138	0.6	150	0.4
	Fr	19405	51.3	22200	53.2	29500	52.9	38000	53.8
Airline	**Pa**	800	7.0	950	7.9	2400	10.6	5200	13.0
	Fr	34	0.1	41	0.1	100	0.2	190	0.3
Pipeline	**Pa**	-	-	-	-	-	-	-	-
	Fr	606	1.6	645	1.5	950	1.7	1200	1.7

Source: CTI (2000), Wang (2000); Pa: **Pa**ssenger, Fr: **Fr**eight.

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Table 3 Transport energy consumption of different modes in 1995

Transport Modes		*Volume*		*Energy-consumption*	
		Unit	*Turnover*	*Unit*	*Consumption*
Highway	**Pa**	pkm, 10^8	4603	10^4 TSC	542
	Fr	tkm, 10^8	4695	10^4 TSC	3943
Railway	**Pa**	pkm, 10^8	3546	10^4 TSC	300
	Fr	tkm, 10^8	12870	10^4 TSC	1085
Waterway	**Pa**	pkm, 10^8	172	10^4 TSC	30
	Fr	tkm, 10^8	17552	10^4 TSC	2631
Airway	**Pa**	pkm, 10^8	681	10^4 TSC	324
	Fr	tkm, 10^8	22.3	10^4 TSC	147
Pipeline	**Fr**	tkm, 10^8	590	10^4 TSC	40.5
UPT	**Pa**	pkm, 10^8	1328.4	10^4 TSC	172
PT				10^4 TSC	25.3

Resource: STI (1998), NSB (1999); TSC: **T**on of **S**tandard **C**oal, Pa: **Pa**ssenger, Fr: **Fr**eight, UPT: **U**rban **P**ublic **T**ransport, PT: **P**rivate **T**ransport.

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Table 4 Physical consumption of different energy forms by transport

Items	*Unit*	*1985*	*1990*	*1995*
Coal	10^4 tons	1932	1396	746
Gasoline	10^4 tons	1187	1666	2621
Diesel gas	10^4 tons	1170	1646	2221
Kerosene	10^4 tons	69	122	320
Electricity	10^4 kw	1291085	2511369	3635038

Source: NSB (1999).

Table 4 Energy consumption of highway and railway of China (1995)

Mode	Energy Consumption
Highway Passenger	116.74 kcal/pkm
Railway Passenger	59.22 kcal/pkm
Highway Freight (*based on diesel engine*)	446.76 kcal/tkm
Railway Freight	59.22 kcal/tkm

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Table 5 Forecast for energy-consumption of different modes

Items	*Unit (Standard Coal)*	*2000*	*2010*	*2020*
Railway	10^4tons	1615	1809	2363
Highway	10^4tons	6247	9668	13737
Waterway	10^4tons	3320	4573	5518
Airway	10^4tons	884	2430	3856
Pipeline	10^4tons	37.8	36.9	36.4
Urban transit	10^4tons	294.8	522.0	1018.2
Total	10^4tons	12398.6	19038.9	26528.6

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Table 6 Oil Demands Forecast

Items		*Unit*	*2000*	*2010*	*2020*
Gasoline	Inter-city	10^4 tons	3091	5499	6899
	Urban	10^4 tons	270.4	301.9	588.2
	Total	10^4 tons	3361.4	5800.9	7487.2
Diesel oil	Railway	10^4 tons	379	492	500
	Highway	10^4 tons	1082	1926	2284
	Waterway	10^4 tons	2113.6	2910.9	3512.3
	Pipeline	10^4 tons	16.6	15.2	13.8
	UPa	10^4 tons	30	53	104
	Total	10^4 tons	3621.2	5397.1	6414.1
Kerosene		10^4 tons	601	1652	2622

Upa: **U**rban **Pa**ssenger.

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Table 7 Emissions by transport in 1995 (10^4tons)

	CO	**NO_x**	**HC**	**SO_2**	**Total**
Highway	3422	1104	644	81.3	5251.3
Railway	45	111.4	24.9	67.2	248.5
Air	135	111	25	9.3	280.3
Waterway	4.5	126	20	2.6	163.1
Total	3606.5	452.4	713.9	170.4	5943.2

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Table 8 Average transport emissions in 2020

		CO	NO_X	*HC*	SO_2
Passenger Transport (g/pkm)	Highway	14.4	2.4	2.5	0.13
	Railway	0.01	0.15	0.01	0.3
	Air	2.2	1.8	0.4	0.15
Freight Transport (g/tkm)	Highway	0.25	3.0	0.32	0.28
	Railway	0.15	0.4	0.07	0.18
	Waterway	0.018	0.5	0.08	0.05

Source: CTI (1998), GBEPC (2000).

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Table 9 Forecast of total emissions in 2020 (10^4ton)

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	CO	*NO_X*	*HC*	*SO_2*	*Total*
Highway	4173	1346	785	99.2	6403.2
Railway	55	135.8	30.3	81.9	303
Air	165	135	30	11.3	341.3
Waterway	5.5	153	24.5	15.3	198.3
Total	4398.5	1769.8	869.8	207.7	7245.8