Study on Sustainable Development of Various Modes of Transport in China on the Background of Low-carbon Economy

Junwei Zeng[1], Xiaoming Shao[2], Yongsheng Qian[3] and Jinbao Luo[4]

**[1] School of Traffic and Transportation, Lanzhou Jiaotong University
Lanzhou, Gansu, 730070, China**

**[2] School of Traffic and Transportation, Lanzhou Jiaotong University
Lanzhou, Gansu, 730070, China**

**[3] School of Traffic and Transportation, Lanzhou Jiaotong University
Lanzhou, Gansu, 730070, China**

**[4] School of Traffic and Transportation, Lanzhou Jiaotong University
Lanzhou, Gansu, 730070, China**

Abstract

On the basis of study of domestic and foreign experts, according to the existing energy structure and present status of transportation industry, comparing and analyzing the energy consumption and low-carbon economy indicators of different modes of transportation, this paper put forward the thinking of constructing low-carbon comprehensive transport system, which takes railway as main and also considers the low-carbon development of other modes of transportation.

Keywords**:** *Low-carbon economy, mode of transportation, Sustainable development, Comprehensive system of transport*

1. Introduction

Currently, global warming caused by increasing greenhouse gas is a great challenge for the existence and development of human beings, which makes it a worldwide problem to saving energy and reducing greenhouse gas emission. With the characteristics of lower energy consumption, less pollution and less emission, "low-carbon economy" is becoming the strategic choice for every country in the world to change the development mode to achieve sustainable development. China, ranking second in total carbon dioxide emission in the world, has a great responsibility to facing climate changes. Especially since the Copenhagen Conference "game of carbon", the economic growth mode of China is facing unprecedented challenges. As a great energy user, transportation industry is the key area of energy conservation. It is a strategic opportunity for speeding up industry structure adjustment and developing modern transportation industry to establish a comprehensive low-carbon transport system.

2. Low-carbon development of transportation at home and abroad

As an important component of national economy, transport plays a fundamental role in the development of economy, but accompanies huge energy consumption at the same time. In recent years, under the tendency of low-carbon economy, every country in the world is actively taking measures to save energy and reduce emission.

2.1 Low-carbon development of transportation overseas

According to statistics, the world average proportion of transportation energy consumption to total energy consumption is 29.6%, and the United States is 40.4%. Such a huge consumption makes it an important part of the Utilization. At the same time, industry standards and related taxes have been made to save energy. American energy plans to save energy and enhance the efficiency of energy utilization in the transportation industry. Since 1969, the United States has developed a series of laws and regulations to improve the efficiency of energy.

The scarcity of energy makes Japan put a more emphasis on saving energy compared with other developed countries. Since 1979, Japan has enacted the provisions to control the driving cycle and limits of automobile fuel. Japanese realized that technology innovation is an important guarantee for energy-saving and emission-reducing, so that they vigorously develop clean-energy vehicles. At the same time, carry out the

policy of high oil prices to inhibit the growth of oil consumption.

2.2 Low-carbon development of transportation in China

At present, transportation is the second largest oil consumption industry next to manufacturing industry. Chinese government started to pay attention to energy conservation as early as in "sixth-five" period, and made five-year plan and ten-year energy plan specially. After 1980, the policy of "both development and conservation, the conservation first" was put forward, a three-level management of energy networks and energy statistics index system was established and followed by the development of related laws and regulations and industry standards. However, compared with developed countries, China's development of low-carbon transportation still has significant gaps. Low-carbon economy is not only demand of the new round of scientific and technological revolution but also an important path changing the mode of development of China's transportation.

3. Energy and resource consumption of different transportation modes

There are two aspects of meanings of energy and resource consumption of transportation. One is the consumption of energy and resource in the construction process of vehicles and infrastructures; the other one is the petroleum products consumption in the operation process of various modes of transportation.

3.1 Energy consumption of different transportation modes

Energy is an important material basis for economic growth and the development of transportation needs the support of energy. Energy consumption is one of the operating costs, energy saving and low-carbon indicators of various modes of transportation.

3.1.1 Status of transportation energy consumption

In recent years, with the rapid development of motorization in China, energy consumption in transport sector is growing fast [10, 3, 11] (as shown in table 1, 2). Oil is the most important energy in transport sector. In 2007, about 94% of the total energy consumption of transportation is oil and about 95% of the gasoline, 60% of the diesel oil and 90% of the kerosene are consumed by transportation vehicles [6]. The growth rate of transportation energy consumption is higher than the growth rate of the whole society. On the other hand, China's dependence degree on foreign energy is continually rising, the latest data shows that China's dependence degree on foreign oil is as high as 55.14% [2] in the fist half of this year. The healthy and continuous development of transport industry is facing increasingly stringent constrains because of the scarcity of energy.

Table 1： Since 1990, status of transportation, storage and postal services energy consumption and its proportion in total energy consumption [10]

Unit：Ten thousand tce

Year / Compared item	1990	1995	2000	2005	2007
Total energy consumption	98703	131176	138553	224682	265583
Transportation, storage and postal services energy consumption	4541	5863	10067	16629	20643
Proportion of transportation, storage and postal services (%)	4.60	4.47	7.27	7.40	7.77

Table 2： Since 1990, status of transportation, storage and postal services oil consumption and its proportion in total oil consumption [10]

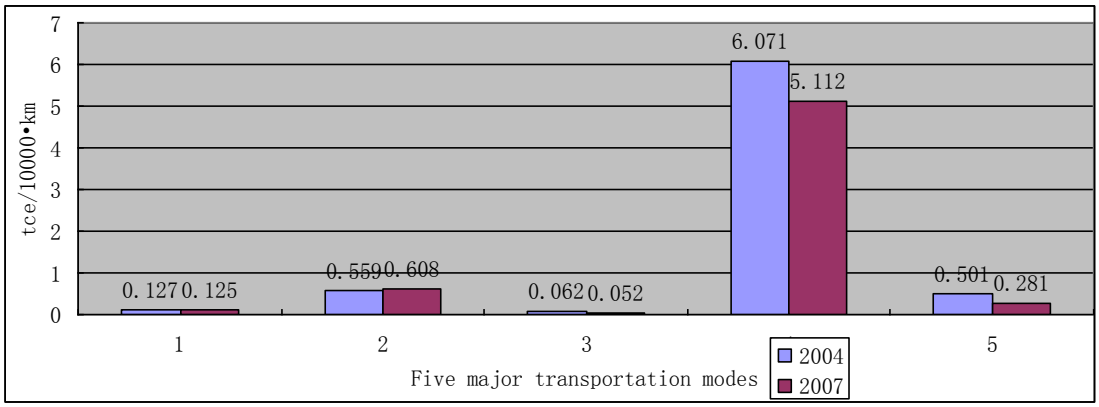
Unit：Ten thousand tce

Year / Compared item	1990	1995	2000	2005	2007
Total oil consumption	11485.6	16064.9	22439.3	32535.4	36570.1

Transportation, storage and postal services oil consumption	1683.2	2863.6	5509.4	9708.5	1229.6
Proportion of transportation, storage and postal services (%)	14.65	17.83	24.55	29.84	33.62

3.1.2 Analysis on energy consumption of different modes of transportation

With the development of economy and improvement of people's living standards, world transport energy consumption and its proportion in the total energy consumption is gradually increasing. In developed countries, transport energy consumption accounts for about 1/3 of the total consumption. In the five major transportation modes: railway, highway, water, air and pipeline, the highest unit energy consumption is air transport with 6071kgce per 10000 ton kilometer in 2004 and 5112kgce in 2007, next highest is road and pipeline with 559 kgce and 501kgce respectively in 2004 and 608kgce and 281kgce in 2007. The unit energy consumption of railway is 127kgce per 10000 ton kilometer in 2004 and 125kgce in 2007, and water is 62kgce in 2004 and 52kgce in 2007. As shown in fig. 1.



Note：1—railway；2—highway；3—water；4—air；5—pipeline

Fig. 1： unit energy consumption comparison chart of various modes of transport in 2007 in China [3],[10]

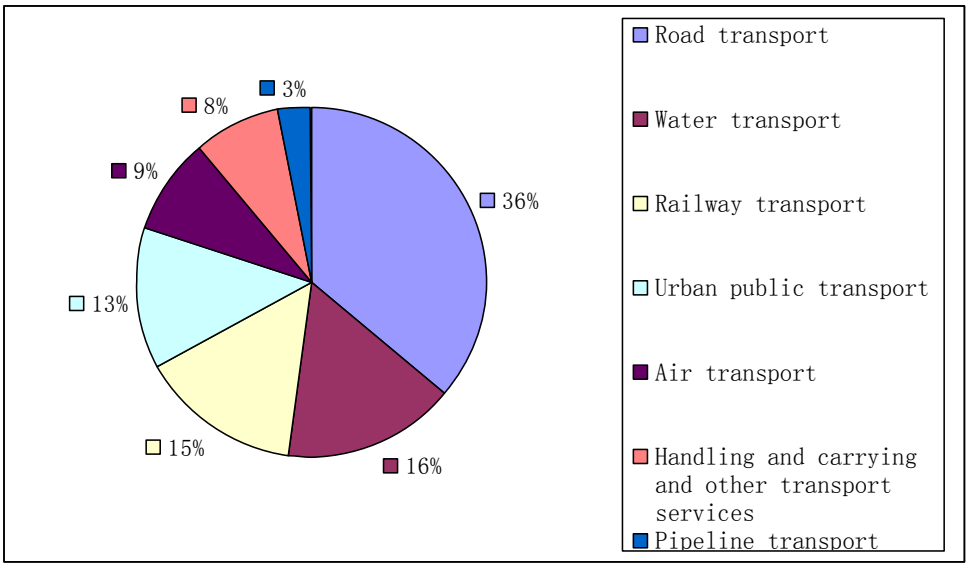


Fig. 2： China's transport energy consumption structure diagram in 2007[3],[10]

3.2 Land resources consumption of various modes of transportation

Transportation is highly dependent on land resources and the constraints for transport of the land shortage are obvious. Taking highway and railway as an example [7, 12], according to annual carrying capacity, the land occupied by roads is 1.28～1.36 times of that of railway and 1.76～2.54 times according to unit carrying capacity. If only considering the land consumption of various modes of transportation, we can see that highway is the largest, followed by railway and pipeline is the smallest. The consumption of land resources not only affects the construction costs directly, but also has a significant influence on the ecosystem and the development of low-carbon economy.

3.3 Analyses on transport turnover growth and energy consumption rate

According to statistics, China's total transport turnover is 7092.8 billion t km in 2004 and 10335 billion in 2007, the corresponding energy consumption for every 10,000 tons ·km is 213 kgce and 200 kgce, which declined 6.5% in 3 years and is far lower than the energy consumption growth rate of 36.7% [3]. This reflects that the task for the development of low-carbon transportation modes is arduous and further work should be done to reduce the unit turnover energy consumption. It is one of the key areas for experts to make breakthrough in technical means and management methods.

4. Low-carbon economy indicators of different transport modes

4.1 Analyses on transport macro emission indicators

From a global perspective, transport is one of the main contributors to the greenhouse gas emission, and the proportion of transport CO2 emission in developed countries is higher than the world average. According to related research abroad, CO2 emissions from transport account for about 22% of the whole society, the nitrogen oxides contribution rate of that is more than 60%. In addition, 80 % ～ 90 % of the CO comes from transportation sectors and its emissions of benzene, hydrocarbons etc also has an absolute share. According to a domestic study [4], in 2005, China's total CO2 e emission is approximately 4.85 billion tons, 10.1% of which, 0.49 billion tons, should owe to transport, storage and postal services. In some cities, 85% of the CO and 45%～60% of the nitrogen oxides come from car exhaust. Under the trend of low-carbon economy, this development mode of high consumption, high pollution and high emission has been unsustainable, and it is imperative to promote energy saving transport system.

4.2 Analyses on low-carbon emission indicators of different transport modes

According to the ECMT “Report on reducing transport CO_2 emission” in 2007, 34% of the CO_2 emissions due to

fuel consumption of OECD countries comes from transportation, in which 23% comes from road transportation, 2% comes from water transportation, 6% come from air transportation and 3% comes from other transportation modes[9]. A German railway 2000 annual environmental report shows that, the CO_2 emission of road passenger transport is 16.8 kg per 100 people kilometer hour, air is 13.4 kg and railway is 4.8 kg; for freight transport, road is 79.8 kg per 100-ton kilometer hour, air is 10.7 kg and railway is 2.6 kg. With the rapid growth of demand, the energy consumption and pollution emissions of transport sectors will grow rapidly. It can be seen that the CO_2 emissions level is directly related to the total energy consumption, and the CO_2 emissions proportion of transportation is roughly equal to its energy consumption proportion. In the background of increasingly energy shortage and environmental capacity decrease, the development of transport is facing increasingly serious challenges.

4.3 Analysis of transport external cost under the background of "carbon offsetting"

As the foundation of China's first carbon offsetting enterprise and the completion of China's first carbon offsetting transaction, carbon offsetting, this brand new environment protection concept and method has been acquainted, accepted and promoted by Chinese community and businesses gradually. In Copenhagen, China promises to decrease the CO_2 emission of unit GDP by 40%～45%. And according to statistics, China's CO_2 emissions will rise to the fist of the world by 2025. People's choices and carbon emissions cost will make certain influence on the external cost of different transport modes with the growing pressure of carbon emission, the acceptance of the "carbon offsetting" conception and the establishment of carbon trading market. Through the analysis and calculation of the external costs of several typical transport modes [13,14], we can see that civil aviation is the highest (0.1184Yuan/person• km), followed by highway (0.0557Yuan/person•km), high-speed railway is minimum (0.0192Yuan/ person • km).

5. Sustainable developments of different transport modes under the background of low-carbon economy

5.1 Background of low-carbon sustainable development of transport enterprises

After the extensive quantitative growth, the structural contradiction inside the integrate transport system become more and more sharp. from 1995 to 2005, air transport and road transport developed fast[5], the market share of air passenger transport increased from 4.1% to 11.7%, and the market share of road passenger and freight transport increased from 46.6% and 18.6% to 52.3% and 20.8% respectively; at the same time, the market share of railway passenger and freight transport decreased from 46.6% and 58.7% to 34.7% and 49.7%, and the market share of pipeline transport decreased from 3.5% to 2.6%. Obviously, high energy consumption and high emissions transport modes are taking increasingly high proportion of transport market share, which reveals that the internal structure of our nation's transportation is not consistent with "low-carbon economy".

5.2 Characteristics of low-carbon sustainable development of different transport modes

5.2.1 Railway transport

Energy consumption of railway transport is closely related to traction power. with the rapid progress of the electric railways and the gradually appearing effects of the energy-saving work of "electricity instead of oil", the unit workload comprehensive energy consumption of our rail transport gradually decreased from 104.1kgce / 10-thousand-ton kilometer in 2000 down to 88.6 kgce / 10-thousand-ton kilometer in 2006[1]. No matter in terms of the needs of the development of low-carbon economy or the correlation between national energy structure remove and energy security [15], our low-carbon integrated transport system should take railway as the aorta, at the same time balanced develop highway, waterway, pipelines and air transport to optimize the internal structure of the transport industry to achieve higher transport efficiency and lower social costs.

5.2.2 Road transport

Road transport is the largest energy consumption transport mode, accounting for 80% of total transport energy consumption. Automobile exhaust has become an important mobile pollution source in many cities. The following improvement should be done to meet the trend of low-carbon transport: first, optimize infrastructure, vehicle capacity and vehicle energy consumption structure; second, develop intelligent transportation technologies and strengthen vehicles' energy-saving technology; third, raise the level of road freight and passenger transport organizations; fourth, improve the energy saving quality of automobile drivers; fifth, highway network should be well coordinated with railways, water and air transportation.

5.2.3 Water transport

As an important low-carbon transport mode, water transport has a huge contribution on the low-carbon economy, and has attracted more and more attention of many governments. Taking the Yangtze river as an example, transport capacity generated by a investment of 100 million Yuan on water transport is 17 times of that of road and 3 times of railway. And its unit energy consumption and emission is respectively 1/14 and 1/15 of road and 1/2 and 1/1.2 of railway [4]. Water transport should be harmonized with road, railway, air, and pipeline transportation in the low-carbon transportation system, and joined with water conservancy, hydropower and environmental protection project. The inland water transport of China is relative lag and becomes a weak link of the integrated transport system, which directly affects the integrated efficiency and comparative advantage of various transport modes.

5.2.4 Air transport

Air transport is high energy consumption and noise pollution transport mode, "Green, and environment friendly" will be the future subject of civil aviation industry to meet the request of low-carbon economy [8]. In the matter of fact, the air transport is one of the most improved industries from an environmental view point. Now the aircraft fuel consumption is 70% lower than 40 years ago and 20% lower than 10 years ago. The new technology is the key factor for the air transport industry to achieve environment friendly. From the perspective of energy supply, China's air transport industry should be maintained at appropriate levels meanwhile allocate resources reasonably to minimize vicious competition and repeated construction. At the same time, we should improve the competitive ability of aviation industry and participate in international division of labor actively.

5.2.5 Pipeline transport

The advantages of pipeline transportation include large volume, small footprint, small impact on environment and energy consumption, particularly its good safety performance and high transport efficiency. A 7000 kilometer oil pipeline can save about 1 billion Yuan a year compared with railway transport because of transport cost reducing, power saving and transport losses decreasing. Because of the constriction of transport objects, the development of pipeline transport in China was very slow; the current proportion of its cargo turnover is less than 2%. It has great potential for further development under the conditions of industrial structure optimization and low-carbon economy. At present, key technologies of transport of non-fluid objects, such as ore, coal, building materials, chemicals and food, is becoming gradually perfect and mature. The application of these technologies will expand the categories of pipelines transport items, which deserves high attention.

5.3 Construction of integrated low-carbon transport system

Currently, our traffic is still in a building and development period, the demands for resources and energy are still strong, the task of energy saving and emission reducing is arduous, which makes it urgent to establish a low-carbon comprehensive transport system. To establish low-carbon comprehensive transport system, we must focus on industry structure adjustment and optimization, develop low energy consumption and low emission transport modes, make full use of the combination advantages of various transport modes, allocate resources rationally to promote the reasonable distribution of transportation hubs and achieve “seamless connection” of different transport modes gradually.

6. Conclusions

"Low-carbon economy" is determined by energy structure, technological level, industrial structure, policies, institutional arrangements and the people's consumption behavior jointly. China's resource endowment is poor in oil and rich in coal, before the breakthroughs of production technologies of new energy and alternative energy, China's demand for oil of the transportation industry is irreplaceable or limited alternative in the next 20 years. In this condition, we must take a series of technical and management methods, such as optimizing the internal structure of transportation industry; improving the energy efficiency of different modes of transport; developing and using renewable energy; enhancing organization and management and leading people’s consumption behaviors, to maximize the effectiveness and efficiency of the transport system.

Acknowledgment

This work is partly supported by the Humanities Social Sciences Programming Project of the Ministry of Education of China (no. 10YJA630126), the State Social Science Fund Project (no. 11CJY067), the Natural Science Foundation of Gansu Province (no. 1107RJYA070), the Young Scholars Science Foundation of Lanzhou Jiaotong University (no. 2012056), and the Natural Science Foundation of Gansu Province (no. 1107RJYA070 and no. 1208RJZA164).

References

[1] CHANG Shi-yan,HU Xiao-jun,OU Xun-min,et al.“Decomposition analysis of intercity passenger transportation energy consumption in china”,China Population Resources and Environment, 20(03), pp.24-29,(2010).
[2] CHEN Qi-yu. “The dependence rate of foreign oil resources has exceeded 55% in China”,China Industrial Economic Information Network,2010.08.11.http://www.cinic.org.cn/site951/hgpd/2010-08-11/427474.shtml.2010.08.01.
[3] GENG Qin,SHE Xiang-yun,ZHU Hong,et al.“Preliminary discussion and analysis on transportation energy consumption in China”,Energy of China,29(10), pp.19-22,(2007).
[4] HAN Jing-wei.“Development strategy of inland water transport during the low-carbon economy era”,Comprehensive Transportation,05,pp.18-20,(2010).
[5] JI Nian.“How to develop the low-carbon economy in transportation”,Environment Protection,10, pp.62-64,(2010).
[6] LI Lian-cheng.“Energy saving and emission reduction is the important work during the twelfth five-year plan”,Marine Energy Saving,02 ,pp.44-45(2009).
[7] LUO Ren-jian.“The comparative study of land occupation between highway and rasilway”,Comprehensive Transportation,05, pp.18-20,(2004).
[8] LI Yong-qun.“Green environment—the development themes of aviation”,People's Daily,2007.06.20.
[9] MOT.“Background material of the impact of transport on climate change”,Ministry of Transport of the People's Republic of China Network,2008.06.14. http://www.moc.gov.cn/2006/jiaotongjj/07jiaotjnw/jienengxcz/200806/t20080612_497913.html.2010.08.01
[10] National Bureau of Statistics of China.China Statistical Yearbook 2009. Beijing:China Statistics Press.
[11] WU Wen-hua.“The compare of energy consumption and emission in transportation between china and typical city”,Energy of China,29(10) ,pp.19-22(2007).
[12] XU Chuang-jun,YANG Li-zhong, YANG Hong-wei,et al. “Research on evaluation index system for ecological sustainability of transport system”,Railway Transport and Economy,29（05）,pp.04-07(2007).
[13] ZHANG Li,LI Qun-ren.“Calculating and Analyzing the Exterior Cost of Several Main Modes”,Railway Transport and Economy,22（01）,pp.36-38 (2000).
[14] ZHANG Xin-yu,CHEN Jing-yan.“Evaluation and Internalization of the External Costs on Traffic and Transport”,Journal of Northern Jiaotong University,23(03),pp.17-21(1999).
[15] Zhou Xin-jun.“Study of relevancy between china's national energy security and the development of railway”, Energy of China, 30（12）,pp.10-16(2008).

Junwei Zeng received her M.A. in the School of Traffic and Transportation of Lanzhou Jiaotong University, Gansu, China, in 2011. He is now a lecturer in the School of Traffic and Transportation of Lanzhou Jiaotong University. His main research interest is simulation of transportation and traffic economics.

Xiaoming Shao received his B.E. in the Hebei University of Technology, Hebei, China, in 2010. He is now a postgraduate in the School of Traffic and Transportation of Lanzhou Jiaotong University. His main research interest is simulation of transportation and traffic economics.

Yongsheng Qian received his Ph.D. in the Northwest Normal University, Gansu, China, in 2010. He has been a full professor in the School of Traffic and Transportation of Lanzhou Jiaotong University. His main research interest is simulation of transportation and traffic economics.