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ANALYSING CO2 EMISSION FROM FREIGHT TRANSPORT IN CHINA - DECOMPOSITION INTO FACTORS DUE TO CHANGES IN LIFE STYLE AND INTER-INDUSTRIES RELATIONS

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This is an abridged version of the paper presented at the conference. The full version is being submitted elsewhere. Details on the full paper can be obtained from the author.

ISBN: 978-85-285-0232-9

13th World Conference on Transport Research

www.wctr2013rio.com

15-18 JULY 2013
Rio de Janeiro, Brazil

ANALYSING CO_2 EMISSION FROM FREIGHT TRANSPORT IN CHINA -DECOMPOSITION INTO FACTORS DUE TO CHANGES IN LIFE STYLE AND INTER-INDUSTRIES RELATIONS -

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Submission for track:
F: Transport, Land Use and Sustainability

ABSTRACT

In order to find out the potential causes that affect CO_2 emission and their changes in freight transport sector and understand the unbalance CO_2 emission distribution in the freight transport sector, this paper mainly focuses on examining the relationship between carbon dioxide emission and transport activities. First of all, this study calculates CO_2 emission from the freight transport sector from 1990 to 2007 based on presented methods. Secondly, LMDI (Logarithmic Mean Deviation Index) method is employed to analyze the factors influencing CO_2 emission in freight transport sector. Thirdly, the concept of Lorenz curve is used to describe the unbalanced development in per capita GDP and CO_2 emission in the freight transport sector of China. As a result, we find: (1) from 1990 to 2007, the CO_2 emission from freight transport increased by 525%, i.e., from 65.4 million tons to 344 million-tons; (2) it is found population effect, per capita GDP effect and modal shift effect have positive effects on CO_2 emission; while the factors transport intensity and the emission coefficient effect have negative influences on CO_2 emission; (3) we find the unbalance of per capita GDP in each province of China increases, the unbalance of per capita freight transport CO_2 emission in each province of China also increases. Considering quick and unbalanced increase of freight transport CO_2 emission increase, it is essential for policy makers to make policies to encourage eco-friendly transport mode (such as rail transport) and reduce travel distance by accelerating industry agglomeration to reduce CO_2 emission in the freight transport sector.

Key word: China, Freight transport, CO_2 emission, Decomposition method, Unbalance

1. INTRODUCTION

At present, China is the biggest contributor to CO_2 emission in the world so that it is facing high pressure of CO_2 reduction. In 2009, Chinese government declared that China would reduce its CO_2 emission intensity by 40% to 45% by the year of 2020.

Recently, Chinese economy has developed at a high speed. Accordingly freight transport has boomed. Consequently, energy consumption and CO_2 emission have increased greatly, which is a big challenge to China's energy security and global warming. With the development of economy and the configuration of economy, income and the activity of goods movement have been changing. Thus, as one of the most important parts in transport sector, freight transport is booming. Hence, it is more and more urgent to improve the efficiency of freight transport and find its affecting factors. At the same time, causes for the increase of freight transport need to be found and countermeasures should be taken to slow down the trend.

Hence, this paper aims at: (1) describing CO_2 emission trend in the freight transport sector and its distribution in different provinces in China; (2) finding and explaining the driving forces and the influencing factors in the freight transport sector in different provinces; (3) giving necessary policy suggestions.

This paper is presented in accordance with the following outline. Section 2 reviews related literatures. Section 3 states the data and methodologies related to the estimation of CO_2 emission as well as the decomposition method and the methodology to describe the difference in different provinces/cities. Section 4 examines the trends of CO_2 emission in China from 1990 to 2007 and their regional difference in freight transport sector CO_2 emission. In addition, this paper not only shows the result of the decomposition in the freight transport sector but also discusses how life-style changes and structural shift to industries causes these changes. Then, based on the analysis in section 4, policies are put forward for the reduction of CO_2 emission in section 5. Finally, main conclusions are given in section 6.

2. REVIEW AND OBJECTIVES

There have been several important researches related to this topic as follows:

After examining freight energy use and carbon emission in 11 IEA countries, Joyong Eom and Lee shipper[1)] found that, the energy intensity of trucking showed very large variations among countries and modal shift from trucking to rail enabled substantial opportunities to reduce freight transport CO_2 emission. Therefore, they suggested the countries should review their transport policies to remove any barriers and improve the efficiency of transport efficiency in a long term.

A.C. McKinnon[2)] not only used various methods to measure CO_2 emission from road freight transport, but also found many factors that affected the accuracy of CO_2 emission in freight sector and advised clarifying the differing scope of CO_2 measurement and public revisions of statistical series and to reconcile difference in truck-km estimates.

Steve Sorrell[3)] used decomposition method to analyse the energy use of road freight in UK from 1989 to 2004. In this way, the factor that affected CO_2 emission in UK could be divided into 11 sub-factors. As a result, it was shown that the main factor contributing to the decoupling of energy consumption in UK road freight from GDP declined in the value of domestically manufactured goods related to GDP, the other factor about the decoupling of the energy consumption in road freight transport from GDP was composed of empty run of vehicles, the reduction in energy use per vehicle-km, shift towards larger cars and changes in the average length of haul. The factor that went against the decoupling the energy consumption in road freight transport from GDP included the reduction in the average payload weight for individual categories of vehicle, increase in freight intensity, shifts in the mix of domestically produced commodities as well as a modal shift towards road.

Fredrik[4)] analysed the CO_2 emission in the freight transport sector of Sweden from 1990 to 2008 , finding that the different and changing relations between growth and emission over the growth cycle indicated that the observed development in emission was far from linear and could not be explained straight forwardly by economic growth.

Wang[5)] utilized LMDI method to analyse CO_2 emission in the transport sector in China and found that the factor affecting CO_2 emission could be divided into six factors including emission coefficient, transport service share, transport modal shift, transport intensity, per capita economic activity and population. Among the six factors, per capita economic activity and transport modal shift were found to be the main contributors to the increase of CO_2 emission.

In the said studies, the decomposition methods are used to distinguish the influencing factors. Actually, there are various kinds of decomposition methods that can be used to measure the impacts of different factors on CO_2 emission. In literatures, two well-known decomposition techniques, namely SDA (structural decomposition analysis)[6)] and IDA(index decomposition analysis), have been widely used to analyse the driving forces. The former is based on the input-output model, while the latter utilizes the concept of index number in decomposition. Ang[7)8)] compared various methods of index decomposition analysis and showed that the LMDI method was preferred because of its theoretical foundation, adaptability, ease of use and interpretation of results.

The general conclusion of these researches is that the growth in economic output has been the main factor affecting the increase in freight transport work and its energy use. Despite this, less effort has been made to express the balance of CO_2 emission difference at different stages of social-economic development. However, the driving force of the increase of CO_2 emission in the freight transport sector is not described and compared, respectively.

3. METHODLOGY AND DATA

3.1 Measurement of CO_2 emission

According to the IPCC guidline[9)], CO_2 emission in the year t is estimated based on transport volume, energy consumption per transport volume and carbon emission factors, which are shown in the following equation:

$$C^t = \sum_i C_i^t = \sum_{i,j} C_{ij}^t = \sum_{i,j} V_{ij}^t \times R_{ij}^t \times F_j \quad (1)$$

where,

C^t : total freight transport CO_2 emission (in Million tons, Mt) in year t

C_i^t : CO_2 emission (in Million tons, Mt) of the i th transport mode in year t

C_{ij}^t : the emission coefficient of the i th transport mode based on fuel type j in year t

V_{ij}^t : transport volume of the i th transport mode based on the fuel type j in year t

R_{ij}^t : energy consumption per transport volume of the i th transport mode based on fuel type j in year t

F_j : CO_2 emission factor of the j th fuel (kg-CO_2/ unit)

V_{ij}^t and R_{ij}^t is obtained from Yearbook of each province[10)] and Yearbook of China Transportation and Communication[11)].

3.2 Decomposition of the Component

The CO_2 emission can be divided into six factors by using Kaya identity as follows:

$$\begin{aligned} C^t &= \sum_{i,j} C_{ij}^t = \sum_{i,j} \frac{C_{ij}^t}{V_{ij}^t} \times \frac{V_{ij}^t}{V_i^t} \times \frac{V_j^t}{V^t} \times \frac{V^t}{GDP^t} \times \frac{GDP^t}{P^t} \times P^t \\ &= \sum_{i,j} C_{ij}^t \times SS_{ij}^t \times TS_i^t \times TI_i^t \times TG^t \times P^t \end{aligned} \quad (2)$$

Where,

C_{ij}^t : the emission coefficient of the i th transport mode based on fuel type j in year t

V_{ij}^t : transport volume of the i th transport mode based on the fuel type j in year t

V_i^t : transport volume of the i th transport mode in year t

V^t : total transport volume in year t

GDP^t : GDP in year t

P^t : population in year t

SS_{ij}^t : transport volume share of the i th transport mode based on fuel type j in year t to the i th transport mode

TS_i^t : transport modal share of the i th transport mode

TI^t : the transport intensity in year t

TG^t : per capita economic activity in year t;

Each individual factor that affects CO_2 emission from the base year *0* to the year t can be calculated as follows:

$$\Delta C_{tot} = \Delta C_{ci} + \Delta C_{ss} + \Delta C_{ts} + \Delta C_{ti} + \Delta C_{tg} + \Delta C_{tp} \quad (3)$$

Where,

ΔC_{tot}: the changes of total CO_2 emission in transport sector

ΔC_{ci}: the changes in the emission coefficient effect

ΔC_{ss}: the changes in the transport volume share effect

ΔC_{ts}: the changes in the transport modal shifting effect

ΔC_{ti}: the changes in the transport intensity effect

ΔC_{tg}: the changes in the per capita economic activity effect

ΔC_{tp}: the changes in the population effect

Each variable in this equation can be calculated by adopting LMDI method provided by Ang[7) 8)] the as follows:

$$\Delta C_{ci} = \sum_{i,j} \Delta C_{ci,ij} = \begin{cases} \Delta C_{ci,ij} = 0, & \text{if } C_{ij}^t \times C_{ij}^0 = 0 \\ \Delta C_{ci,ij} = \sum_{i,j}; L\left(C_{ij}^t, C_{ij}^0\right) \ln\left(\dfrac{C_{ij}^t}{C_{ij}^0}\right), & \text{if } C_{ij}^t \times C_{ij}^0 \neq 0 \end{cases} \qquad \Delta C_{ss} = \sum_{i,j} \Delta C_{ss,ij} = \begin{cases} \Delta C_{ss,ij} = 0, & \text{if } C_{ij}^t \times C_{ij}^0 = 0 \\ \Delta C_{ss,ij} = \sum_{i,j}; L\left(C_{ij}^t, C_{ij}^0\right) \ln\left(\dfrac{SS_{ij}^t}{SS_{ij}^0}\right), & \text{if } C_{ij}^t \times C_{ij}^0 \neq 0 \end{cases}$$

$$\Delta C_{ts} = \sum_{i,j} \Delta C_{ts,ij} = \begin{cases} \Delta C_{ts,ij} = 0, & \text{if } C_{ij}^t \times C_{ij}^0 = 0 \\ \Delta C_{ts,ij} = \sum_{i,j}; L\left(C_{ij}^t, C_{ij}^0\right) \ln\left(\dfrac{TS_{ij}^t}{TS_{ij}^0}\right), & \text{if } C_{ij}^t \times C_{ij}^0 \neq 0 \end{cases} \qquad \Delta C_{ti} = \sum_{i,j} \Delta C_{ti,ij} = \begin{cases} \Delta C_{ti,ij} = 0, & \text{if } C_{ij}^t \times C_{ij}^0 = 0 \\ \Delta C_{ti,ij} = \sum_{i,j}; L\left(C_{ij}^t, C_{ij}^0\right) \ln\left(\dfrac{TI_{ij}^t}{TI_{ij}^0}\right), & \text{if } C_{ij}^t \times C_{ij}^0 \neq 0 \end{cases}$$

$$\Delta C_{tg} = \sum_{i,j} \Delta C_{tg,ij} = \begin{cases} \Delta C_{tg,ij} = 0, & \text{if } C_{ij}^t \times C_{ij}^0 = 0 \\ \Delta C_{tg,ij} = \sum_{i,j}; L\left(C_{ij}^t, C_{ij}^0\right) \ln\left(\dfrac{TG_{ij}^t}{TG_{ij}^0}\right), & \text{if } C_{ij}^t \times C_{ij}^0 \neq 0 \end{cases} \qquad \Delta C_{tp} = \sum_{i,j} \Delta C_{tp,ij} = \begin{cases} \Delta C_{tp,ij} = 0, & \text{if } C_{ij}^t \times C_{ij}^0 = 0 \\ \Delta C_{tp,ij} = \sum_{i,j}; L\left(C_{ij}^t, C_{ij}^0\right) \ln\left(\dfrac{P_{ij}^t}{P_{ij}^0}\right), & \text{if } C_{ij}^t \times C_{ij}^0 \neq 0 \end{cases} \quad (4)$$

According to Equation (3), it can be converted into

$$\frac{\Delta C_{ci}}{\Delta C_{tot}} \times 100\% + \frac{\Delta C_{ss}}{\Delta C_{tot}} \times 100\% + \frac{\Delta C_{ts}}{\Delta C_{tot}} \times 100\% + \frac{\Delta C_{ti}}{\Delta C_{tot}} \times 100\% + \frac{\Delta C_{tg}}{\Delta C_{tot}} \times 100\% + \frac{\Delta C_{tp}}{\Delta C_{tot}} \times 100\% = 100\% \quad (5)$$

Each component in Equation (4) stands for different factors affecting CO_2 emission.
Emission coefficient factor (ΔC_{ci}) is used to describe emission efficiency, it denote how much CO_2 is needed for each transport type, it can be improved by technology innovation, fuel improvement, lighter weight of the vehicle. Energy source factor (ΔC_{ss}) is used to describe the change of the fuel type in certain transport mode. Modal shift factor (ΔC_{ts}) is used to describe the share of a transport mode in total transport volume. Transport intensity factor (ΔC_{ti}) is used to describe the intensity of transport volume, namely how much transport volume consumed by each GDP. Per capita GDP factor (ΔC_{tg}) is used to describe how per capita GDP affect CO_2 emission of freight transport sector. Population factor (ΔC_{tp}) is used to describe how population affect CO_2 emission of freight transport sector.

3.3 Source of Data and Research Boundary

The data of transport volume and mode share are collected from the yearbook of each individual province[10)] during the period from 1990 to 2007, respectively. Additionally, data of energy efficiency is collected from yearbook of China Transportation and Communication[11)]. The transport volume is measured in terms of ton-km in this paper.
This research take most of province of China into consideration, including: Anhui, Beijing, Shanghai, Chongqing, Tianjin, Fujian, Guangdong, Guangxi, Hainan, Gansu, Hebei, Henan and Heilongjiang, Hubei, Hunan, Jilin, Jiangsu, Jiangxi, Ningxia, Qinghai, Shandong, Shanxi, Liaoning, Inner Mongolia, Tibet, Xinjiang, Sichuan and Zhejiang. Because of the data availability, there are 4 provinces in China are not included, that most due to data availability, that might not affect the result.
With respect to the data source in the research, inter-city transport is counted as traffic volume data, but inner-city transport is not counted. The transport that takes the city as both origin and destination is accounted as the traffic volume of that city. Besides, data about transport volume (in ton-km) and energy consumption are measured and recorded in terms of trucks, trains, planes and ships, which are settled by weighted average method. Next, the average value of energy efficiency (in terms of fuel/ton-km) of all vehicles is provided as the data about energy efficiency by the local statistics bureau. Road, rail, domestic aviation and domestic water transport sector are taken into account. The reason why international transport is not considered is that it reflects the development of the whole country instead of the development of one region.
Energy used in road transport includes gasoline and diesel, the one used in rail transport consists of diesel and electricity, the one applied to aviation transport sector is composed of aviation kerosene, and the one used in water transport sector is diesel.

4. ANALYSIS

4.1 CO_2 Emission Trend

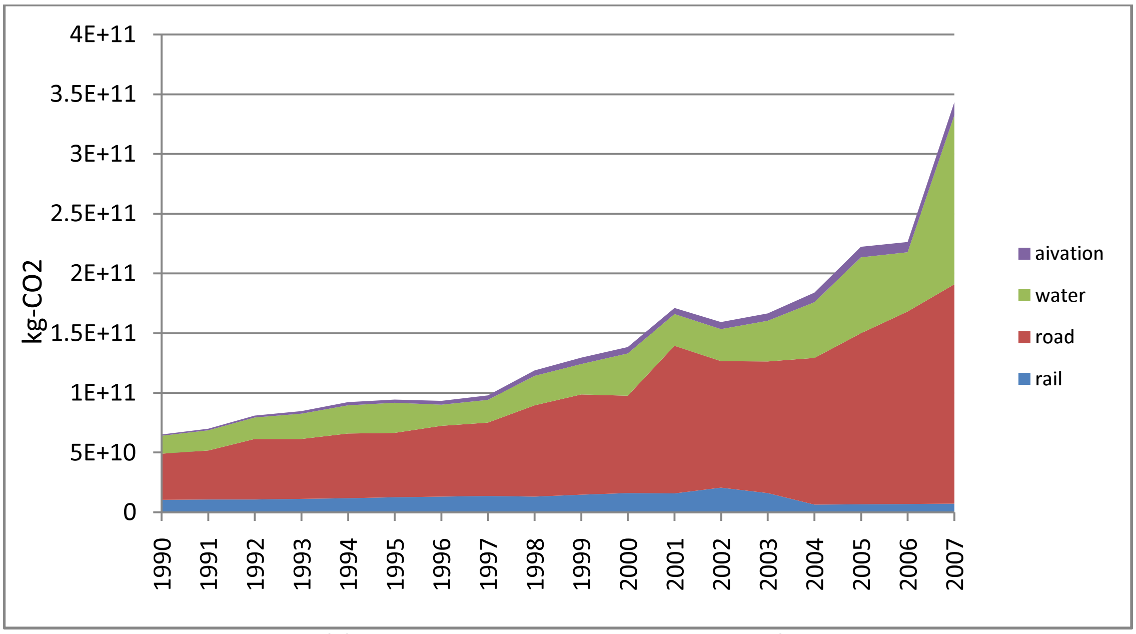

Fig. 1 CO_2 emission in the transport sector in 28 Chinese province

As shown in Fig. 1, the road sector is the main contributor to CO_2 emission. The total CO_2 emission increased from 65.4 Mt in 1990 to 344 Mt in 2007, with the annual average growth rate of 10%. At the same time, the total GDP increased from RMB 1,893 billion in 1990 to RMB 29,407 billion in 2007, with the annual growth rate of 17.5%. The annual GDP increase is higher than that in the freight transport sector. In another word, GDP grows much quicker than the CO_2 emission in the freight transport sector.

As the biggest emitter, CO_2 emission share from the road sector occupied 59.0% of the total freight transport CO_2 emission in 1990 and increased to 69.2% in 2007. The second biggest emitter was water transport, the share which decreased from 22.9% in 1990 to 21.9% in 2007. Besides, the share of CO_2 emission from rail transport decreased dramatically from 16.3% in 1990 to 2.2% in 2007, while the share of CO_2 emission from aviation transport increased from 1.7% in 1990 to 3.8% in 2007.

The CO_2 emission in the whole freight transport sector continuously increased and was accelerated with economic growth. As the freight transport increasingly relied on road, road transport was the dominant mode and its share had been increasing from 1990 to 2007. However, the share of rail transport decreased constantly, which was taken place by aviation and road transport. Furthermore, water transport sector kept stable and aviation sector increased quickly.

4.2 Decomposition Analysis of the 28 Province

Considering the decomposition of each province from 1990 to 2007, the year 1990 is taken as the base year to calculate the results of 1992, 1997, 2002 and 2007. The decomposition result includes: emission coefficient factor (ΔC_{ci}), energy source factor (ΔC_{ss}), modal shift factor (ΔC_{ts}), transport intensity factor (ΔC_{ti}), per capita GDP factor (ΔC_{tg}) and population factor (ΔC_{tp}).

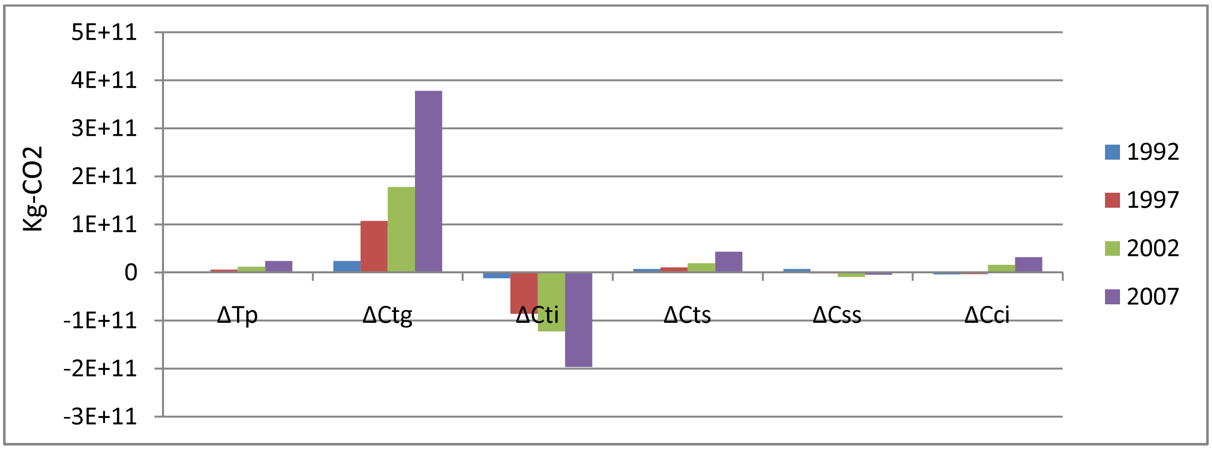

Fig. 2 Decomposition result of 28 province/cities

According to Fig. 2, we find that GDP and the transport intensity are the main contributors to the increase in CO_2 emission. The increase of the total CO_2 emission from the freight transport of these 28 regions was 275 Mt from 1990 to 2007. In 2007, concerning freight transport CO_2 emission, the factor population generated 24.2 Mt, the factor per capita GDP contributed 377 Mt, the factor modal shift caused 43.3 Mt and emission coefficient produced 31.8Mt. However, in the aspect of CO_2 emission in the freight transport, the factor transport intensity contributed -197 Mt and the factor energy source generated -4.7 Mt. Population, GDP and modal shift changed very steadily from 1990 to 2007. Indeed, the effect of energy source could nearly be neglected. Moreover, per capita GDP, mode share and population had the positive effect on CO_2 emission. Among them, per capita GDP had the strongest effect. Nevertheless, the energy intensity showed the strongest negative effect and the effect increased year by year steadily.

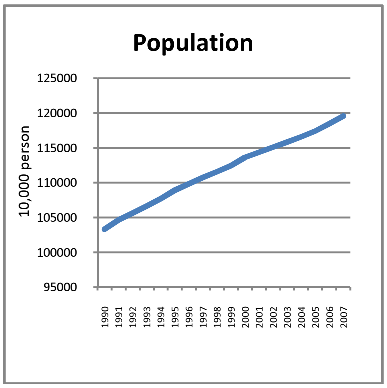

Fig. 3 Population

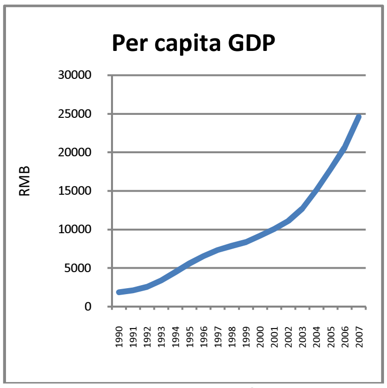

Fig. 4 Per capita GDP

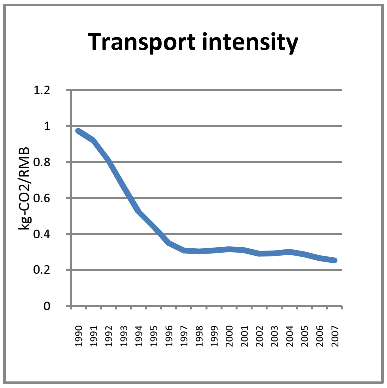

Fig.5 Transport intensity

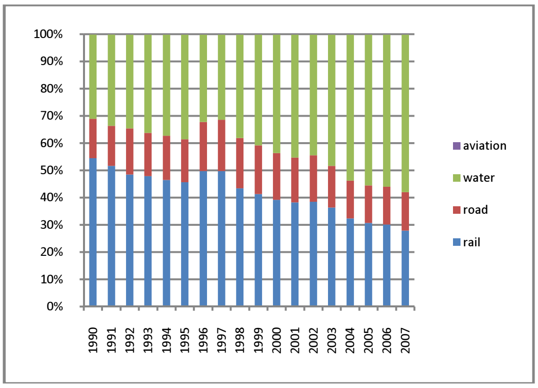

Fig. 6 Mode share

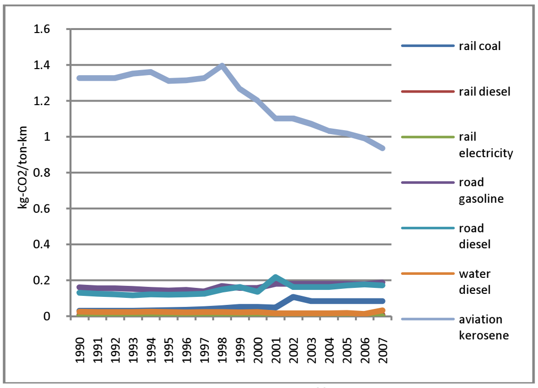

Fig. 7 Emission coefficient

Based on the Fig 3-7, it is shown that the growth of population increased CO_2 emission. The reason for this was that the increase of population caused an increasing demand for transport. Hence, the increase of population led to the increase in CO_2 emission. The population increased by 15.7% from 1990 to 2007, which contributed 24.2 Mt to the increase in CO_2 from 1990 to 2007.

As the per capita GDP and consequential income increased, personal consumption also grew, which not only caused increasing demands for goods but also led to more freight transport. The increase in per capita GDP contributed 377 Mt to the increase in CO_2 emission from 1990 to 2007. This effect shows CO_2 emission increased continuously, as shown in Fig. 4.

With the evaluation of economy, the share of the tertiary industry increase, while the share of the primary and secondary industries decrease constantly. The reason for this is that the secondary industry relies on freight transport to a large extent, while the tertiary industry depends more on labour force. As the economic structure changes obviously, the transport intensity has the strongest negative effect on CO_2 emission, which contributed -197 Mt to CO_2 emission from 1990 to 2007 and decreased from 0.97 ton-km/RMB in 1990 to 0.25 ton-km/RMB in 2007.

4.3 Analysis Based on I-O Tables

To understand the contribution of the freight transport sector to the whole economy, the Input-Output table (in terms of value) of China[12)] in the year 1997 and 2007 are used to describe how the freight transport sector has impacts on the whole economy. In the analysis, I-O table (in terms of value) of 1997 with 124 sectors and the I-O table (in terms of value) of 2007 with 135 sectors are employed. The impact from the freight transport are divided into 4 sectors, i.e., road, rail, water and aviation sectors. Here, we rank top 10 sectors that freight sector influences, which occupies more than 40% of demands for transport (in terms of money).

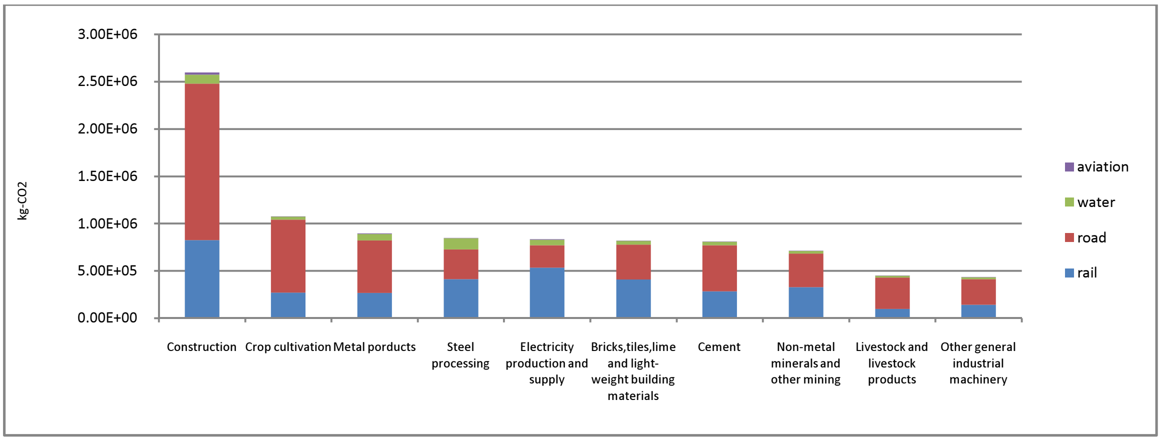

Fig. 8 Top 10 sectors affected by freight transport in 1997

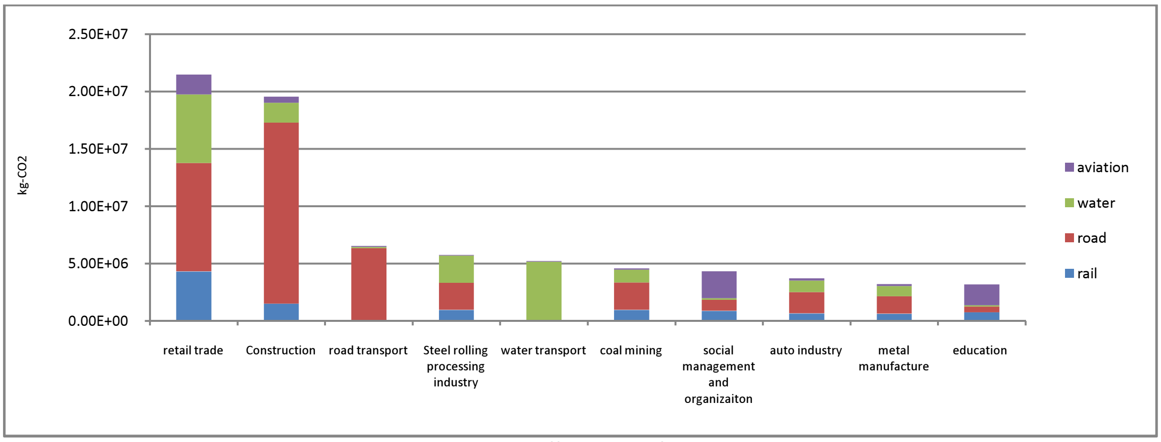

Fig. 9 Top 10 sectors affected by freight transport in 2007

As shown in Fig. 8 and Fig. 9, the top 10 sectors changed a lot from 1997 to 2007. In detail, the construction sector ranked No. 1 in 1997, but retail trade sector was the first in 2007. The top 10 sectors were mainly composed of the secondary industry in 1997, such as mining, construction and manufacture. However, in 2007, most of the top 10 sectors came from the tertiary industry, such as retail trade, other transport sector and education; and the industry also changed into the high-tech one like metal manufacture and auto industry. Meanwhile, both the absolute value (investment) and the share of aviation increased from 1997 to 2007. The said means that, in China, the change in the economic structure also made the freight transport sector change. Additionally, the freight provided more service to the tertiary industry and high technology industry and these sectors were the ones with high added value. Consequently, the same transport service would provide more value added in GDP, so the transport intensity decreased. What's more, these sectors needed quick service so that the aviation and road transport share increased. Hence, the mode share tended to be more eco-unfriendly.

4.4 Distribution of Per Capita GDP and Freight Transport Sector CO_2 Emission among Provinces

(1) Introduction of Lorenz Curve

The Lorenz curve is a graphical representation of the cumulative distribution function of the empirical probability distribution of wealth, showing the proportion of the distribution assumed by the bottom y% of the values. It is often used to represent income distribution, where it shows for the bottom x% of households, what percentage y% of the total income they have.

In this study, we use this concept to describe distribution of per capita freight transport sector CO_2 emission in provinces and the per capita GDP distribution among provinces. Such as in the Fig.10, Gini coefficient is the ration of area A/(area A + area B). In this study, this concept is used to describe the difference in GDP and transport sector CO_2 emission in different provinces.

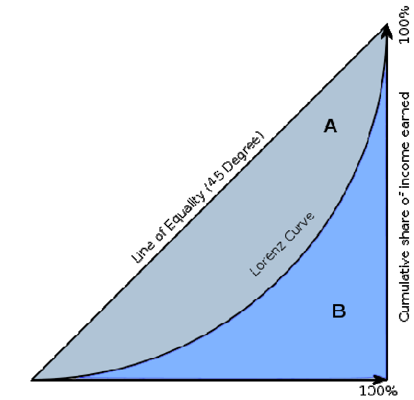

Fig 10 Concept of Lorenz curve

(2) Difference in per capita GDP and per capita CO_2 emission from freight transport sector CO_2

China is a big country, the development of China is unbalanced, and regional difference is huge in GDP and CO_2 emission from freight transport sector. In this paper, Lorenz curve is used to describe the difference as shown in Fig. 11 and Fig. 12.

The data is treated by province, within each province, GDP is regarded equally distributed to everyone, Lorenz curve is used to distinguish the difference between provinces. The horizontal axis stands for the cumulated population, while the vertical axis stands for cumulated GDP. The provinces are located in the figure in the order of per capita GDP. In Fig. 10, Gini coefficient, (Area of A) /(area of (A+B)), is between the value of 0 and 1 .

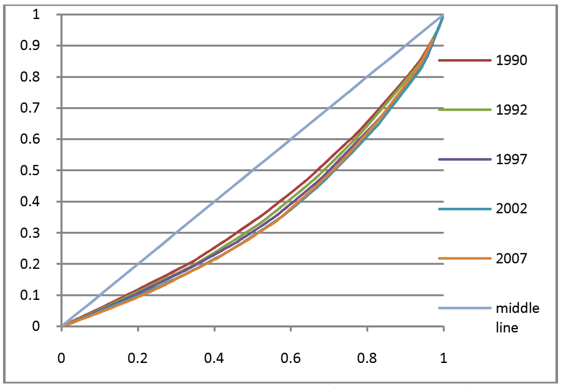

Fig 11 Lorenz curve of per capita GDP

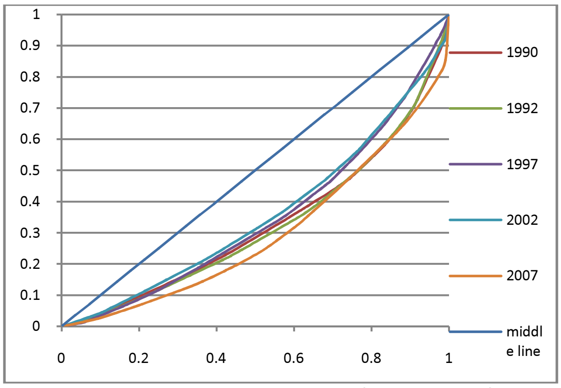

Fig 12 Lorenz curve of per capita freight transport CO_2 emission

The per capita GDP Lorenz curve of the year 1990, 1992, 1997 2002 and 2007 is shown in Fig11, the curve has grown since 1990 till 2002and then become bigger in 2007.This means that the GDP unbalance is now bigger from 1990 to 2007, the Gini coefficient changes from 0.23 in 1990 to 0.29 in 2007.That means that: the developed area in China developed much quicker than the undeveloped area. This unbalance is because of the agglomeration in China, especially in the south eastern area of China, the Foreign Direct Investment focus on this area because of the technology agglomeration and human resource agglomeration, and this kind of agglomeration accelerate the development of these areas. Gini coefficient is shown in Table 1.

Table 1 Gini coefficient of per capita GDP

Year	1990	1992	1997	2002	2007
GDP-Gini	0.23	0.26	0.28	0.30	0.29

When describing the freight transport sector CO_2 emission difference, data is treated by provinces, within each province, freight transport sector CO_2 emission is regarded equally distribute to everyone, Lorenz curve is used to distinguish the difference between the provinces. The horizontal axis stands for the cumulated population, while the vertical axis stands for cumulated transport sector CO_2 emission. The provinces are located in the figure in the order of per capita freight transport CO_2 emission.

The freight transport sector CO_2 emission Lorenz curve of the year 1990, 1992,1997 2002 and 2007 is shown in Fig. 12, the curve first shrink from 1990 to 2002 and then become bigger from 2002 to 2007, the Gini coefficient changes is shown as follows:

Table 2 Gini coefficient of per capita freight transport sector CO_2 emission

Year	1990	1992	1997	2002	2007
CO_2-Gini	0.35	0.36	0.30	0.28	0.40

From 1990 to 2002, Gini coefficient decreased because: in the developed area, transport intensity (transport volume/GDP) decreased a lot, while in the lowly developed provinces the transport intensity did not decrease so much.

From 2002 to 2007, Gini coefficient increased because: in developed provinces, road transport and aviation transport trend to be more attractive, then the mode share of road transport and aviation increase quicker than that of lowly developed provinces. While, the CO_2 emission intensity of road transport and aviation transport is very high. Hence, the freight transport CO_2 emission in developed provinces increase quicker than that of lowly developed provinces. Hence, difference between developed provinces and lowly developed provinces increased, Gini coefficient increased.

(3) **Differences in driving forces of freight transport CO2 emission among provinces**

To understand how the factors cause changes in per capita freight transport sector CO_2 emission from 1990 to 2007, decomposition method provided by section 3.2 is used. The result is shown as follows:

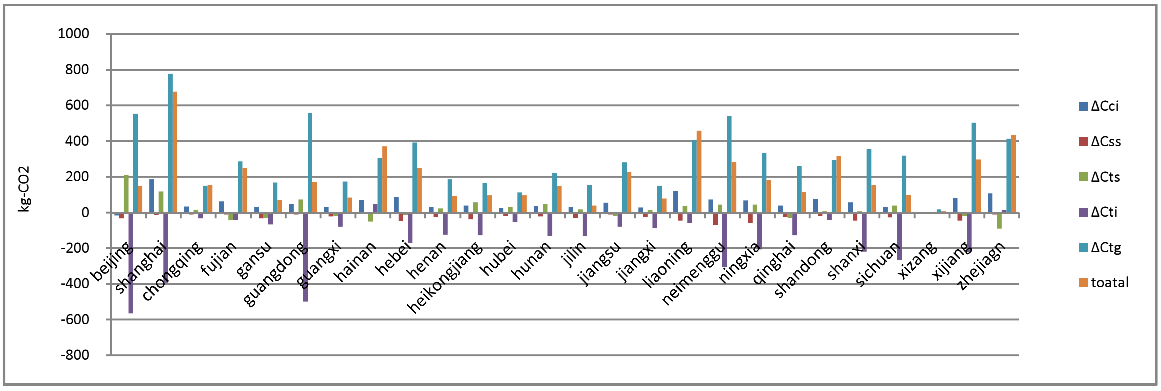

Fig 13 Decomposition result in each individual province

From Fig. 13, we can find that: (1) within all of the provinces, per capita GDP shows the biggest positive effect, while transport intensity shows the biggest negative effect. (2) Transport mode mainly shows positive to CO_2 emission, especially in some developed area, such as Shanghai, Beijing and Guangdong. That is because these developed regions rely more on aviation mode and road mode. (3) Per capita transport CO_2 emission increase shows big differences among provinces, which is mainly related with the economic structure and economic development stage. Shanghai and Beijing have similar per capita GDP increase. In Shanghai, the main contributor of economy is the secondary industry, while in Beijing the main contributor of economy is the tertiary industry. Hence, the freight transport sector CO_2 emission increase of Shanghai is much bigger than that of Beijing as shown in the Fig. 13.

5. POLICY IMPLICATIONS

Based on the analysis in section 4, we obtain the following policy implications along the three strategies of Avoid, Shift and Improve:

5.1 Avoiding Freight Transport Demand

Encourage citizens to use local products to reduce travel distance in freight transport and implement recycling of regional goods. Accelerate reduction of transport intensity, accelerate the evolution of industry from low value added to high value added. Promote policies to encourage clustering industry, hence, the travel distance can be reduced.

5.2 Shifting to More Eco-friendly Transport Modes

As analysed in section 4, road and aviation are now increasing quickly in recent years, while the share of rail transport decreased from 13% in 1990 to 2% in 2007. This is because the service of rail transport is not good enough to attract freight. Aviation and road can provide door to door convenience and fast services respectively. Thus, the only way shifting transport demand to rail and water is to provide high speed and feeder collection & delivery services in rail and water sectors.

5.3 Improving the Efficiency of Each Transport Mode

According to Fig. 7, the fuel efficiency has not yet improved greatly from 1990 to 2007 expect for aviation. We should use more efficient engine for trucks and improve loading factor of trucks by well designed logistic systems. At the same time, we should constantly improve energy and motor efficiency of rail, truck, air-plane and ship as well as alternative energy source for rail, truck airplane and ship.

6. CONCLUSION

This paper takes freight transport sectors in 28 provinces of China as examples. We then calculated CO_2 emission from freight transport sector from 1990 to 2007. Furthermore, the LMDI method developed by Ang[7)8)] is used to decompose into six factors, namely, emission coefficient, energy source, modal shift transport intensity, per capita GDP and population. The contribution of each factor from 1990 to 2007 is calculated by fixing the initial year 1990. Having examining the change in each factor, we find relative significance of causes. The variation of per capita GDP and CO_2 emission from freight transport sector in the 28 provinces/cities are also calculated. Additionally, the difference among these provinces is explained by Lorenz curve. Main findings and suggestions of this paper are concluded as follows:

(1) The total CO_2 emission from freight transport sector increased from 65 Mt in 1990 to 344 Mt in 2007, with the annual average growth rate of 10%.

(2) With LMDI method, the influencing factors are divided into six kinds of effects. Moreover, population, per capita GDP and mode share have positive impacts on CO_2 emission in China, while, transport intensity and the emission coefficient have negative effects on CO_2 emission;

(3) In China, changes the economic structure caused the changes in CO_2 emission from freight transport. From 1990 to 2007, the freight generally provided more services for the tertiary industry and high technology industry. In these high value added sectors, the same transport service would provide more value added in economy, which made transport intensity decrease. At the same time, the transport mode relied more on road and aviation to a larger extent and was not so eco-friendly.

(4) Employing Lorenz curve to describe the unbalance of per capita GDP and per capita CO_2 emission from freight transport sector, we find the variation of per capita GDP increases among 28 provinces, with Gini coefficient growth from 0.23 in 1990 to 0.29 in 2007. The unbalance of per capita transport sector CO_2 emission also increases, with Gini coefficient growth from 0.34 in 1990 to 0.40 in 2007. Economic structure and development stage in

different province are the main reason for these changes.

(5) Policies aiming at low carbon freight transport can be classified into three strategies: a) avoid: it is essential to encourage citizens to use local products, implement goods recycling and construct urban and industrial clusters systematically; b) shift: we can use more eco-friendly modes (rail and ship) to replace eco-unfriendly modes (aviation and road); c) improvement: we should build an efficient freight logistic system in road and railway freight as well as improve energy source of each transport mode.

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