In order to find out the potential causes that affect CO$_2$ emission and their changes in freight transport sector, this paper examines the relationship between carbon dioxide emission and transportation activities in the sector. First, CO$_2$ emission from the freight transport sector from 2001 to 2010 is calculated based on presented methods. Second, LMDI (logarithmic mean Divisia index) method is employed to analyze the influencing factors of CO$_2$ emission in freight transport sector. As a result, we find: (1) from 2001 to 2010, CO$_2$ emission of freight transport in Beijing increased by 69%, i.e., from 3.50 million tons to 5.91 million-tons, while that in Shanghai rose by 242%, i.e., from 4.23 million tons to 14.5 million tons; (2) based on the result obtained by using LMDI method, population effect, per capita GDP effect, energy source effect and mode shift effect have positive effects on CO$_2$ emission in both cities; while the factors of transport intensity and the emission coefficient effect show negative impacts on CO$_2$ emission; (3) the reason why the decrease in transport intensity appears is that transported products are becoming more and more valuable and more value added. Therefore, policy makers should make corresponding policies to encourage rail transport and shorter travel distance in the freight transport sector to reduce CO$_2$ emission.

**Key Words**: LMDI method, Freight transport, Mega cities, CO$_2$ emission, China
factors on CO₂ emission. In literatures, two well-known decomposition techniques, namely SDA (structural decomposition analysis) and IDA (index decomposition analysis), have been widely applied to analyze the driving forces. The former is based on the input-output model, while the latter uses index number concept in decomposition. Ang⁵³⁶ compared various methods of index decomposition analysis and showed that LMDI method was preferred because of its theoretical foundation, adaptability, ease of use and interpretation of results.

LMDI method consists two kinds, one of which is additive LMDI method and the other is multiplicative LMDI method. Essentially, these two methods are similar. However, the results of additive LMDI method can be compared with each other more conveniently, because they are absolute values. However, the results of multiplicative LMDI result are relative values so that they can hardly be compared in different cases. What’s more, to capture annual changes of factors from 2001 to 2010, additive LMDI can be used to provide more meaningful result for comparison. Hence, additive LMDI method is chosen. The details of LMDI method are described in Section 2.

Although there are some scholars who have used decomposition technique to carry out studies on CO₂ emission of the transport sector, for example, Govinda⁵ used LMDI method to analyze CO₂ emission in the whole transport sectors of Asian countries and found different driving forces for CO₂ emission in these countries, the decomposition methods are seldom applied to researches on CO₂ emission of the freight transport sector.

CO₂ emission of the freight transport sector can be expressed as an extended Kaya identity and then can be decomposed into influencing factors by LMDI method. With this method, the characteristics of the factors affecting CO₂ emission in the freight transport sector can be obtained from 2001 to 2010.

This paper is organized as follows. Section 2 describes the data and methodologies for the estimation of CO₂ emission as well as the decomposition method. Section 3 examines the trends of CO₂ emission in Shanghai and Beijing from 2001 to 2010. In addition, this paper not only shows the result of the decomposition in the freight transport sector but also discusses the causes for these changes. Then, based on the discussion in section 3, policies are suggested for the reduction of CO₂ emission. Finally, main conclusions are presented in section 4.

2. DATA AND METHODOLOGY

(1) Source of data
The data of Beijing and Shanghai in this paper are collected from Yearbook of Shanghai⁷ and Yearbook of Beijing⁸ in the period 2001-2010, respectively. Some data about energy efficiency are collected from Yearbook of China Transportation and Communication⁹. The transportation services are measured in terms of ton-km.

In this data source, inter-city transport is counted as traffic volume data, but inner-city transport is not counted. The transport that takes the city as origin and destination is accounted as traffic volume of that city.

Transport volume data (in ton-km) and energy consumption data are measured and recorded in terms of trucks, trains, planes and ships, which are settled by weighted average method. Then, the average value of energy efficiency (in terms of fuel/ton-km) of all the vehicles is provided as the data about energy efficiency by the local statistics bureau.

In Beijing, road, rail and domestic aviation transport sectors are considered. In Shanghai, road, rail, domestic aviation and domestic water transport sector are taken into consideration. The reason why international transport is not considered is that it reflects the development of the whole country, but not one city’s own development.

Energy used in road transport includes gasoline and diesel, energy used in rail transport consists of diesel and electricity, the one applied to aviation transport sector includes aviation kerosene, energy used in water transport sector is diesel.

(2) Definition of Variables
Description of Variables:

\[ C_i^t : \text{CO}_2 \text{ emission (in Million tons, Mt) of the } i \text{ th transportation mode in year } t \]

\[ V_i^t : \text{transportation service of the } i \text{ th transportation mode using fuel type } j \text{ in year } t \]

\[ R_j^t : \text{energy consumption per transportation service of the } i \text{ th transportation mode using fuel type } j \text{ in year } t \]

\[ F_j : \text{CO}_2 \text{ emission factor of the } j \text{ th fuel (kg-CO}_2/\text{unit) } \]

\[ V^t : \text{total transportation service in year } t \]

\[ GDP^t : \text{GDP in year } t \]

\[ p^t : \text{population in year } t \]

\[ CI_i^t = \frac{C_i^t}{V_i^t} : \text{emission coefficient of the } i \text{ th trans-} \]
transportation mode using fuel type \( j \) in year \( t \)
\[ SS'_{ij} = \frac{V'_{ij}}{V_{ij}} \]: transportation service share of the \( i \)th transportation mode using fuel type \( j \) in year \( t \) to the \( i \)th transportation mode. \( SS'_{ij} \) affects on the amount of CO₂ emission per ton-km movement reflecting the different energy sources used in each transport mode. Diesel in water transport; kerosene in aviation; diesel and gasoline in road transport; coal, diesel and electricity in rail transport. Because there is only one kind of energy source each in water and aviation transport sectors, \( SS'_{ij} \) reflects the energy source change in road and rail transport sectors.

\[ TS'_{i} = \frac{V'_{i}}{V_{i}} \]: transportation modal share of the \( i \)th transportation mode

\[ TP_{i} = \frac{V'_{i}}{GDP_{i}} \]: the transportation intensity in year \( t \)

\[ TG_{i} = \frac{GDP_{i}}{P_{i}} \]: per capita economic activity in year \( t \);

\( \Delta C_{i} \): the changes of total CO₂ emission in transport sector

\( \Delta C_{aa} \): the changes in the emission coefficient effect

\( \Delta C_{ss} \): the changes in the transportation service effect

\( \Delta C_{ts} \): the changes in the transportation modal shifting effect

\( \Delta C_{ii} \): the changes in the transportation intensity effect

\( \Delta C_{pp} \): the changes in the per capita economic activity effect

\( \Delta C_{p} \): the changes in the population effect

CO₂ emission in the year \( t \) is estimated based on transportation service, energy consumption per unit of transportation service, carbon emission factors, as shown in the following equation:

\[ C' = \sum_{i,j} C'_{ij} = \sum_{i,j} C'_{ij} = \sum_{i,j} V'_{ij} \times R'_{ij} \times F_{ij} \] (1)

\( V'_{ij} \) and \( R'_{ij} \) is obtained from Yearbook of Shanghai, Yearbook of Beijing and Yearbook of China Transportation and Communication. \( F_{ij} \) is obtained from IPCC Guideline\(^1\). (3) Decomposition of the components

The CO₂ emission can be divided into six factors by using Kaya identity as follows:

\[ C' = \sum_{i,j} C'_{ij} = \sum_{i,j} C'_{ij} \times \frac{V'_{ij}}{V_{ij}} \times \frac{V_{ij}}{GDP_{i}} \times \frac{GDP_{i}}{P_{ij}} \times P_{ij} \] (2)

\[ = \sum_{i,j} C'_{ij} \times SS'_{ij} \times TS'_{ij} \times TP_{ij} \times TG_{ij} \times P_{ij} \]

Each individual factor that affects CO₂ emission from the base year \( 0 \) to the year \( t \) can be calculated as follow:

\[ \Delta C_{tot} = \Delta C_{aa} + \Delta C_{ss} + \Delta C_{ts} + \Delta C_{ii} + \Delta C_{pp} + \Delta C_{p} \] (3)

Each variable in this equation can be calculated as follows by using the LMDI method provided by Ang\(^5\):

\[ \Delta C_{aa} = \sum_{i,j} \Delta C_{aa_{ij}} \]

\[ = \begin{cases} \Delta C_{aa_{ij}} = \Delta C_{aa_{ij}} = 0, & \text{if } C'_{ij} \times C'_{ij_{0}} = 0 \\ \Delta C_{aa_{ij}} = \sum_{i,j} L \left( C'_{ij}, C'_{ij_{0}} \right) \ln \left( \frac{C'_{ij}}{C'_{ij_{0}}} \right), & \text{if } C'_{ij} \times C'_{ij_{0}} \neq 0 \end{cases} \]

\[ \Delta C_{ss} = \sum_{i,j} \Delta C_{ss_{ij}} \]

\[ = \begin{cases} \Delta C_{ss_{ij}} = \Delta C_{ss_{ij}} = 0, & \text{if } C'_{ij} \times C'_{ij_{0}} = 0 \\ \Delta C_{ss_{ij}} = \sum_{i,j} L \left( C'_{ij}, C'_{ij_{0}} \right) \ln \left( \frac{SS'_{ij}}{SS'_{ij_{0}}} \right), & \text{if } C'_{ij} \times C'_{ij_{0}} \neq 0 \end{cases} \]

\[ \Delta C_{ts} = \sum_{i,j} \Delta C_{ts_{ij}} \]

\[ = \begin{cases} \Delta C_{ts_{ij}} = \Delta C_{ts_{ij}} = 0, & \text{if } C'_{ij} \times C'_{ij_{0}} = 0 \\ \Delta C_{ts_{ij}} = \sum_{i,j} L \left( C'_{ij}, C'_{ij_{0}} \right) \ln \left( \frac{TS'_{ij}}{TS'_{ij_{0}}} \right), & \text{if } C'_{ij} \times C'_{ij_{0}} \neq 0 \end{cases} \]

\[ \Delta C_{ii} = \sum_{i,j} \Delta C_{ii_{ij}} \]

\[ = \begin{cases} \Delta C_{ii_{ij}} = \Delta C_{ii_{ij}} = 0, & \text{if } C'_{ij} \times C'_{ij_{0}} = 0 \\ \Delta C_{ii_{ij}} = \sum_{i,j} L \left( C'_{ij}, C'_{ij_{0}} \right) \ln \left( \frac{TP'_{ij}}{TP'_{ij_{0}}} \right), & \text{if } C'_{ij} \times C'_{ij_{0}} \neq 0 \end{cases} \]

\[ \Delta C_{pp} = \sum_{i,j} \Delta C_{pp_{ij}} \]

\[ = \begin{cases} \Delta C_{pp_{ij}} = \Delta C_{pp_{ij}} = 0, & \text{if } C'_{ij} \times C'_{ij_{0}} = 0 \\ \Delta C_{pp_{ij}} = \sum_{i,j} L \left( C'_{ij}, C'_{ij_{0}} \right) \ln \left( \frac{PP'_{ij}}{PP'_{ij_{0}}} \right), & \text{if } C'_{ij} \times C'_{ij_{0}} \neq 0 \end{cases} \]

\[ \Delta C_{p} = \sum_{i,j} \Delta C_{p_{ij}} \]

\[ = \begin{cases} \Delta C_{p_{ij}} = \Delta C_{p_{ij}} = 0, & \text{if } C'_{ij} \times C'_{ij_{0}} = 0 \\ \Delta C_{p_{ij}} = \sum_{i,j} L \left( C'_{ij}, C'_{ij_{0}} \right) \ln \left( \frac{PP'_{ij}}{PP'_{ij_{0}}} \right), & \text{if } C'_{ij} \times C'_{ij_{0}} \neq 0 \end{cases} \]

where, \( L(a,b) = \frac{(a - b)}{(\ln a - \ln b)} \)
According to equation (3), it can be changed into
\[
\frac{\Delta \text{C}}{\Delta \text{C}_{\text{tot}}} \times 100\% + \frac{\Delta \text{C}}{\Delta \text{C}_{\text{tot}}} \times 100\% + \frac{\Delta \text{C}}{\Delta \text{C}_{\text{tot}}} \times 100\% = 100\%
\]
(5)

Each component in equation (4) stands for different factors that affect CO₂ emission.

Emission coefficient (\(\Delta \text{C}_{\text{e}}\)) is used to describe emission efficiency, which denotes how much CO₂ is needed for each transport services (i.e., ton-km) and it can be improved by technology innovation, fuel improvement and lighter weight of the vehicle. Energy source factor (\(\Delta \text{C}_{\text{s}}\)) describes the change of the fuel types in a certain transport mode. Mode shift factor (\(\Delta \text{C}_{\text{t}}\)) states the share of a transport mode in total transport service. Transport intensity effect (\(\Delta \text{C}_{\text{t}}\)) is adopted to describe the intensity of transport service, that is, how much transport service is consumed per unit GDP. Per capita GDP factor (\(\Delta \text{C}_{\text{p}}\)) shows how per capita GDP affects CO₂ emission of the freight transport sector. Population factor (\(\Delta \text{C}_{\text{p}}\)) is utilized to state how population affects CO₂ emission of the freight transport sector.

### 3. RESULTS AND INTERPRETATION

(1) Analysis of CO₂ emission

According to equation (1), CO₂ emission of Shanghai and Beijing are calculated. The share of each transport mode and GDP in Beijing and Shanghai are shown in Fig.1 and Fig.2, Table 1 and Table 2, respectively.

In accordance with Fig.1, we can find that CO₂ emission of the freight transport sector in Beijing increased from 3.51Mt in 2001 to 5.92 Mt in 2010, with the annual average growth rate of 5.9%. At the same time, GDP increased from 370 billion CNY in 2001 to 1411 billion CNY in 2010, with the annual growth rate of 16%. The biggest emitter was aviation, which occupied 54.5% of the total CO₂ emission in 2001, and increased to 69.2% in 2010. Road transport sector decreased from 41% in 2001 to 27% in 2010.
The CO\textsubscript{2} emission share of railway reduced from 4.5% in 2001 to 3.3% in 2010.

From Fig.2, it is shown that CO\textsubscript{2} emission of the freight transport sector in Shanghai dramatically increased from 4.23 Mt in 2001 to 14.5 Mt in 2010, with the annual growth rate of 14.6%. At the same time, GDP increased from 521 billion CNY in 2001 to 1716 billion CNY in 2010, with the annual growth rate of 14%. The biggest emitter was water transport sector, which accounted for 50.2% of total CO\textsubscript{2} emission 2001 and occupied 43.1% in 2010. The second biggest emitter was aviation sector, which held 25.8% of the total CO\textsubscript{2} emission in 2001 and reached 33.6% in 2010. Road transport sector increased from 22.0% in 2001 to 23.1% in 2010. The CO\textsubscript{2} emission share of railways decreased from 1.9% in 2001 to 0.1% in 2010.

According to Fig.1 and Table 1, we can see that GDP increased much quicker than CO\textsubscript{2} emission of the freight transport sector in Beijing. The share of aviation increased, while the shares of road and railway sectors decreased, which stated that the freight transport in Beijing was becoming more and more “high-carbon”. In Fig.2 and Table 2, it can be found that CO\textsubscript{2} emission of the freight transport sector in Shanghai increased as quickly as GDP and the water and aviation transport were the dominant modes that made CO\textsubscript{2} emission increase in the freight transport sector.

In addition, we can also conclude that Shanghai generated more CO\textsubscript{2} emission than Beijing and increased quickly mainly because of quick increase in water and road sector.

(2) Result of decomposition

By using equation (3) and (4), fixing the initial year at 2001 and applying LMDI method to the period from 2002 to 2010, decomposition results of each year are captured, which are shown as follows:

The contribution of each factor in Beijing is shown in Fig.3. The increase of the total CO\textsubscript{2} emission in the freight sector of Beijing was 2.41 Mt from 2001 to 2010. In 2010, population generated 1.58 Mt, the factor per capita GDP contributed 4.49 Mt and mode shift caused 2.25 Mt for the change in CO\textsubscript{2} emission. While, transport intensity effect contributed -4.92 Mt and emission coefficient generated -0.99 Mt for the change in CO\textsubscript{2} emission of the freight transport. The effect of energy source could nearly be neglected. Population, GDP and mode shift changed very steadily from 2002 to 2010. Hence, they showed positive effect from 2002 to 2010, while transport intensity and emission coefficient had negative effect in this period. The effect of energy source could nearly be neglected.

The contribution ratio of each factor in Shanghai is shown in Fig.4. In the year of 2010, the total CO\textsubscript{2} emission of the freight sector in Shanghai increased by 10.3 Mt. Population contributed 2.66 Mt, per capital GDP generated 7.19 Mt and mode shift caused 3.26 Mt, energy source effect contributed 0.06 Mt for the change in CO\textsubscript{2} emission. However, transport intensity contributed -2.43 Mt and emission coefficient generated -0.43 Mt for the change in CO\textsubscript{2} emission of the freight transport. Therefore, population and GDP showed positive effect from 2002 to 2010, transport intensity effect showed positive effect from 2002 to 2008 but converted to negative effect from 2009. Mode shift displayed less effect from 2002 to 2007 but showed bigger positive effect from 2008 to 2010. Emission coefficient showed positive effect from 2002 to 2008, but it was converted into negative effect after 2009. Besides, the effect of energy source could nearly be neglected.

Both Population and GDP in Shanghai and Beijing had big positive effect. However, their effect in Shanghai was bigger than that of Beijing. Transport intensity showed strong negative effect in Beijing, while it displayed positive effect in Shanghai from 2002 to 2008 in Shanghai. The reason for this was that transport intensity decreased stably in Beijing but fluctuated in Shanghai, as shown in Fig.11. Mode
shift effect showed positive effect in both Beijing and Shanghai. The effect of energy source was so small in Beijing and Shanghai that we could ignore it. In addition, emission coefficient had positive effect in Shanghai but negative effect in Beijing.

(3) Analysis of influencing factors

As the base of analyses, the general introduction of Beijing and Shanghai is provided at first. Then, factors are analyzed individually.

Beijing and Shanghai are the most developed cities in China. Beijing is the capital of China with population of 19.6 million and the area of 16807.8 km$^2$. Shanghai locates in the east of China, which has the population of 23 million and the area of 6350 km$^2$.

As the most developed cities of China, Beijing and Shanghai have different economic structure. According to Fig.5 and Fig.6, it is shown that the secondary industry in Shanghai occupied about 50% of all the GDP while that of Beijing was around 25% - 30%. The tertiary industry of Shanghai increased from 52.4% in 2001 to 57.3% in 2010, while that of Beijing increased from 67% in 2001 to 75% in 2010. Different economic structure and industrial structure caused different demand for freight structure. The secondary industry relied on freight transport to a larger extent but the tertiary industry did not.

Considering freight transport, the biggest difference between Beijing and Shanghai is shown in Fig.13 and Fig.14. In another word, Shanghai had a large part of water transport but Beijing didn’t.

Based on Fig.5 and Fig.6, we can see that the road length of Shanghai increased quickly, which nearly doubled in the last ten years, but the road length of Beijing was still much longer than that of Shanghai. The railway length of Beijing decreased from 987 km in 2001 to 956 km in 2010, while the one of Shanghai increased from 257 km in 2001 to 414 km in 2010.

a) Population effect:

The decomposition results show that the increase of population made CO$_2$ emission increase. The reason for this was that the increase of population led to the increase in demand of transport. Hence, the increase
of population led to the increase of CO$_2$ emission. The population increased by 41% in Beijing and by 38% from 2001 to 2010. The increase of population increase contributed 1.58 Mt to the increase of CO$_2$ in Beijing and 2.66 Mt in Shanghai from 2001 to 2010.

b) Per capita GDP effect:

As the per capita GDP increased and consequential income increases, personal consumption also grew, which caused more demand for goods and led to more freight transport. According to Fig.10, it is found that per capita GDP in Shanghai and Beijing was nearly the same. The contribution of this effect to the increase of CO$_2$ emission was 4.49 Mt in Beijing and 7.19 Mt in Shanghai from 2001 to 2010.

As shown in Fig.10, per capita GDP of Beijing and that of Shanghai have changed in a very similar way, but the contributions to CO$_2$ emission have been as different as 4.49 Mt in Beijing and 7.19 Mt in Shanghai. Total change of CO$_2$ emission of Shanghai is bigger than that of Beijing from 2001 to 2010 as shown in Fig.1 and Fig.2. Hence, the same change in per capita GDP caused more CO$_2$ emission change in Shanghai. The reason was that: though per capita GDP has changed in a very similar way, industrial structures to create GDP were different as shown in Fig.7 and Fig.8. GDP of Beijing has relied more on the tertiary industry, which did not generate much freight transport, while GDP of Shanghai relied more on the secondary industry, which generated more freight transport than the tertiary industry. Hence, similar per capita GDP increase had different impacts on CO$_2$ emission in two cities.

c) Transport intensity effect:

Transport intensity defined as transport volume (ton-km) divided by GDP showed the strongest negative effect on CO$_2$ emission in Beijing. It contributed -4.92 Mt to CO$_2$ emission in Beijing in 2010 and -2.43 Mt to CO$_2$ emission in Shanghai in 2010. The transport intensity decreased dramatically from 0.085 to 0.028 ton-km/CNY in Beijing and reduced from 0.284 to 0.211 ton-km/CNY in Shanghai.

The difference of transport intensity between Beijing and Shanghai is very obvious, for the economic structure and value of goods are different between Beijing and Shanghai.

1) The difference of economic structure. According to Fig.7 and Fig.8, we can see that the ratio of the secondary industry decreased from 31% in 2001 to 24% in 2010 in Beijing, which highly relied on freight transportation, for example, building material. At the same time, the ratio of the tertiary industry increased from 67% in 2001 to 75% in 2010, which depended on labor force instead of freight transport. However, in Shanghai, the ratio of the secondary industry decreased from 46% in 2001 to 42% in 2010, the ratio of tertiary industry increasing from increased from 52.5% in 2001 to 57.3% in 2010. After comparing Beijing with Shanghai, the tertiary industry was dominant in Beijing while the secondary industry was do-
d) **Mode shift effect**

As described above, mode shift factor contributed 2.24 Mt to CO$_2$ emission in Beijing and 3.26 Mt to CO$_2$ emission in Shanghai. As seen in Fig.12, the share of aviation increased because more valuable goods were transported. The share of rail and road in Beijing nearly kept constant, the share of rail decreased and the share of road increased in Shanghai. In Shanghai, the share of water transport was the dominant, the share of road and aviation increased a lot, while the share of rail decreased.

e) **Energy source effect**

Because the factor does not affect CO$_2$ emission a lot and the change in energy source in each transport sector is not obvious, we pay little attention to it in this paper. Nevertheless, this part has great potential to decrease CO$_2$ emission, for instance, changing fuel type from gasoline and diesel.

f) **Emission coefficient effect**

Emission coefficient contributed -0.99 Mt and 0.43 Mt to CO$_2$ emission in Beijing and Shanghai in 2010, respectively. According to Fig.15 and Fig.16, we can find that emission coefficient of aviation improved constantly and the efficiency of truck that used gasoline and diesel rose with fluctuations, which might be caused by traffic construction. The efficiency of railway was much better than that of aviation and truck. In addition, the efficiency of water transport increased a little.

4) **Policy Suggestion**

Based on the previous analysis, a systematical policy-package to low carbon freight transport can be suggested as follows.

a) **Avoiding freight demand.**

Encourage citizens to use local products to reduce freight transport distance and implement regional goods recycling. Besides, structure urban clusters and industrial clusters to reduce the distance of industrial goods transported.
b) Shifting to more eco-friendly transport mode.
Improve the efficiency of road transport and railway transport to replace CO₂ high-intensity aviation. Additionally, structure railway freight system to improve railway system and replace road freight transport system.

c) Improving each transport mode.
Structure efficiency road and railway freight distribution system to reduce inefficient travel; constantly improve energy efficiency of rail, truck and airplane; and replace energy source of rail, truck and airplane by more energy efficiency fuel.

4. CONCLUSION

This paper takes freight transport sectors of Beijing and Shanghai as examples. Thus, CO₂ emission from 2001 to 2010 is computed. Next, LMDI method developed by Ang⁵,⁶ are used to decompose six factors, namely, emission coefficient, energy source, mode shift transport intensity, per capita GDP and population. The contribution of each factor from 2002 to 2010 is calculated by fixing the initial year 2001. The change of each factor is examined and causes for these changes are also found out. Main findings and suggestions of this paper can be concluded as follows.

(1) From 2001 to 2010, CO₂ emission of Beijing increased by 69%, i.e., from 3.51 million-tons to 5.91 million tons, while the CO₂ emission of Shanghai grew by 242%, i.e., from 4.23 million-tons to 14.5 million-tons;

(2) Using LMDI method, we divided the influence factors into six kinds of effects. Moreover, population, energy source, per capita GDP and mode share had positive impacts on the CO₂ emission in Beijing and Shanghai;

(3) However, in both cities, transport intensity and the emission coefficient had negative effects on CO₂ emission;

(4) Factors including population, per capita GDP and mode share were the main contributors to the increase of CO₂ emission in the freight transport. Among these factors, transport intensity was the biggest contributor to the decrease of CO₂ emission in the freight transport, which had big space for improvement.

(5) Policies aiming at lowing carbon freight transport could be classified into 3 stages: a) avoidance: encourage citizens to use local products, implement goods recycling and systematically structure urban clusters and industrial clusters; b) shifting: replace eco-unfriendly mode (aviation, road) by eco-unfriendly mode (rail or ship); c) improvement: structure efficiency road and railway freight distribution system as well as improve energy source of each transport mode.

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