Nature Environment and Pollution Technology
An International Quarterly Scientific Journal

ISSN: 0972-6268 | Vol. 14 | No. 4 | pp. 791-798 | 2015

Original Research Paper

Calculation and Evaluation of Carbon Dioxide Emissions of Regional Logistics Ecosystem: A Study in China

Lingyun Zhou*†, Zhonghua Gu, Gang Zhao* and Jianfeng Luo***
*School of Management Engineering, Huaiyin Institute of Technology, Huaian 223001, China
**Department of Public Policy, City University of Hong Kong, 999077, Hong Kong
†Corresponding author: Lingyun Zhou

Nat. Env. & Poll. Tech.
Website: www.neptjournal.com
Received: 15-09-2015
Accepted: 10-10-2015

Key Words:
Regional logistics ecosystem
Ecological environment
Energy consumption
CO_2 emission
Performance measurement

ABSTRACT

Regional logistics with a large quantity of energy consumption and carbon emissions has great important impacts on the regional ecological environment. Therefore, constructing the regional logistics ecosystem has become a crucial way to minimize the environmental impacts. This paper aims to accurately obtain the characteristics and causes of carbon dioxide (CO_2) emissions of regional logistics ecosystem. It firstly analyses the main factors affecting carbon emissions of regional logistics ecosystem, and then builds the calculation model and the performance evaluation model of carbon emissions of regional logistics ecosystem respectively based on regional logistics activities and their energy consumption structures. According to energy consumption statistics of 30 provinces in China, it calculates the total amounts and differences of CO_2 emissions of logistics activities in different regions of China. The results illustrate that the overall regional logistics ecosystem in China is in its initial stage with huge carbon emissions; and there are significant variations in CO_2 emission intensities of regional logistics and CO_2 emission amounts per unit of cargo turnover between different regions. This research offers accurate information for policy making of logistics industry and setting the carbon emission reduction targets in different regions of China.

INTRODUCTION

Since the Industrial Revolution began around 1750, human activities have contributed substantially to climate change by adding greenhouse gases to the atmosphere. With the growing deterioration of the environment, the scientific communities and the governments have basically reached a consensus that CO_2 is the leading cause of global warming and the greenhouse effect that poses a serious threat to the welfare of the planet earth and its inhabitants of plants, animals and humans. In the setting of energy shortage, climate change and environmental pollution, more and more countries have realized that economic growth should not be at the expense of environment deterioration. Low carbon economy is being accepted by more and more countries as it can combine with both economic development and environmental protection (Kinzig et al. 1998). Low carbon economy is an economic development model which has a minimal output of greenhouse gas emissions into the biosphere, especially refers to the effective control of carbon dioxide. Since logistics industry is an important productive service industry with lots of energy consumption and carbon emissions (Aronsson et al. 2006), thereby low carbon logistics is a crucial component of low carbon economy. Nowadays, under the background of the growing awareness of environmental protection and the decline of natural resources, building regional logistics ecosystem has become an inevitable way to develop low carbon logistics and promote a socio-economic sustainable development society. Regional logistics ecosystem is an ecological industrial system, which aims at reducing the pollution of the environment and the consumption of resources, using advanced logistics technology planning and implementation of transport, storage, packaging, handling, processing and distribution methods. To evaluate the carbon emissions of regional logistics activities, and to formulate policies and measures of carbon emissions based on the scientific development concept are important issues in regional logistics industry.

At present, China has been the world's largest greenhouse gas emitter, which accounts for 29% of the whole world's emissions. At the conference of United Nations climate change in December 2009, China promised that China's carbon emissions per unit of gross domestic product (GDP) in 2020 would fall by 40% to 45% compared to the level of 2005. By 2014, China's carbon emissions per unit of GDP were 33.8% lower than 2005 according to a calculation by Xinhua based on official statistics. China aims to hit the CO_2 emissions peak by around 2030 and slash CO_2 emissions per unit of GDP by 60% to 65% from the 2005 level. Thereby, reducing logistics carbon emissions is not only the key and focus of China's energy saving and emission reduction, but also the important way to achieve China's 2030 targets of carbon emission reduction. At present, with the rapid development of regional economy, the scales of regional logistics in China are increasing. However, China's regional logistics development mode is extensive, and the carbon dioxide emissions generated by all logistics activities are increasing. Therefore, it is urgent to speed up the quantitative monitoring and evaluation of regional logistics carbon emissions, so as to promote the development of low-carbon logistics and accelerate the construction of regional logistics ecosystem.

During the last decade, logistics ecosystem has received increasing attention from both academic researchers and industrial practitioners. These studies mainly concentrate in the following areas: reverse logistics system, green supply chain, low carbon logistics technology and so on. Carter et al. (1998) proposed a framework of reverse logistics in business and society. Dowlatshahi (2000) elaborated the opportunities on recycling and the theory framework of reverse logistics. Corbett et al. (2001) elaborated the emissions during transportation having the greatest environmental impact on all activities in a product's life cycle. Sarkis (2003) proposed a strategic decision framework for green supply chain management. Hsu et al. (2013) utilized the Decision-making Trial and Evaluation Laboratory (DEMATEL) approach to recognize the influential criteria of carbon management in green supply chain for improving the overall performance of suppliers in terms of carbon management. Mathiyazhagan et al. (2014) analysed the pressure for green supply chain management implementation in Indian industries using analytic hierarchy process method. Jens Tacken et al. (2014) carried out a qualitative evaluation of the transport-related CO_2 emissions and reduction initiatives in the German logistics sector through the case study of ten logistics service providers. Kristina et al. (2015) used a transport portfolio framework to reduce carbon footprint. Yin et al. (2015) evaluated the long-term energy consumption and CO_2 emissions of China's transportation sector from a global perspective. Yingli Wang et al. (2015) investigated empirically how information and communication technologies (ICT) can contribute to reduction of CO_2 emissions in road freight transport, and identified the opportunities for further improvements.

There is not enough research addressing the reduction of CO_2 emissions of logistics industry in China. The present researches on carbon emissions in logistics activities are mostly confined to the theoretical analysis and the discussion of the countermeasures. However, because of the unbalanced development of regional logistics industry, the carbon emissions of regional logistics activities in different regions also show big variations. This study aims to calculate the CO_2 emissions of regional logistics ecosystem in China from energy consumption perspective and reflect the regional differences and causes of carbon emissions of regional logistics activities. It can help different regions to set out scientific and reasonable reduction strategies of carbon emissions of logistics industry.

IMPACT FACTORS OF CARBON EMISSIONS OF REGIONAL LOGISTICS ECOSYSTEM

Economic scale and structure: There is a close relationship between economic growth, logistics industry development and carbon emissions (Ramanathan 2006). Regional economic scale is one of the most direct factors that affect the carbon emissions of regional logistics industry. Regional economic growth directly boosts the demand growth of logistics, so the logistics industry needs to expand the scale of logistics activities. These logistics activities demand a lot of energy consumption, which result in the increase of carbon emissions. When the amount of economic output is fixed, the difference between the industrial structure of agriculture, manufacture and service industry can also lead to differences in the demand quantity and service structure of logistics activities, which can affect the energy consumption and carbon emissions of the logistics industry.

Logistics infrastructure network: The layout of logistics infrastructure network has important effects on the production plans and operation processes of regional logistics, which may lead to the added carbon emissions (Pishvaee et al. 2012). Compared with the developed countries, the modernization level of China's logistics hardware facilities is generally not high.

Firstly, the hardware facilities layout is not reasonable. Secondly, logistics management mode is extensive, and the integrity, cooperativity and coordination of logistics network are not good. Thirdly, the overall logistics efficiency is not high, so logistics costs are high. From 2000 to 2014, the total logistics costs ratio to GDP in China has dropped from 19.4% to 17.8%. This ratio is still too high, twice of that in developed countries. In addition, logistics enterprises pay little attention to energy consumption, social benefits and ecological benefits (Henrik et al. 2014). These problems result in a huge waste of resources and lots of carbon emissions, and increase the negative impacts on the environment.

Logistics technology level: Technological progress is a controlling factor of low carbon economy. China logistics technology level is relatively low, which is shown as follows: The application rate of automated and intelligent storage equipment, handling equipment and other technical equipment is low. The radio frequency identification technology is not widely used in logistics industry, and the application rate of logistics information system including warehouse management system (WMS), transportation management system (TMS), distribution management system (DMS), automatic sorting system is not high. The application of network technology is still at the initial level, and the standards of logistics transportation equipment are not uniform. The construction of public logistics information platform is lagging behind, and it does not yet meet the growing demand for logistics information sharing for different firms. The above problems not only result in a waste of resources, but also restrict the improvement of energy efficiency in logistics industry.

Energy consumption structure: Energy structure has an important effect on the development of low carbon economy. Carbon dioxide in logistics activities is mainly produced in the process of fossil energy consumption. Fossil energy refers to the coal, oil, natural gas, and so on. The more the three kinds of energy consumption is, the higher the carbon emissions. At present, the energy consumption of China's logistics industry mainly relies on coal, gasoline and diesel and other non-renewable energy, so the energy consumption structure is the primary cause for the growth of China's logistics industry carbon emissions.

Energy utilization efficiency: Efficient energy use, sometimes simply called energy efficiency, is the goal to reduce the amount of energy required to provide products and services. It reflects the level of energy consumption and the use of the effect, that is, the effective use of energy efficiency indicators. Carbon emission reduction is consistent with efficiency increase (Halldórsson et al. 2010), and no matter direct or indirect measurements by means of technology or management to increase efficiency and decrease energy consumption, it can play a role in emission reduction. Nowadays, energy consumption volume is increasing while energy utilization efficiency is comparatively low.

Under the influences of capital, technology, energy price, etc., China's energy utilization efficiency is far lower than that of the developed countries. For example, energy comprehensive utilization efficiency was 36.3% in 2014, which was almost 10 percentage points lower than the international advanced level. In addition, China's energy consumption per unit of GDP was about 2 times than the world average in 2014. In the field of logistics industry in China, highway transportation with the low energy utilization efficiency accounts for a larger proportion in the whole cargo transportation market, while the market shares of railway transport and water transport with low carbon are low. As for choice of means of transportation, it is preferable to use ships or trains as much as possible for long distance transport and trucks for short distance transport (Carbone et al. 2011). Furthermore, environmental friendly transport vehicles should be chosen in order to reduce emission pollution.

CALCULATING CARBON EMISSIONS OF REGIONAL LOGISTICS ECOSYSTEM

Carbon emissions analysis of regional logistics activities: Greenhouse gases with carbon emissions include CH_4, N_2O, CO_2, HFCS, PFCS, SF_6, and the main greenhouse gases produced by the logistics industry include CH_4, N_2O, CO_2. Logistics is a service industry, which is composed of transportation, warehousing, distribution, processing, loading and unloading, packaging and information services and other logistics activities. These logistics activities often consume coal, fuel, electricity, heat, etc., which inevitably result in lots of carbon emissions (Kengpol et al. 2014). Thereby, the carbon emissions in regional logistics ecosystem come from the above all logistics activities.

According to the traceability of carbon emissions, carbon emissions can be divided into two types: direct emissions and indirect emissions. For example, the carbon emissions of transportation, loading and unloading using the fuels refer to the direct emission, while the carbon emissions in the operation of static logistics facilities consuming electricity from public power grid and heating power from public heating network refer to indirect emissions.

Calculating total carbon emissions of regional logistics activities: The total sum of carbon emissions can be estimated based on the amounts of different energy consumption. In order to study the sources of carbon emissions in logistics activities, the consumption of energy is divided into five categories, namely oil energy (crude oil, gasoline, kerosene, diesel oil, fuel oil, lubricating oil, liquefied petroleum gas and other petroleum products), coal energy (raw coal, briquette, clean coal, coke, etc.), gas energy (natural gas and liquefied natural gas), heating energy, electrical energy (Ang et al. 1994).

The formula for calculating the total amount of CO_2 emissions in regional logistics ecosystem is expressed as follows:

$$E^t = \sum_{i=1}^{n} E_i^t \qquad ...(1)$$

$$E_i^{t} = E_{io}^t + E_{ic}^t + E_{ig}^t + E_{ih}^t + E_{ip}^t \qquad ...(2)$$

Where t indicates the time of year; E^t represents the total CO_2 emissions of regional logistics in the period of t; i denotes the internal province; E_{io}^t, E_{ic}^t, E_{ig}^t, E_{ih}^t and E_{ip}^t respectively denote CO_2 emissions of oil energy, coal energy, gas energy, heat energy and electric energy in the logistics industry of province i in the period of t.

***Carbon emissions of oil energy in regional logistics*:** The carbon emission coefficient of oil energy is fixed in general (Zhou et al. 2011). The CO_2 emissions of oil energy in regional logistics are calculated by the following formula:

$$E_{io}^{t}=\sum_{j=1}^{m}P_{ij}^{t}\times L_{j}\times CC_{j}\times COF_{j} \qquad ...(3)$$

Where, P_{ij}^{t} denotes the physical quantity of oil energy j consumed by the logistics industry of province i in the period of t; L_j denotes the average calorific value of oil energy j; CC_j denotes the carbon emission factor of oil energy j; COF_j denotes the oxidation rate of oil energy j in the burning process.

***Carbon emissions of coal energy in regional logistics*:** The coal fuel used in the process of logistics operation is mainly used for the consumption of the static logistics nodes, such as logistics park, logistics center, distribution center and other logistics facilities. Considering the non-oxidized proportion of the coal combustion process, the CO_2 emissions of coal energy in regional logistics are calculated by:

$$E_{ic}^{t}=\sum_{k=1}^{u}C_{ik}^{t}\times M_{k}\times CC_{k}\times(1-CS_{k}^{t})\times COF_{k} \qquad ...(4)$$

Where, C_{k}^{t} denotes the physical quantity of coal energy K consumed by the logistics industry of province i in the period of t; M_K denotes the average calorific value of coal energy K; CS_{k}^{t} denotes the non-oxidized proportion of coal energy j in the burning process in the period of t; the meanings of other variables are consistent with that of the above oil energy.

***Carbon emissions of gas energy in regional logistics*:** The carbon emission coefficient of gas energy is fixed in general. The CO_2 emissions of gas energy in regional logistics are calculated by the following formula:

$$E_{ig}^{t}=\sum_{s=1}^{v}G_{is}^{t}\times N_{s}\times CC_{s}\times COF_{s} \qquad ...(5)$$

Where, G_{is}^{t} denotes the physical quantity of gas energy S consumed by the logistics industry of province i in the period of t; N_S denotes the average calorific value of gas energy S; the meanings of other variables are consistent with that of the above oil energy.

***Carbon emissions of heating energy in regional logistics*:** Heating energy can be natural, like the heat we get from the sun, or man-made (Churkina 2008). The heating energy used in logistics industry is produced by consuming other kinds of energies. The raw energies producing heating energy in different regions are different, which lead to the different carbon emission coefficients in different regions. The CO_2 emissions of heating energy in regional logistics are calculated by the following formula:

$$E_{ih}^{t}=H_{i}^{t}\times\theta_{i}^{t} \qquad ...(6)$$

Where, H_{i}^{t} denotes the heating energy amount consumed by the logistics industry of province i in the period of t; θ_{i}^{t} denotes the coefficient of CO_2 emissions of heating energy in the logistics industry of province i in the period of t.

Carbon emissions of electrical energy in regional logistics: Electrical energy is made from other energies as raw materials. The generating capacities of hydropower, thermal power, solar power, wind power and other new energy are different in different regions, which lead to the different carbon emission coefficients of electrical energy in different regions. The CO_2 emissions of electrical energy in regional logistics are calculated by the following formula:

$$E_{ip}^{t}=P_{i}^{t}\times\mu_{i}^{t} \qquad ...(7)$$

Where, P_{i}^{t} denotes the electrical energy amount consumed by the logistics industry of province i in the period of t; μ_{i}^{t} denotes the coefficient of CO_2 emissions of electrical energy in the logistics industry of province i in the period of t.

EVALUATING CARBON EMISSION PERFORMANCE OF REGIONAL LOGISTICS ECOSYSTEM

Evaluating carbon emission structure of regional logistics: According to the above calculation results, the structure of carbon emissions of various types of logistics activities can be calculated, namely determining the proportion of carbon dioxide emissions generated by different kinds of energies in regional logistics operation. The calculation formula is as follows:

$$\%\Delta E_{i}^{t}=\frac{E_{i}^{t+1}\quad E_{i}^{t}}{E_{i}^{t}} \qquad ...(8)$$

$$\%E_{i}^{t}=\frac{E_{i}^{t}}{E^{t}} \qquad ...(9)$$

Where, $\%\Delta E_{i}^{t}$ denotes the increasing speed of CO_2 emissions in the logistics industry of province i in the period of t; $\%E_{i}^{t}$ denotes the proportion of CO_2 emissions in the logistics industry of province i to the total CO_2 emissions of all provinces in the period of t.

Evaluating carbon emission intensity of regional logistics: Carbon emissions intensity index of regional logistics denotes the amount of carbon dioxide emissions per unit of logistics industrial added-value, which reflects the carbon dioxide emissions per unit of logistics output. The calculation formula is as follows:

$$CEI_i^t = E_i^t / GLP_i^t \quad ...(10)$$

Where, CEI_i^t denotes the amount of CO_2 emissions per unit of logistics industrial added-value of province *i* in the period of *t*; GLP_i^t denotes the logistics industrial added-value of province *i* in the period of *t*. With the implementation of the new national energy strategy, the development of green transportation mode and the application of low carbon logistics technology and equipment, the carbon emission intensity of regional logistics should show a downward trend.

Evaluating carbon emission per unit of per unit of cargo turnover: The amount of CO_2 emission per unit of per unit of cargo turnover is calculated by the following formula:

$$CQI_i^t = E_i^t / Q_i^t \quad ...(11)$$

Where, CQI_i^t denotes the amount of CO_2 emissions per unit of cargo turnover of province *i* in the period of *t* ; Q_i^t denotes the amount of cargo turnover of province *i* in the period of *t*. With the development and application of low-carbon logistics technology, carbon emissions per unit of cargo turnover should be reduced step by step.

A CASE STUDY

Data collection: Nowadays, there is no observation data of the logistics industry in the current statistics of China. Due to transportation, storage and postal services account for more than 80% of the logistics industry, they can largely reflect the development of the logistics industry. According to the statistics of "China Energy Statistical Yearbook" and the energy consumption status in China's logistics industry, 14 kinds of energies, including raw coal, coal briquette, coke, gasoline, kerosene, diesel oil, fuel oil, lubricating oil, liquefied petroleum gas, natural gas, liquefied natural gas, heating and electricity, are used as main energy consumption to evaluate CO_2 emissions of regional logistics ecosystem.

"China Energy Statistical Yearbook 2013" can well reflect China's energy construction, production, consumption, supply and demand balance of authoritative information. However, it only includes 30 provinces of China with energy consumption statistics. Therefore, this paper chooses these 30 provinces to study the CO_2 emissions of regional logistics. The average calorific values and the carbon emission coefficients of different energy sources are determined according to the 2006 guidelines of Intergovernmental Panel on Climate Change, and the CO_2 emission coefficient of heating and electricity is determined according to the data of the China Energy Statistical Yearbook 2013 and the value recommended by the National Development and Reform Commission of China.

Carbon emission amount evaluation of regional logistics ecosystem: In order to facilitate comparison, China is divided into seven regions by the traditional method, namely Northeast Region, North Region, East Region, Central Region, South Region, Southwest Region and Northwest Region.

According to the formula (1)-(7), the total amounts and sources of CO_2 emissions of all regions have been calculated, and the results are given in Table 1.

It can clearly be seen that the carbon emissions of regional logistics is related to the amounts of the logistics activities which are caused by regional economic development. China's total CO_2 emissions in 2012 is 7.946 tons (not including Tibet, Hong Kong, Macao and Taiwan), and CO_2 emissions of logistics industry in Shandong, Shanghai, Liaoning, Inner Mongolia, Hubei, Jiangsu, Hunan, Zhejiang, Sichuan, Henan are huge. The overall characteristics are that CO_2 emissions of logistics industry in the eastern developed provinces and regions of China are more because of the larger economic scale, while CO_2 emissions of logistics industry in the western provinces of China are fewer due to the smaller economy scale.

Carbon emission structure evaluation of regional logistics ecosystem: According to the formula (9), the structure of CO_2 emissions of regional logistics in China is calculated, and the result is given in Table 2. It can be seen that the majority of CO_2 emissions of logistics activities in China come from the oil energy consumption, and the CO_2 emissions of oil, electricity, coal in logistics operations respectively account for 82.177%, 9.583% and 6.438% of the total CO_2 emissions in the logistics industry of China.

Carbon emission intensity measure of regional logistics ecosystem: According to the logistics industrial added-value data of "China Statistical Yearbook 2013", the carbon emission intensity of regional logistics is calculated using the formula (10), and the results are given in Table 3.

The carbon emission intensities of logistics activities in Southwest Region, Northwest Region and Northeast are high. This is due to the reason that their logistics infrastructure is bad, and their third party logistics development lags behind, and their whole logistics efficiency is low.

Carbon emissions measurement per unit of cargo turnover of regional logistics ecosystem: According to the regional cargo turnover data of "China Statistical Yearbook 2013", the carbon emissions per unit of cargo turnover is

Table 1: Amounts of CO_2 emissions of regional logistics ecosystem of China in 2012.

Region and Province		CO_2 emissions of coal (10^4kg)	CO_2 emissions of oil (10^4kg)	CO_2 emissions of gas (10^4kg)	CO_2 emissions of heating (10^4kg)	CO_2 emissions of electricity (10^4kg)	Total CO_2 emissions of logistics (10^4t)
North Region	Beijing	42979	1956119	73986	73	483770	2557.743
	Tianjing	80323	1020427	12396	16	173880	1287.726
	Heibei	119551	1802392	82555	11	494060	2498.568
	Shanxi	171434	1603151	136895	0	363440	2275.767
	Inner Mongolia	1296499	2578643	66462	153	137200	4080.143
Northeast Region	Liaoning	216740	3784426	2090	22	273350	4277.925
	Jilin	236546	944505	46398	65	101290	1329.266
	Heilongjiang	746932	1606211	0	90	82320	2436.152
East Region	Shanghai	5138	4498299	7733	7	271180	4783.253
	Jiangsu	7774	3641962	85690	3	330680	4066.109
	Zhejiang	888	2973171	418	1	232470	3209.300
	Anhui	41749	1547925	86108	1	138250	1814.032
	Fujian	9361	1891806	7106	0	144340	2052.613
	Jiangxi	8478	1115571	0	0	130970	1255.019
	Shandong	73383	6602276	93841	52	461580	7231.132
Central Region	Henan	0	2486900	0	48	387310	2874.258
	Hubei	1073740	2684653	106799	0	206010	4071.202
	Hunan	232718	1835900	23839	4	1229340	3321.800
South Region	Guangdong	6537	6444504	0	0	476770	6927.810
	Guangxi	457	1950953	0	0	100450	2051.860
	Hainan	0	675042	21736	0	23730	720.508
Southwest Region	Chongqing	98427	1320046	146927	0	93450	165.8850
	Sichuan	22951	2583668	123082	0	225960	2955.661
	Guizhou	115024	1373503	0	0	183820	1672.348
	Yunnan	38440	2136503	418	0	140770	2316.131
Northwest Region	Shaanxi	158979	1876912	115081	0	332360	2483.332
	Gansu	123740	677531	29469	1	233030	1063.771
	Qinghai	32146	221953	19437	1	37450	310.987
	Ningxia	17297	286953	48697	5	53130	406.081
	Xinjiang	137190	1168560	94050	4	71190	1470.994

calculated using the formula (11), and the results are given in table 4.

The overall characteristics are that CO_2 emissions of logistics industry in Southwest Region, Northwest Region far away from the coastal area are more because of bad logistics location conditions and low logistics development level, while CO_2 emissions of logistics industry in East Region are less because of good logistics location conditions, advanced transport network, perfect marine and inland waterway conditions and high logistics development level.

DISCUSSION AND CONCLUSION

The major contribution of this paper lies in the development of a comprehensive methodology for evaluating the amounts and sources of carbon emissions in China's regional logistics ecosystem. First, it analyses the main factors affecting carbon emissions of regional logistics ecosystem, including regional economic scale and structure, logistics infrastructure network, logistics technology level, energy structure and energy intensity. Second, according to the regional logistics activities and their energy consumption structure, it builds the calculation model and the performance evaluation model of carbon emissions of regional logistics ecosystem respectively. Third, the total amounts of CO_2 emissions of regional logistics ecosystems of 30 provinces in China are calculated based on the energy consumption statistic data and the 2006 guidelines of Intergovernmental Panel on Climate Change, and the variations of CO_2 emissions of different regional logistics ecosystem in China are illustrated.

The proposed method can be extended to evaluate the amounts and sources of CO_2 emissions of regional logistics ecosystem in different regions and countries. It has significant policy implications on planning low carbon logistics and setting carbon emission reduction targets of regional logistics. For China, it is urgent to accelerate the transformation of logistics development mode and to construct the modern logistics ecosystem. The specific countermeasures and policy implications include: (1) Adjusting the proportion of transport system, and encourage the development of

Table 2: CO_2 emission structure of regional logistics ecosystem of China in 2012.

Province	CO_2 emissions proportion of coal (%)	CO emissions proportion of oil (%)	CO_2 emissions proportion of gas (%)	CO_2 emissions proportion of heating (%)	CO_2 emissions proportion of electricity (%)
Beijing	1.680%	76.478%	2.893%	0.003%	18.914%
Tianjing	6.238%	79.243%	0.963%	0.001%	13.503%
Heibei	4.785%	72.137%	3.304%	0.000%	19.774%
Shanxi	7.533%	70.444%	6.015%	0.000%	15.970%
Inner Mongolia	31.776%	63.200%	1.629%	0.004%	3.363%
Liaoning	5.066%	88.464%	0.049%	0.001%	6.390%
Jilin	17.795%	71.055%	3.490%	0.005%	7.620%
Heilongjiang	30.660%	65.932%	0.000%	0.004%	3.379%
Shanghai	0.107%	94.043%	0.162%	0.000%	5.669%
Jiangsu	0.191%	89.569%	2.107%	0.000%	8.133%
Zhejiang	0.028%	92.642%	0.013%	0.000%	7.244%
Anhui	2.301%	85.331%	4.747%	0.000%	7.621%
Fujian	0.456%	92.166%	0.346%	0.000%	7.032%
Jiangxi	0.676%	88.889%	0.000%	0.000%	10.436%
Shandong	1.015%	91.303%	1.298%	0.001%	6.383%
Henan	0.000%	86.523%	0.000%	0.002%	13.475%
Hubei	26.374%	65.943%	2.623%	0.000%	5.060%
Hunan	7.006%	55.268%	0.718%	0.000%	37.008%
Guangdong	0.094%	93.024%	0.000%	0.000%	6.882%
Guangxi	0.022%	95.082%	0.000%	0.000%	4.896%
Hainan	0.000%	93.690%	3.017%	0.000%	3.294%
Chongqing	5.933%	79.576%	8.857%	0.000%	5.633%
Sichuan	0.776%	87.414%	4.164%	0.000%	7.645%
Guizhou	6.878%	82.130%	0.000%	0.000%	10.992%
Yunnan	1.660%	92.244%	0.018%	0.000%	6.078%
Shaanxi	6.402%	75.580%	4.634%	0.000%	13.384%
Gansu	11.632%	63.691%	2.770%	0.000%	21.906%
Qinghai	10.337%	71.371%	6.250%	0.000%	12.042%
Ningxia	4.259%	70.664%	11.992%	0.001%	13.084%
Xinjiang	9.326%	79.440%	6.394%	0.000%	4.840%
National average	6.438%	82.177%	1.801%	0.001%	9.583%

Table 3: CO_2 emission intensity of regional logistics ecosystem of China in 2012.

Region	National average	North Region	Northeast Region	East Region	Central Region	South Region	Southwest Region	Northwest Region
CO_2 emission intensity (KG/104 RMB)	2886.44	2210.4	3410.96	2593.2	3244.49	3102.64	3987.81	3668.60

Table 4: CO_2 emissions per unit of cargo turnover of regional logistics ecosystem of China in 2012.

Region	National average	North Region	Northeast Region	East Region	Central Region	South Region	Southwest Region	Northwest Region
CO_2 emissions per unit of cargo turnover (KG/104 ton-kilometer)	501.14	443.10	533.49	371.78	573.37	637.12	1196.57	655.32

water transport, railway, multimodal transportation and other low-carbon transport; (2) Optimizing the energy structure in logistics industry, and improving energy efficiency in logistics industry; (3) Encouraging the development and utilization of logistics equipment using clean and renewable energy and renewable energy; (4) Optimizing logistics and supply chain management, and improving logistics and supply chain coordination efficiency; (5) Integrating the existing logistics resources, optimizing the allocation of logistics resources, and scientifically planning and constructing logistics nodes; (6) Accelerating the construction of enterprise reverse logistics system and green supply chain; (7) Enlarging the application of information technology, information management system and public information platform in logistics industry, and improving information sharing level; (8) Reasonably setting the reduction targets and policies of carbon emissions in different regions to promote the development of low carbon logistics.

ACKNOWLEDGEMENTS

This work was supported by the National Natural Science Foundation of China (Granted No. 71403096), the Supported by Science Foundation of the Chinese Education Commission (Granted No. 15YJC630185) and the Research Project of Ministry of Housing and Urban-Rural Development of China (Granted No. 2015-K1-033). Thanks to my tutor professor Dong Mu for her guidance and correction to this article.

REFERENCES

Aronsson, H. and Huge Brodin, M. 2006. The environmental impact of changing logistics structures. International Journal of Logistics Management, 17(3): 394-415.

Ang, B.W. and Lee, S.Y. 1994. Decomposition of industrial energy consumption: some methodological and application issues. Energy Economics, 16(2): 83-92.

Corbett, C. and Kleindrofer, P.R. 2001. Introduction to the special issue to the environmental management and operation. Journal of Production and Operations Management, 10(3): 225-228.

Carbone, V. and Moatti, V. 2011. Towards greener supply chains: an institutional perspective. International Journal of Logistics: Research and Applications , 14(3): 179-197.

Carter, C. R. and Ellram, L. M. 1998. Reverse logistics: a review of the literature and future investigation. Journal of Business Logistics, 19(1): 85-102.

Churkina, G. 2008. Modeling the carbon cycle of urban systems. Ecological Modeling, 216(2): 107-113.

Dowlatshahi, S. 2000. Developing a theory of reverse logistics. Interfaces, 30(3): 143-155.

Halldórsson, Árni and Kovács Gyöngyi. 2010. The sustainable agenda and energy efficiency: Logistics solutions and supply chains in times of climate change. International Journal of Physical Distribution & Logistics Management, 40(1/2): 5-13.

Henrik Pålsson and Gyöngyi Kovács. 2014. Reducing transportation emissions: a reaction to stakeholder pressure or a strategy to increase competitive advantage. International Journal of Physical Distribution & Logistics Management, 44(4): 283-304.

Hsu, C. W., Kuo, T. C., Chen, S. H. and Hu, A. H. 2013. Using DEMATEL to develop a carbon management model of supplier selection in green supply chain management. Journal of Cleaner Production, 56: 164-172.

Jens Tacken, Vasco Sanchez Rodrigues and Robert Mason. 2014. Examining CO_2 reduction within the German logistics sector. The International Journal of Logistics Management, 25(1): 54-84.

Kengpol, A., Tuammee, S. and Tuominen, M. 2014. The development of a framework for route selection in multimodal transportation. The International Journal of Logistics Management, 25(3): 581-610.

Kinzig, A. P. and Kammen, D. M. 1998. National trajectories of carbon emissions: analysis of proposals to low-carbon economies. Global Environment Change, 8(3): 183-208.

Kristina, L., Martin, C. and Dan, A. 2015. Using a transport portfolio framework to reduce carbon footprint. The International Journal of Logistics Management, 26(2): 296-312.

Mathiyazhagan, K., Kannan Govindan and Noorul Haq, A. 2014. Pressure analysis for green supply chain management implementation in Indian industries using analytic hierarchy process. International Journal of Production Research, 52(1): 188-202.

Ramanathan, R. 2006. A multi-factor efficiency perspective to the relationship among world GDP, energy consumption and carbon dioxide emission. Technological Forecasting and Social Change, 73(5): 483-494.

Pishvaee, M. S., Torabi, S. A. and Razmi, J. 2012. Credibility-based fuzzy mathematical programming model for green logistics design under uncertainty. Computers & Industrial Engineering, 62(2): 624-632.

Sarkis, J. 2003. A strategic decision framework for green supply chain management. Journal of Cleaner Production, 11 (4): 397-409.

Yin, X., Chen, W. Y. and Jiyong Eom, etc. 2015. China's transportation energy consumption and CO_2 emissions from a global perspective. Energy Policy, 82: 233-248

Yingli Wang, Vasco Sanchez Rodrigues, and Leighton Evans. 2015. The use of ICT in road freight transport for CO_2 reduction-an exploratory study of UK's grocery retail industry. The International Journal of Logistics Management, 6(1): 2-29.

Zhou, Y., Wang, D.P. and Zhao, Y. 2011. Study on the CO_2 emission evaluation of the provincial logistics operation and low-carbon strategy in China. China Population, Resources and Environment, 21(9): 81-87.