ESTIMATION OF CO_2 EMISSIONS FROM TOURISM TRANSPORT IN HEILONGJIANG PROVINCE, CHINA

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ABSTRACT
The rapid development of China's tourism industry has been accompanied by an increase in CO_2 emissions, while the tourism transport accounts for a major share of CO_2 emissions. The purpose of this paper is to investigate the dynamic change of CO_2 emissions from tourism transport in Heilongjiang Province over the period 1978–2012. The results showed that the total CO_2 emissions of tourism transport rose from 13.1×10^4 *t* in 1978 to 224.17×10^4 *t* in 2012, following an average annual growth rate of 9.47%. Among four transport modes, highways transport represented the leading source of CO_2 emissions from tourism transport. CO_2 emissions from airways transport have increased dramatically and became the second largest contributor since 2003. Emissions from railway transport have remained relatively stable and that of waterways transport showed a decreased trend over the years.
Keywords: CO_2 emission, Heilongjiang Province, tourism transport.

1 INTRODUCTION

After the reform and opening up, China's economy has maintained remarkable growth. At the same time, transport industry has developed rapidly, and the type of vehicles have become rich and varied. People's travel became convenient and frequent, which caused the volume of traffic increase significantly. However, the transportation sector has been identified as one of the major contributors to China's energy consumption and CO_2 emissions [1]. According to the International Energy Agency, China's transportation sector contributed about 7% of the national CO_2 emissions [2,3].

As one of the largest industries in the world, the tourism industry accounts for 9% of the global gross domestic product and 8% of the global total employment in 2010 [4]. In 2013, the international tourists had reached 1.09 billion, accounting to one-seventh of the world's population. A study commissioned by the World Tourism Organization, the tourism industry is responsible for nearly 4.9% of the global greenhouse gas (GHG) emissions [5]. Travel and tourism often relies on fossil fuels for the transporting tourists to and from as well as within destinations [6], which generated 75% of the tourism-related GHG emissions. The share of emissions from air transport was 40%, cars were 32%, and the others were 3% [5].

Accordingly, some scholars have paid more attention to CO_2 emissions from tourism transport. Becken *et al*. proposed that transportation contributes 65–73% of the total energy consumption in tourism industry [7]. Richard accounted that the carbon tax on aviation fuel would particularly affect long-haul flights and short-haul flights [8]. Smith and Rodger assessed competing offsetting options for aviation emissions of international travel from comprehensive national level [9]. Perch-Nielsen *et al*. showed that air transport stood out as the tourism sector with by far largest emissions (80%) and highest GHG intensity in Switzerland [10]. Lin indicated that CO_2 emission factor of private car

ISSN: 1743-7601 (paper format), ISSN: 1743-761X (online), http://www.witpress.com/journals
DOI: 10.2495/SDP-V10-N4-520-527

reveals a higher value in five national parks in Taiwan [11]. Wei *et al*. showed that CO_2 emissions in China's tourism transport increased quickly in the last three decades [12]. Xiao *et al*. suggested that the average travel distance was the most important factor controlling CO_2 emissions, and the spatial structure of carbon emissions in different subsections of travel distance had significant discrepancies [13]. However, there is lack of system research on the provincial dynamic change of CO_2 emissions from tourism transport in China. Therefore, taking a case of Heilongjiang Province, this study investigated the dynamic change of CO_2 emissions from tourism transport in Heilongjiang Province from 1978 to 2012. Then some suggestions for developing sustainable transport in Heilongjiang Province are presented.

2 STUDY AREA

Located in northeast China, Heilongjiang Province covers a land area of 473,000 sq km, accounting for 4.9% of the national land area (Fig. 1). The topography is higher in the northwestern, northern and southeastern hills and lower in the northeastern and southwestern plains. Plains areas account for 37% of the land. The population is 38.34 million in 2012, accounting for the national total population (2.83%). Abound natural and human tourism resources in Heilongjiang Province provide a big space for tourism development. In 2012, the earning of tourism industry in Heilongjiang Province was about 130.03 billion yuan, accounting for 9.5% of Gross Domestic Product (GDP).

3 METHODOLOGY AND DATE PROCESSING

3.1 Methodology

According to previous literatures [3,5,12,14], this study estimated CO_2 emissions from tourism transport using bottom–up approach by the following equation:

$$Q_T = \sum_{i=1}^{n} \alpha \cdot N_i \cdot D_i \cdot P_{Ti} \tag{1}$$

Figure 1: The location of Heilongjiang Province in China.

Table 1: Generalized CO_2 emission factors for the tourism transport.

Transport mode	α (%)	Data sources	Emission factor (g/pkm)	Data sources
Railways	32.7	[14]	27	[5,12]
Highways	27.9	[14]	133	[16,18]
Waterways	10.6	[12]	106	[12,17]
Airways	36.7	[19]	137	[12,18]

where, Q_T is CO_2 emission from tourism transport; α is the proportion of tourists in passengers; N_i indicates the total number of passengers choosing transport mode i; D_i is trip distance for transport mode i; $N_i D_i$ denotes passenger turnover volume of transport mode i; P_T is CO_2 emission per unit for transport mode i (g/pkm).

3.2 Data sources and processing

Considering that the data in the China's Statistics Yearbook is mainly on four transport modes, such as railways, highways, waterways and airways, this study focuses on estimating CO_2 emissions from railways, highways, waterways and airways. All statistical data were collected from *Heilongjiang Statistical Yearbook* [15]. The research period in this study spans from 1978 to 2012.

Some parameters were obtained based on a full reference of the previous empirical studies [5,12,14,16–18]. According to the *Development Report of China Civil Aviation* [19], and the researches of Wu and Shi [14] and Wei *et al*. [12], the value of α are 32.7%, 27.9%, 10.6% and 36.7% for railways, highways, waterways and airways, respectively. CO_2 emission per unit for different transport modes is set up as 27 g/pkm for railways, 133 g/pkm for highways, 106 g/pkm for waterways and 137 g/pkm for airways (Table 1). Furthermore, because the 1978–2012 period analyzed in this study is a relatively short term, the above-mentioned parameters are supposed to be constant in this study.

4 RESULTS

4.1 Passenger turnover volume

In China, explanatory notes on statistical indicators ‘passenger turnover volume', also called passenger-kilometers, refer to the sum of the product of the volume of transported passengers multiplied by the transport distance. It is an important indicator to reflect the achievement of the transportation industry. According to *Heilongjiang Statistical Yearbook* [15], in Heilongjiang Province, the total passenger turnover volume rose from 90.8×10^8 passenger-km in 1978 to 733.9×10^8 passenger-km in 2012, and increased by 8.08 times (Fig. 2). Among four transport modes, the passenger turnover volume of railways maintained larger percentage, and grew from 72.2×10^8 passenger-km in 1978 to 254.7×10^8 passenger-km in 2012. The next is highways, its passenger turnover volume increased from 17.5×10^8 passenger-km in 1978 to 296.8×10^8 passenger-km in 2012. The passenger turnover volume of airways is fastest growing in four transport modes, almost 606.67 times as much as the figure in 1978 (from 0.3×10^8 passenger-km in 1978 to 182×10^8 passenger-km in 2012). Comparatively, the passenger turnover volume of waterways is smallest, and decreased from 0.7×10^8 passenger-km in 1978 to 0.4×10^8 passenger-km in 2012.

4.2 CO_2 emissions from tourism transport

Figure 3 shows CO_2 emissions from tourism transport in Heilongjiang Province over the period 1978–2012. As can be seen from Fig. 2, the total CO_2 emission from tourism transport increased dramatically, from 13.1×10^4 *t* in 1978 to 224.17×10^4 *t* in 2012, implying an average annual growth rate of 9.47%. As shown in Fig. 2, it is obvious that CO_2 emission as a total has experienced three periods of development: increasing at a relatively slow rate between 1978 and 1995, growing relatively quickly between 1996 and 2007, and rising at a rapid pace since 2008. In fact, CO_2 emission from tourism transport in Heilongjiang Province increased by 17.12 times from 1978 to 2012.

Among all the transport modes, CO_2 emissions from highways were the largest, increasing from 6.49×10^4 *t* in 1978 to 110.13×10^4 *t* in 2012. It is also observed that the change of CO_2 emission from highways displayed a similar trend to that of CO_2 emission from tourism transport (Fig. 3). It can be concluded that highways had the greatest impact on tourism transport in CO_2 emissions. The trend for CO_2 emission from airways demonstrated a very high growth rate, especially after 2003. In 1978, airways produced less than 0.15×10^4 *t* of CO_2 emissions, but it produced 91.51×10^4 *t* of CO_2 emissions in 2012. CO_2 emission from airways exceeded that from railways in 2003, and

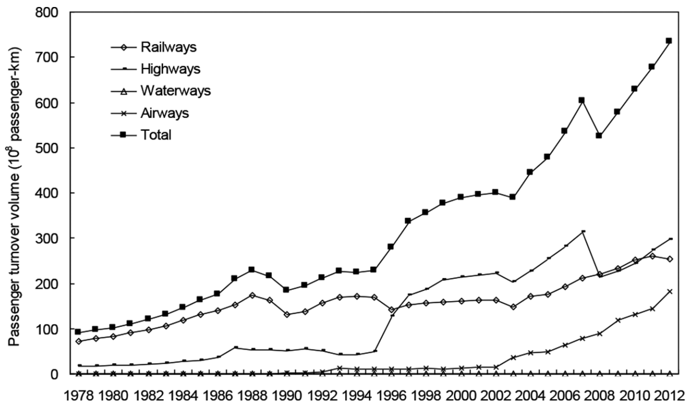

Figure 2: Passenger turnover volume in Heilongjiang Province from 1978 to 2012.

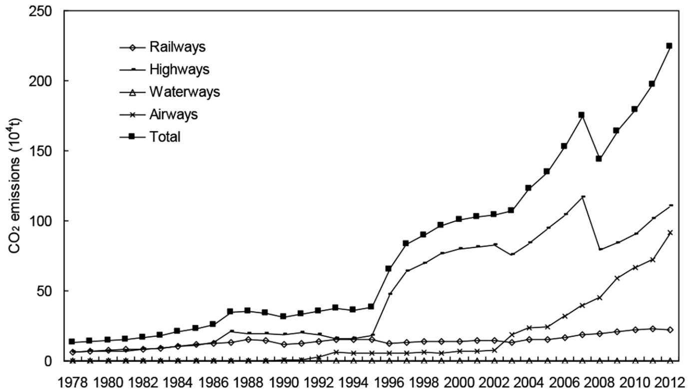

Figure 3: CO_2 emissions from tourism transport in Heilongjiang Province from 1978 to 2012.

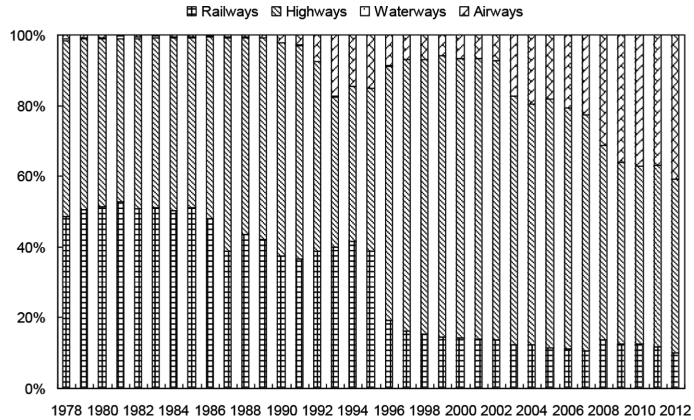

Figure 4: Shares of different tourism transport modes in total CO_2 emissions.

became the second discharge source in tourism transport since then. Comparatively speaking, CO_2 emissions from railways showed slight changes and increased from 6.37×10^4 t in 1978 to 22.49×10^4 t in 2012, which indicated that railways only made rather small impacts to the change in CO_2 emissions from tourism transport during this period. In addition, CO_2 emissions from waterways showed a decreased trend from 1978 to 2012. Waterways emitted 0.04×10^4 t CO_2 in 2009, a level even lower than its emissions in 1978 (0.08×10^4 t).

Figure 4 presents the percentage shares of CO_2 emissions from tourism transport in Heilongjiang Province. In 2012, the shares of CO_2 emissions by railways, highways, waterways and airways were 10.03%, 49.13%, 0.02% and 40.82%, respectively. The respective shares in 1978 were 48.67%, 49.58%, 0.6% and 1.15%. As shown in Fig. 4, the shares of railways and waterways in total emissions decreased, whereas the share of airways increased. The share of highways increased first and then declined during the study period. It can be seen that CO_2 emissions from tourism transport in Heilongjiang Province were dominated by railways and highways during the period 1978–2002, whereas they were dominated by highways and airways during the period 2003–2012.

4.3 Proposals of measures for establishing the sustainable traffic in Heilongjiang Province

The rapid, healthy and orderly development of tourism industry depends on the support of transportation. To establish low energy consumption, low pollution and low emission of tourism transport system, Heilongjiang Province should adopt some sustainable strategies to promote the development of low-carbon transportation, such as policy guidance, structure optimization, technology improvement, intelligent transportation and low-carbon travel.

In terms of policy guidance, the governments should build the comprehensive transportation system of energy saving and low carbon by making related policies and plans, constructing green traffic infrastructure, and strengthening guidance and motivation, and so on. For example, Heilongjiang Province should construct the integrated traffic system among major cities to shorten the distance between the city and city, which can realize 3 hours transportation circle in Harbin City, Daqing City, Qiqihar City, Mudanjiang City and Jiamusi City. Meanwhile, they will also become new tourist routes and enhance the service quality in Heilongjiang tourism circle.

In terms of structure optimization, Heilongjiang Province should tighten up controls in the road sector through adjusting traffic routes and layout, revitalizing railways and promoting waterways.

In accordance with the principle of 'suitable for railway to develop railway, suitable for airway to develop airway, suitable for waterway to develop waterway', Heilongjiang Province should give full play to the comparative advantage and combination efficiency of various transportation means. At the same time, tourists can be attracted to more sustainable transport modes by improving in public transport, bicycle and pedestrian infrastructure [3].

In terms of technology improvement, Heilongjiang Province should vigorously promote the vehicle using clean fuel. Along with the quick increase of the automobile quantity, it has become the inevitable trend of auto industry to develop the new energy vehicles. Hybrid electric vehicle is an important solution to energy conservation and emission reduction on transportation in the short term. In the meantime, transport enterprises should exert their enthusiasm and initiative in supporting the widespread use of clean energy transport, and developing and applying new energy conservation and environmental protection technology for low-carbon transport.

In terms of intelligent transportation, Heilongjiang Province should strengthen the construction of traffic information. The interline and sharing of traffic information is the embodiment of traffic modernization, networked and intelligentization. It is important that data streams of main cities' traffic are monitored and analyzed by Intelligent Transportation System (ITS), and Public Travel Information Service System [20]. The tourism operators and managers can carry out the traffic digital communication in main transportation node by using GIS, GPS and ITS, which can make tourists to enjoy more convenient and comfortable travel.

In terms of low-carbon travel, tourists should develop a strong environmental consciousness and actively promote the choice of low-carbon and green way to travel. Long distance travel can adopt the way of public transport, and short distance travel can use the way of the 'bicycle + walk'. Scenic area should explore the non-motorized traffic and improve pedestrian traffic and the bicycle traffic. Public bicycle systems (PBS) should be introduced combined with residential, commercial and tourism area. It encourages tourists to give up their cars for a travel and choose low-carbon and energy conservation trip mode, such as bus, bike or walking.

5 CONCLUSIONS

In Heilongjiang Province, the total passenger turnover volume increased by 8.08 times over period 1978–2012. CO_2 emissions from tourism transport have grown substantially from 1978 to 2012. In Heilongjiang Province, CO_2 emissions from tourism transport have increased from 13.1×10^4 *t* in 1978 to 224.17×10^4 *t* in 2012, following an average annual growth rate of 9.47%. Among all the transport modes, highways transport is the leading and most rapidly growing contributor. CO_2 emissions from highways increased from 6.49×10^4 *t* in 1978 to 110.13×10^4 *t* in 2012. The second largest source of tourism transport CO_2 emissions was railways before 2002 and was airways since 2003. CO_2 emissions from airways transport have increased dramatically since 1978. Waterways transport has also been a low transport emission mode. The results of this paper strongly suggest that some strategies should be systematically implemented for developing sustainable transport.

ACKNOWLEDGMENTS

This research is funded by the National Philosophy and Social Science Foundation of China (13BJY144), the National Natural Science Foundation of China (71073041, 71273073), the project of humanities and social sciences of the Ministry of Education of China (12YJCZH295), and projects of philosophy and social sciences for research and planning of Heilongjiang Province (13D028, 13E027, 13E031), the project teaching reform of higher education in Heilongjiang

Province (JG2013010343, JG2013010330, JG2014010817, JG2014010818), the youth project of educational science in Heilongjiang Province (GBD1213020, GBD1213004), and the project of soft science in Heilongjiang Province (GC14D303). The authors are sincerely grateful for the anonymous reviewers' valuable comments and suggestions that have greatly helped to improve the paper's quality.

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