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# Factors Influencing the Energy Efficiency of Tourism Transport in China

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**Abstract:** Transport is a major component of energy consumption and $CO_2$ emissions in travelling. Understanding changes in the energy efficiency of tourism transport (EETT) and factors affecting this is important to the promotion of low-carbon tourism. This paper established a new method following the top to bottom principle and analyzed EETT variation characteristics and influencing factors from 1994 to 2013 in China. We found that the energy consumption of tourism transport (ECTT) increased from 178.21 PJ in 1994 to 565.82 PJ in 2013 at an average annual growth rate of 6.27%; $CO_2$ emissions of tourism transport (CETT) went up from $14.96\times10^6$ t to $47.94\times10^6$ t due to person-trip and trip distance growth. EETT went from $3.22\times10^6$ person-trips $PJ^{-1}$ in 1994 to $5.99\times10^6$ person-trips $PJ^{-1}$ in 2013 at an average annual growth rate of 4.90%, and the $CO_2$ emissions of tourism transport unit person-trips (CETTU) shifted from 26.07 kg person-trips$^{-1}$ in 1994 to 14.01 kg person-trips$^{-1}$ in 2013. Energy intensity decline, scale effects and policy promotion were key factors that enhanced EETT. Meanwhile, trip mode changes and enjoyment-oriented transport hindered EETT. Based on our analysis, we suggest methods to decrease ECTT and CETT, and enhance EETT.

**Key words:** tourism transport; energy consumption; $CO_2$ emissions; energy efficiency; influencing factors; China

## 1 Introduction

Environmental issues caused by large-scale tourism and its energy consumption and $CO_2$ emissions have been widely researched (Gössling 2002, 2013; Scott *et al*. 2010). Tourists are responsible for 4.4% of global $CO_2$ emissions and this is projected to grow continuously for the next several decades (Dubois *et al*. 2011; Mayor and Tol 2010; Scott *et al*. 2010) at a growth rate of 3.2% annually until 2035 (Peeters and Dubois 2010). The contribution rate of the tourism industry accounted for 5%-14% of anthropogenic global warming and this will increase 188% by 2035 (UNWTO 2008).

Tourism energy consumption generally includes the three components of tourism transport, tourism accommodation and tourism activity (Dolnicar *et al*. 2010; Gössling *et al*. 2005). Tourism transport is the main component, such as in New Zealand where energy consumption from tourism transport accounted for 65-73% of the total tourism industry (Becken *et al*. 2003); in France, the share of tourism transport in total tourism industry energy consumption is predicted to rise to 90% in 2050 (Dubois *et al*. 2006); in Switzerland, greenhouse gases from tourism transport accounted for 87% of the total tourism industry (Perch-Nielsen *et al*. 2010); and in the Yangtze River Delta area of China, $CO_2$ emissions related to tourism transport were 8.32 Mt in 2011 (Tao *et al*. 2015). Travelling by air is a dominating and increasing factor of energy consumption of tourism transport (ECTT) and $CO_2$ emissions of tourism transport (CETT) (Gössling *et al*. 2007; Xi *et al*. 2010), accounting for 2-3.4% of the global gross amount (Gössling and Peeters 2007;

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Owen *et al.* 2010). For example, the number of $CO_2$ emissions was over $6.5\times10^5$ t according to flight kilometers and energy consumption parameters for travelling from Hong Kong to New Zealand by air (Becken 2002). In New Zealand, airplane $CO_2$ emissions resulting from foreign tourists were $7.89\times10^6$ t and $3.95\times10^6$ t from civil tourists (Smith and Rodger 2009). The $CO_2$ emissions per capita of short-haul air transport (less than 500 km) is the highest, because taking off and reaching cruising attitude consume a large amount of fuel (UNWTO-UNEP-WMO 2008) (see Filimonau *et al.* 2013 for data for travel from the UK to France). Long-haul air transport only accounts for 2% of all travelling, but the carbon emissions are 17% of total emissions (Simpson *et al.* 2008). In Cyprus, long journey by air was a thrill factor to energy consumption and carbon emissions (Katircioglu *et al.* 2014). Karen and Richard (2010) found that annual growth rates of $CO_2$ emissions by air would remain at 4.1% from 1995–2050, and slow down in the middle of the 21st century. Peeters and Eijgelaar (2014) analyzed tourism climate mitigation dilemmas involved in flying between rich and poor countries.

Some researchers have analyzed tourism ecological efficiency and influencing factors. The results show that visitor numbers, management style, technical equipment and fuel mix impact total energy consumption, and a detailed examination of the energy use pattern of an operator often improves energy efficiency (Becken and Simmons 2002). Gössling *et al.* (2005) suggested that travel distance, means of transport, average length of stay, and expenditure per day influenced ecological efficiency. Lin (2010) showed that $CO_2$ emissions could be reduced by increasing load factors of transport, switching from private cars to public transport and going to destinations close to points of departure, which could be achieved by authorities through activity management, regulation and price adjustment. Liu *et al.* (2011) thought that energy intensity, expenditure size and the size of the industry were generally found to be principal drivers of emissions growth, whereas energy share and consumption structure were not found to have a sizable influence on the growth of tourism industry emissions. Tol (2007) found that a carbon tax on aviation fuel would particularly affect long-haul and short-haul flights and that medium distance flights would be affected least. Xiao *et al.* (2012) argued that the average travel distance was the most important factor in controlling $CO_2$ emissions.

These studies have broadened our understanding of tourism energy consumption and $CO_2$ emissions, but limitations remain. First, the majority of studies have focused on time cross-section characteristics of a country or regional energy consumption and $CO_2$ emissions, which is beneficial to data collection, but goes against temporal comparisons and trend discussion. Second, the coefficients of tourism energy consumption and $CO_2$ emissions mainly reflect developed country characteristics and this method is likely to overestimate or underestimate China's ECTT and CETT. After all, as a developing country, China is very different from developed countries regarding economic development level, population size and tourism industry development stage. Third, less attention has been paid to China's ECTT and CETT (Wu and Yue 2013). Here, based on Chinese measurements of energy consumption parameters of different transport means, we attempt to analyze energy consumption, $CO_2$ emissions, energy efficiency and influencing factors of tourism transport (tourists move from origin regions to destination regions and from destination regions to origin regions) since 1994 and propose methods for raising China's EETT.

## 2 Methods and data

### 2.1 Methods

Traditionally, the tourism industry is not measured as an economic sector within the national accounts and there is no national statistical system (Becken and Patterson 2006) or systematic method to estimate tourism energy consumption and greenhouse gas emissions (Kuo and Chen 2009). Generally, the methods, "from top to bottom" and "from bottom to top" are used (Becken and Hay 2007; Gössling *et al.* 2005; Gössling 2013; Peeters 2005). The top to bottom method directly estimates the proportion of tourism energy consumption or $CO_2$ emissions accounting for a holonomic system (a whole country or state) based on monitoring data for energy consumption and $CO_2$ emissions. Input-Output Analysis is a theoretical foundation. The bottom to top method is based on Life Cycle Assessment theory, directly calculates greenhouse gas emissions of tourism products or services (Filimonau *et al.* 2011) and estimates energy consumption and greenhouse gas emissions starting with tourist activities step by step. Here, we establish a new method following the top to bottom principle based on the measurement of energy consumption coefficients and statistical tourism transport data in order to estimate ECTT, CETT and EETT in China.

#### 2.1.1 ECTT measurement

The key to measuring ECTT and CETT is to confirm energy consumption parameters of different communications and tourism transport turnover. With regard to parameters, tourism transport is mainly composed of bus, train and airplane in China. Hence, we attempt to measure their energy intensity according to operating bus, train and airplane energy consumption. Although there is no tourism turnover statistical data, it is a component of whole passenger transport, therefore ECTT is a component of overall transport energy consumption. The proportion can be measured by the number of tourist accounting for passenger turnover. Accordingly, we built formula (1) to estimate ECTT:

$$ECTT_t = (CU_t \times C_t + TU_t \times T_t + AU_t \times A_t) \times \frac{4NT_t}{NP_t} \tag{1}$$

where, $CU_t$, $TU_t$, $AU_t$ are energy intensity of operating bus, train and airplane at time *t* respectively; $C_t$, $T_t$, $A_t$ are passenger turnover of operating bus, train and airplane respectively; $NT_t$ is the number of tourists at time *t*; and $NP_t$ is the whole turnover of bus, train and airplane in China. The coefficient 4 means that the travelling process is a round trip from departure to destination and back, which are at least 2 turnovers; if a tourist transforms mode once midway, the turnover will be 4; if a tourist transforms mode twice midway, the turnover will be 6. In general, there are 2-6 turnovers per person-trip and we take the average of 4 turnovers as our basis.

### 2.1.2 CETT Measurement

Based on the result of ECTT, we built formula (2) to measure CETT:

$$CETT_t = \beta_1 \times (\beta_2 \times ECTT_t) \tag{2}$$

where, $\beta_1$=2.46 t $CO_2$ $tce^{-1}$, the $CO_2$ emission coefficient; and $\beta_2$ =34139 t tce $PJ^{-1}$, the energy conversion coefficient, recommended by Energy Research Institute National Development and Reform Commission, China.

### 2.1.3 EETT measurement

According to the ECTT, EETT can be measured using formula (3), reflecting service capacity of unit PJ energy. A bigger $EETT_t$ means higher efficiency, unit PJ energy can serve larger number of tourists. Otherwise, a smaller $EETT_t$ means lower efficiency. $CETTU_t$ can be estimated according to formula (4) whereby a bigger $CETTU_t$ means lower efficiency, unit person-trip lets out more $CO_2$ and a smaller $CETTU_t$ means higher efficiency.

$$EETT_t = \frac{NT_t}{ECTT_t} \tag{3}$$

$$CETTU_t = \frac{CETT_t}{NT_t} \tag{4}$$

## 2.2 Data sources

Most statistical data for operating bus energy consumption from 1994-2010 come from the *Year Book of China Transportation & Communications (1995-2011)*, and energy intensity of gasoline bus and diesel bus from 1994-1999 is measured using formula (5). Other statistical data from 2011-2013 are from the *China Statistical Bulletin of Highway and Waterway Transportation & Communications (2011-2012)*, and *China Statistical Bulletin of Transportation & Communications (2013)*. The linear interpolation method is used to replace missing data from 2008-2009.

$$EU_b = EU_g \times \frac{ET_g}{ET_g + ET_d} + EU_d \times \frac{ET_d}{ET_g + ET_d} \tag{5}$$

where, $EU_b$, $EU_g$ and $EU_d$ are energy intensity of the operating bus, gasoline bus, and diesel bus respectively; $ET_g$, $ET_d$ are gasoline and diesel consumption respectively.

Statistical data for energy intensity by train from 2006-2013 are from the *China Railway Yearbook (2007–2013)* and *China Statistical Bulletin of Transportation & Communications (2013)*. Data for 1994-2005 are measured by formula (6) based on railway conversion turnover and energy consumption from the *China Railway Yearbook (1995-2006)*.

$$EU_r = \frac{ET_r}{T_r} \tag{6}$$

where, $EU_r$ is passenger energy intensity by train; $ET_r$ is total energy consumption; and $T_r$ is railway conversion turnover.

The statistical data of energy intensity by airplane are derived from *Civil Aviation Statistics (1995-2014),* which uses the total volume of circular flow (conversion ton-kilometer) to show passenger and cargo turnover conditions (one passenger is converted to 90 kg).

Total person-trips (including domestic, inbound and outbound tourism), total passenger turnover volume, bus passenger turnover volume, train passenger turnover volume and airplane passenger turnover volume are all from the *China Statistical Yearbook (1995-2014)*. Coal is the main resource in China's energy structure, therefore energy consumption is estimated by coal equivalent, meaning that different kinds of energy consumption are converted into coal equivalent according to Chinese national standards *Calculation Rules of Comprehensive Energy Consumption*.

# 3 Results

## 3.1 ECTT and CETT characteristics

China's ECTT was measured according to formula (1), increasing from 178.21 PJ in 1994 to 565.82 PJ in 2013, with total growth of 217.50% and average annual growth of 6.27%, which had an obvious upward trend expressed by an ascending curve (Fig. 1). ECTT presented a periodic change characteristic, which was nearly stable, fluctuating between 160 PJ and 220 PJ before the year 2000. It maintained accelerated growth from 165.03 PJ in 2000 to 565.82 PJ in 2013, equating to total growth of 242.86% and average annual growth of 9.94%, faster than the average annual growth rate of 6.27% from 1994-2013. CETT was calculated according to formula (2) and was found to increase from $14.96\times10^6$ t in 1994 to $47.94\times10^6$ t in 2013, a similar trend to ECTT (Fig. 1). CETT fluctuated between $13\times10^6$ t and $18\times10^6$ t from 1994-2000; and increased from $13.85\times10^6$ t to $47.94\times10^6$ t from 2000 to 2013.

## 3.2 EETT and CETTU variation trends

According to formula (3) we estimated EETT and found that it increased from $3.22\times10^6$ person-trips $PJ^{-1}$ in 1994 to $5.99\times10^6$ person-trips $PJ^{-1}$ in 2013, meaning energy consumption per PJ supplied $3.22\times10^6$ person-trips with transport service in 1994 and $5.99\times10^6$ person-trips $PJ^{-1}$ with transport service in 2013. The EETT total growth rate was 86.14% and average annual growth rate was 4.90%. During 1994-2000, EETT rapidly increased from $3.22\times10^6$ per

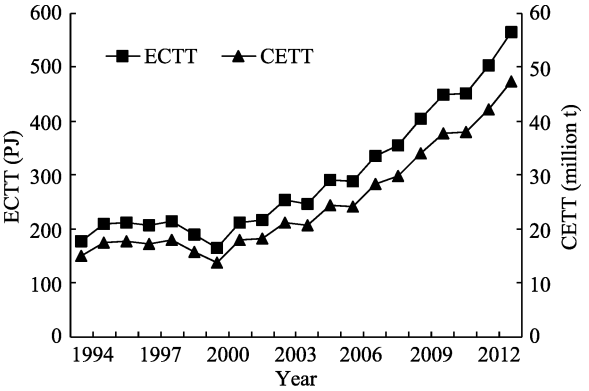

Fig.1 ECTT and CETT variation characteristics, 1994–2013

son-trips $PJ^{-1}$ to $5.08\times10^6$ person-trips $PJ^{-1}$, with an average annual growth rate of 7.89%, exceeding the rate of 4.90% during 1994–2013. During 2000–2013, EETT fluctuated from $5.08\times10^6$ person-trips $PJ^{-1}$ to $5.99\times10^6$ person-trips $PJ^{-1}$ with an average annual growth rate of 1.28%, far below the rate of 4.90% during 1994-2013. The character was in accordance with the ECTT. Before the year 2000, increasing EETT helped to hold back ECTT; after 2000, fluctuating EETT led to promotion of ECTT.

Based on formula (4), CETTU was found to change from 26.07 kg person-$trip^{-1}$ to 14.01 kg person-$trip^{-1}$, and $CO_2$ emissions per person-trip decreased from 26.07 kg in 1994 to 14.01 kg in 2013.

Fig. 2 shows that EETT increased and CETTU declined. However, China energy efficiency of tourism transport tended to improve steadily, and EETT meant higher service capacity per PJ energy, and CETT meant less $CO_2$ emissions per person-trip from 1994 to 2013.

### 3.3 Factors influencing EETT

#### 3.3.1 Factors promoting EETT

China's EETT has increased due to rapid energy intensity reduction, scale effect and policy promotion during 1994–2013. Energy intensity decline was the key factor promoting EETT. As shown in Fig. 3, energy intensity of bus, train and airplane all showed a continuous decreasing trend which went down from 1.00 MJ per passenger kilometers ($pkm^{-1}$), 0.37 MJ $pkm^{-1}$ and 1.79 MJ $pkm^{-1}$ in 1994 to 0.34 MJ $pkm^{-1}$, 0.11 MJ $pkm^{-1}$ and 1.15 MJ $pkm^{-1}$ in 2013, representing a rate of decrease of 68.77%, 65.67% and 35.67%, and average annual rate of 6.26%, 5.77% and 2.42%, respectively. New technology helped bus, train and airplane to improve energy use efficiency. Energy-saving transport facility constantly replaced energy-extensive and led to optimizing transport vehicles and reducing energy consumption. Taking China railway as an example, the terminal energy efficiency of steam locomotive, diesel locomotive and electric locomotive was 6%–9%, 25%–26% and 30–32% respectively (Zhou 2009). Steam locomotives have been replaced gradually since 1994 by diesel locomotives and electric locomotives of higher efficiency (He 2009; Zhang *et al.* 2011).

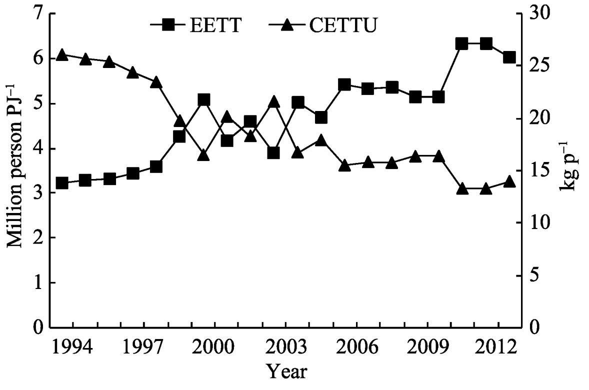

Fig.2 EETT and CETTU variation trends, 1994–2013

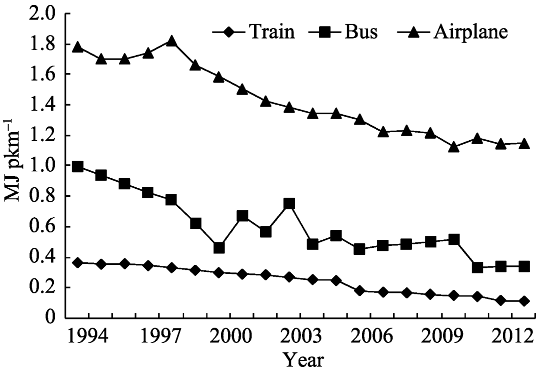

Fig.3 Energy intensity of bus, train and airplane, 1994–2013

China's enormous population base and large-scale population mobility have exerted scale effects since 1990s. The number of passengers by bus, train and airplane was $8.41\times10^9$ person-trips in 1994, and in 2013 the number was $2.75\times10^{10}$, representing a total growth rate of 227.11% and average annual growth rate of 6.44%. Large-scale passenger flow played transport machine carrying capacity effectively. Statistical data indicates that usage of the high-speed railway from Hefei to Wuhan was over 90% and the Shanghai to Nanjing route was 100%, effectively enhancing carrying efficiency and lowering energy consumption.

China macropolicy attached importance to energy conservation and emissions reduction, which supplied good exterior environment with energy-saving vehicles and improved EETT continually. The 9th Five-year Plan (1996–2000) made clear that the energy-saving rate should be 5% per annum. *People's Republic of China Economizing Energy Law* was formulated (1997), and implemented (1998); the 10th Five-year Plan (2001–2005) proposed that the total amount of pollutant emissions reduced 10% compared to the year 2000; the 11th Five-year Plan (2006–2010) paid high attention to energy-saving and energy consumption reduction of 20%; the 12th Five-year Plan (2011–2015) proposed an energy consumption reduction 16% and $CO_2$ emissions reduction of 17% per unit gross domestic product. Therefore, the field in transport also resorted to intensive energy-saving and cost-reducing policies. Taking the motor industry as an example, *Notification about Reinforcing Fuel Prudent and*

*Power Saving* issued by the Central People's Government in 2008 put forward the policy of encouragement to use energy-saving motor. China implemented national standard motor of vehicles I, II, III and IV in 2000, 2004, 2007 and 2011 respectively. These policies decreased energy intensity and reduced energy consumption and $CO_2$ emissions (Jiang 2013).

### 3.3.2 Factors hindering EETT

Trip mode shifts hampered EETT improvement from 1994 to 2013. Tourists tended to choose faster and more convenient transport modes, meaning more energy consumption from energy-saving to energy-intensive. For instance, the proportion of passengers by train decreased, but the proportion of passengers by bus and airplane increased (Fig. 4). The share of passengers by train to the total volume decreased from 43.25% in 1994 to 38.52% in 2013, conversely the share of passengers by airplane increased from 6.56% in 1994 to 20.57% in 2013. It is no doubt that growing demand for air transport will continue in the future. There is a reverse variation relationship between vehicle travelling speed and energy consumption (energy consumption tends to increase with increasing speed). From 1994–2013, train speed continued to increase obviously (from 48.0 km $h^{-1}$ to 72.6 km $h^{-1}$) and promoted energy consumption.

More comfortable and enjoyment-oriented vehicles rely on more energy consumption and $CO_2$ emissions, which is likely to lead to a decrease in EETT. Taking railway as an example, the fixed number of carriages with hard cushioned seats, carriages with semicushioned berths and carriages with soft berths is 128 persons, 66 persons and 36 persons respectively. Carriages with hard cushioned seats have a greater carrying capacity and consume less energy, carriages with semicushioned berths and carriages with soft berths have less carrying capacity and consume more energy. Fig. 5 shows the growth rate of three kinds of train carriages from 1994 to 2013. Carriages with hard cushioned seats were the lowest and often showed negative growth. In contrast, the number of carriages with semicushioned berths and carriages with soft berths increased, especially the growth rate of carriages with soft berths. Comfortable and enjoyment-oriented vehicles increase ECTT and CETT dramatically and decrease EETT.

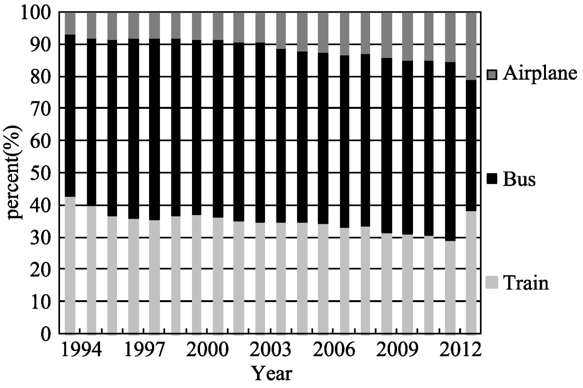

Fig.4 Variation in different trip modes, 1994–2013

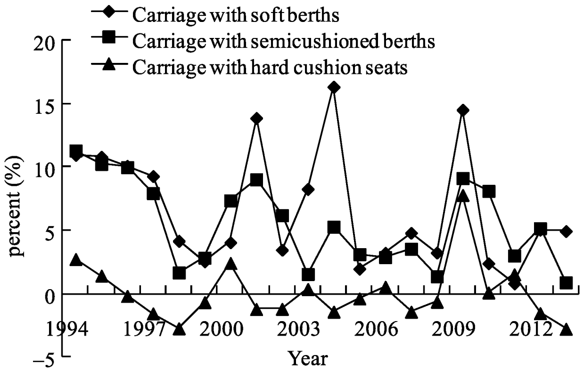

Fig.5 Growth rate of three kinds of train carriages, 1994–2013

## 4 Discussions

### 4.1 ECTT and CETT

The results indicate that China's ECTT tended to increase continuously. Compared to Zhong *et al.* (2014) who found $50.14\times10^6$ t $CO_2$ emissions in 2007, Shi and Wu (2011) who found 308.72 PJ energy consumption in 2008, and Wei *et al.* (2012) who found $61.44\times10^6$ t $CO_2$ emissions in 2009, our results are lower: CETT was $28.26\times10^6$ t in 2007, ECTT was 354.69 PJ in 2008 and CETT was $34.01\times10^6$ t in 2009. This is likely to be influenced by two kind of factors, on the one hand, we underestimated ECTT and CETT to some degree, because bus, train and airplane main trip modes were estimated in this paper without water transport mode; and bus energy consumption was based on operating bus standards, which are lower than for private cars. On the other hand, the coefficients for tourism energy consumption and $CO_2$ emissions in the correlation study mainly came from literature reflecting developed countries and overestimate ECTT and CETT in China.

Person-trip growth and trip distance are major contributors to growth in ECTT and CETT in China. There were a rapidly growing number of person-trips (from $5.74\times10^8$ in 1994 to $33.91\times10^8$ in 2013) which directly drove ECTT and CETT. Furthermore, ECTT and CETT were consistent with the number of tourists and shows that tourist growth is a key factor to ECTT and CETT increasing, because efficiency improvements were unlikely to maintain pace with projected growth in transport volume (Peeters and Eijgelaar 2014).

Trip distance also contributed to ECTT and CETT in accordance with the result that the increase in average travel distance was mainly responsible for increments in $CO_2$ emissions (Bao *et al.* 2012). It is obvious that longer trip distances mean a greater ECTT and CETT, and shorter trip distances mean a lower ECTT and CETT. The average haul distance of bus, train and airplane increased constantly, from 44.2 km, 334.4 km and 1365.6 km in 1994 to 60.7 km, 503.1 km, and 1598.1 km in 2013, total growth rate of 37.33%, 50.45% and 17.03% respectively, which meant tourists tended to travel distance, and longer trip distances consume more energy and release more $CO_2$. This trend is in line with evidence that long-haul tourism in on the increase, outpacing growth in short-haul tourism (Gössling *et al*. 2005). It is anticipated that person-trips will continue to rise with China's economic development and disposable income growth, and in the meantime trip distance is projected to continue to increase and ECTT and CETT will rise. However, the above result was not compatible with the trend that growth in tourism-related $CO_2$ emissions was caused primarily by an increase in travel distance because travel distance was increasing more rapidly than the number of guest nights and trips (Peeters and Dubois 2010; UNWTO-UNEP-WMO 2008), which may be intimately related to the stage of mass tourism in China from 1994 to 2013.

### 4.2 EETT and CETTU

Based on the tourism eco-efficiency concept (the calculation of eco-efficiency ratios for any kind of activity, economic sector, or economic region requires two data-sets, one of energy use and one of economic turnover) proposed by Gössling *et al*. (2005) and tourism greenhouse gas intensity (a ratio comparing the greenhouse gas emissions of an activity or economic sector to the economic value it generates) analyzed by Perch-Nielsen *et al*. (2010), we improved and expanded the concept by taking tourism transport, analyzed energy efficiency, reflecting by EETT and CETTU. The results showed that ECTT and CETT continuously increased, and tourism energy efficiency greatly improved, which is in accordance with upward transportation energy efficiency in China (Zhang *et al*. 2011). EETT showed an increasing trend and $CO_2$ emissions per person-trip had a continuous decreasing trend. EETT obviously improved, which restrained ECTT and CETT excessive growth. According to the standard in 1994, China reduced ECTT 3227.02 PJ, CETT $2.71\times10^8$ t during 1995-2013, indicating low-carbon tourism development.

Multiple factors impacted EETT. Some factors such as energy intensity of bus, train and airplane continuous decreases, scale effects of population mobility, energy conservation policy and emission reduction all promoted EETT and reduced ECTT and CETT. Other factors such as pursuing conveniences and immediacy of transport modes and enjoyment-oriented vehicles hampered EETT, and increased ECTT and CETT. Actually, among all tourism transport means, air travel causes the most unfavorable ecological efficiency (Gössling *et al*. 2005). However, these two kinds of factors did not have a balanced effect. Energy intensity reduction, scale effect, energy conservation policy and emission reduction played a leading role, and transport mode and enjoyment-oriented vehicles were in subordinate positions, which promoted China's EETT continuous improvement.

### 4.3 Low-carbon tourism transport

With global climate change it is necessary to promote low-carbon tourism in China (Zhong *et al*. 2011). Actually, there is still potential to reduce ECTT and CETT and enhance EETT to promote low-carbon tourism transport. As the core factor to drive EETT, it is necessary to depend on technical progress and optimization transport structure to decrease energy intensity of bus, train and airplane. At a macro-perspective level, China's enormous population base and large-scale population mobility are helpful to forming scale effect. At a micro-perspective level, compared to personage-travel, mate-travel is likely to realize scale effect and enhance EETT. Air is a kind of transport mode with the highest energy consumption (Hanandeh 2013), in order to reduce ECTT and CETT and enhance EETT, it is necessary to maintain human environmental tropism (Cheng *et al*. 2011), shift from travelling by air and car to travelling by rail (Filimonau *et al*. 2013; Scott *et al*. 2010), change from high-carbon-intensity vehicles to low-carbon-intensity vehicles without reducing the overall number of trips (Peeters *et al*. 2009; Xiao *et al*. 2012), reduce travel distances by promoting domestic and short-haul markets, encourage slower travel (Buckley 2011; Conway and Timms 2010; Tao *et al*. 2015) and even abstain from long journeys (Becken 2002; Dolnicar *et al*. 2010; Lin 2010; Peeters and Schouten 2006; Scott *et al*. 2010).

## 5 Conclusions

China's ECTT has undergone continuous and rapid growth: from 178.21 PJ in 1994 to 565.82 PJ in 2013, a total growth rate of 217.50% and average annual growth of 6.27%. CETT increased from $14.96\times10^6$ t to $47.94\times10^6$ t due to person-trip and trip distance growth. EETT increased from $3.22\times10^6$ person-trips $PJ^{-1}$ in 1994 to $5.99\times10^6$ person-trips $PJ^{-1}$ in 2013, representing total growth of 86.14% and average annual growth of 4.90%. CETTU went from 26.07 kg person-trip$^{-1}$ in 1994 to 14.01 kg person-trip$^{-1}$ in 2013. Energy intensity declines, scale effect and policy promotion were key factors that enhanced EETT. Some resistance factors, such as trip mode changes and enjoyment-oriented vehicles hampered EETT, playing a subordinate position. There remains potential to decrease ECTT and CETT and enhance EETT. Methods include reducing vehicle energy intensity, playing scale effects, travelling a short distance to a destination, reducing or abstaining from long travel and advocating slow travel.

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## 中国旅游交通的能源效率及其影响因素

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**摘　要：**交通是旅游过程中能源消耗和碳排放的主要环节，认识旅游交通能源效率变化及其影响因素对推动旅游低碳化发展具有重要意义。基于中国旅游交通及相关数据，在测算不同类型旅游交通工具能源消耗系数的基础上，遵循“自上而下”原则构建新的研究方法，分析考察 1994-2013 年旅游交通的能源消耗、碳排放、能源效率及其影响因素。结果显示，1）中国旅游交通能源消耗由 178.21PJ 增长至 565.82PJ，年均增长率为 6.27%，相应的 $CO_2$ 排放由 $14.96\times10^6$ t 增长至 $47.94\times10^6$ t，主要由旅游出游人次数快速增长和旅游出行距离增加引起；2）中国旅游交通能源服务效率由 $3.22\times10^6$ 人次 $PJ^{-1}$ 提高至 $5.99\times10^6$ 人次 $PJ^{-1}$，能源生态效率由 26.07 kg 人次$^{-1}$ 提升至 14.01 kg 人次$^{-1}$；3）单位交通能耗降低、规模效应、政策推动等成为能源效率提高的主导推动因素，但旅游出行方式变化、享受型交通工具的发展等阻碍了能源效率的提升。基于分析结果，提出了中国旅游交通降低能源消耗、提高能源效率的建议措施。

**关键词：**旅游交通；能源消耗；碳排放；能源效率；影响因素；中国