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# Determinants of $CO_2$ emissions from household daily travel in Beijing, China: Individual travel characteristic perspectives

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## HIGHLIGHTS

- We estimated household daily travel $CO_2$ emissions in Beijing from 2000 to 2012.
- We analysed influence factors of $CO_2$ emissions by decomposition analysis.
- Vehicle-use intensity, economic activity and population were driving emissions up.
- Promoting individual behavioural change and reducing car use should be emphasised.

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## ABSTRACT

Recently, there has been much interest in sustainable transport. However, few studies have examined the driving forces for household transportation emissions from the perspective of individual travel characteristic. This research examines the features and driving factors of $CO_2$ emissions from household daily travel in Beijing from 2000 to 2012. It first investigates the changes in personal travel characteristics and $CO_2$ emissions, and then discusses the effects of population, economic activity, transport capacity, vehicle emission intensity, and individual travel characteristic which includes the effects of transportation intensity, transportation mode share, and vehicle-use intensity on $CO_2$ emissions based on decomposition analysis. Results show that: (1) $CO_2$ emission due to urban traffic has increased from 4.34 Mt in 2000 to 18.58 Mt in 2012, following an annual growth rate of 13%; (2) the *per capita* disposable income, vehicle-use intensity, population and transport capacity effects are found to be the main drivers that increase household daily travel $CO_2$ emissions; and (3) the transportation intensity, vehicle emission intensity, and transportation mode share have effects on the reduction of $CO_2$ emissions over the study period.



## 1. Introduction

Global concentrations of carbon dioxide, methane, and nitrous oxide – three of the most notable greenhouse gases – have increased significantly over the past 250 years due to a direct result of human activities [1]. More and more people realised the need to adopt more sustainable lifestyles to reduce the consumption of natural resources and the emission of pollutants. Many countries have established sustainability-related performance standards aimed at reducing energy use and carbon emissions, such as promoting energy efficiency in household appliances, effectiveness of home insulation and fuel economy in motor vehicles [2]. In China, there has been rapid economic growth since the economic reforms of the late 1970s, which brings dramatic improvement in living standards [3]. However, economic growth in China is heavily invested in the development of manufacturing and heavy industries, which leads to a rapid growth in energy consumption and carbon emission. The population is also experiencing dramatic shifts in lifestyle, as well as significant growth in demand for energy. Therefore, it is essential that China promotes sustainable consumption patterns to reduce energy consumption and carbon emissions while meeting domestic demand for consumption.

The transport sector plays a curial role in daily activities around the world. However, transport has been considered as a major contributor to GHG emissions, which accounts for more than 60% of

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global oil consumption and 23% of $CO_2$ emissions in 2007 [4]. With the acceleration of urbanisation and increasing levels of motorisation in China, $CO_2$ emissions from the transport sector have dramatically increased in the past few years, especially in big cities, such as Beijing. For instance, Beijing's vehicle stock increased from 1.04 million in 2000 to 4.94 million in 2012, while transport-associated $CO_2$ emissions grew from 5.16 Mt to 19.5 Mt during the same period, which brings great pressure on attempts to meet emission reduction targets. At present, as China is still in a period of optimisation of her urban traffic structure, a radical change may occur in the travel characteristic of urban residents, which will change their transportation mode share and the number of privately owned vehicles. Furthermore, pervious urban transport systems are increasingly difficult to adapt to the rapid development of cities and the different levels of household transportation demand. In this context, it is necessary to examine the driving forces for household transportation emissions from the perspective of individual travel characteristic, and discuss how to guide residents to choose low carbon, sustainable transportation mode. According to recent studies, the term of stainable transportation includes three aspects: (1) offering safe and efficient transportation modes to meet residents' mobility needs; (2) use renewable resources and energy to minimize the pollutant and waste; (3) promoting equity within and between successive generations [5–7].

Recently, several studies have been concerned with analysing the energy consumption and emissions reduction in the transport sector [8–10]. Some studies focus on a specific country or region [11,12]. For example, Brantley examined consumption-driven environmental impacts from the transport sector in OECD countries [13]. Mraihi et al. analysed the driving factors behind energy consumption change for road-based modes in Tunisian cities [14]. There are also many studies analysing the energy consumption and carbon emissions of the transport sector in the Chinese context [15–18]. Furthermore, some research pays attention to different transport modes [19]. Chèze et al. researched emissions from air transportation [20]. Zhang measured fuel consumption and $CO_2$ emissions for urban buses and provided scientific support for China's national fuel economy standard for buses to be established in the future [21]. Hoffrichter et al. calculated the energy efficiencies and carbon emissions for railway vehicles on a well-to-wheel basis [22]. Okada assessed road transport emissions in Japan [23]. As for research methods, there are five basic methods: firstly, bottom-up sector-based analysis [24–28]; secondly, quantitative methods [29–32]; thirdly, econometric models [33]; fourthly, system optimization methods [34–36]; and fifthly, the decomposition methods, which has been widely used to study the factors affecting the change of aggregate energy consumption and carbon emissions from the transport sector over time [37–42]. Two main decomposition techniques, namely Structural Decomposition Analysis (SDA) and Index Decomposition Analysis (IDA) are used to analyse these driving forces. There are similarities as well as differences between the two approaches in terms of study scope, method formulation, data requirements, and their results [43]. For example, the SDA method is based on input–output coefficients and final demand from an input–output framework, while the IDA approach uses an index number framework and requires sector level data. The SDA method is often characterised by time periods of up to ten years, since the input-output tables are not available annually for many countries. The IDA studies a yearly time period, because aggregated data at sector level are often available [44]. Although there is no consensus among researchers regarding the preferred decomposition method between SDA and IDA, the IDA approach is more suitable for time series modelling in this study. There are three IDA methodologies: Laspeyres index decomposition approach, Arithmetic mean Divisia index method (AMDI) and the Logarithmic Mean Divisia Index approach (LMDI). The LMDI method, which was introduced by Ang [45], has advantages in its theoretical foundation, adaptability, consistency of results decomposed by both multiplicative and additive methods, ease of use, and in the interpretation of its results: it also has the ability to perform a perfect decomposition and to accommodate zero values in the data set [46]. Thus, this study constructs a decomposition analysis model by applying LMDI to investigate the major factors that may affect changes in Beijing's household daily travel $CO_2$ emissions.

In previous studies of carbon emissions from the transport sector, researchers mainly used decomposition methods to investigate factors influencing energy consumption and emissions [47,48]. For instance, Li et al. found that older people, especially older women, are more heavily dependent on car use than younger people [49]. Timilsina et al. analysed the effects of changes in fuel mix, modal shift, economic growth, emission coefficients, and transportation energy intensity on the growth of the transport sector's $CO_2$ emissions in 20 Latin American and Caribbean countries [50]. Chung et al. investigated the influence of energy intensity, regional shift, energy-mix, and transportation activity effects on the energy consumption and efficiency of China's transport sector from 2003 to 2009 [51]. These studies studied the impact of different factors on the increased $CO_2$ emissions in the transport sector. However, few studies have examined the driving forces for household transport $CO_2$ emissions from the perspective of individual travel characteristic. Therefore, this study aims to fill this gap and develops a comprehensive picture of the driving forces behind changing $CO_2$ emissions, related to household daily travel, from a systemic point of view. Thus, taking Beijing as an example, this study first calculates the $CO_2$ emissions from household daily transportation from 2000 to 2012, and then constructs a structural decomposition model to examine the main factors that influence the changes in emissions by using LMDI.

The remainder of this paper is organised as follows: Section 2 introduces the methodology used in this paper. Section 3 analyzes the state of household daily travel $CO_2$ emissions in Beijing from 2000 to 2012. Section 4 gives the main decomposition results. Finally, conclusions and policy implications are provided.

## 2. Methodology

### 2.1. Estimation of $CO_2$ emissions

To improve the air quality and mitigate vehicle emissions in Beijing, we need to understand accurate emissions inventories and the changing trends of emissions emitted by residents in their daily travel. In general, two methods are used to calculate $CO_2$ emissions from the transport sector: the fuel-based method and the distance-based method [52]. In the fuel-based method, emissions are calculated by multiplying the fuel consumption by its $CO_2$ emission coefficient. This method is relatively authoritative, but has difficulties in identifying the fuel type and fuel consumption of different transportation modes. In addition, the transportation statistics in China mainly focus on operational transportation. Thus this method is not suitable to estimate household daily travel emissions. In the distance-based approach, emissions can be estimated by using distance based emission factors and transport activity data such as vehicle-kilometres or person-kilometres travelled by different vehicle types. Due to data limitations, this study uses an improved distance-based method to estimate household daily travel $CO_2$ emissions in Beijing. The methodology presented here has two advantages: on one hand, this approach is more flexible and convenient. While the data on fuel use are often unavailable, the activity data needed for this method can be collected by more than one organisation (*i.e.* National Bureau of Statistics of China, Beijing Municipal Bureau of Statistics, and Beijing Trans-