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Microsimulation of low carbon urban transport policies in Beijing

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ABSTRACT

This study uses microsimulation modelling to simulate the carbon emissions from daily travel in Beijing and evaluate the effects of key low carbon transport polices in Beijing in 2025. Four key low carbon transport polices are selected, including the public transport improvement policy, public bike policy, energy efficiency improvement policy, and electric vehicle development policy. We found that under the combined effects of public transport improvement, public bike development, energy efficiency improvement, and electric vehicle development, the carbon emission in daily travel can be reduced by 43% in Beijing, which amounts to 4.3 million tonnes of CO_2 per year. The public transport improvement and public bike development can be realized under the current technology status, and if these two policies are combined, the emission reduction is 24%, which is higher than the energy efficiency improvement scenario. Electric vehicle ownership in 2025 in Beijing will increase to 1.04 million under enhanced scenario, accounting for 18.4% of total vehicles. Compared with baseline scenario, under enhanced scenario not only consumers who want to purchase additional vehicles, but also consumers who want to replace existing vehicles are attracted to buy additional vehicles.

1. Introduction

Transport sector accounts for 23% of global carbon emissions, which is the second largest sector after electricity and heat generation (IEA, 2015a, 2015b). In China, the proportion of transport sector in total emissions is only 8%. However, it is predicted that China's transport carbon emissions will grow faster than industrial carbon emissions (IEA, 2015a, 2015b; Zhou et al., 2013). Fast growing urban transport demand is among the key driving forces of China's increasing transport emissions. For example, urbanization is predicted to keep increasing to reach 70% in 2030 (Net, 2015). China's car ownership will exceed the U.S. at 2023, and reach 490–580 million in 2050 (Huo and Wang, 2012).

China's cities have taken various policy actions to cope with the challenges brought by increasing urban transport demand. These polices include controlling the vehicle ownership and vehicle use intensity, promoting low carbon transport mode, and developing clean vehicles. A key research question is what the effects are of these policies on reducing urban transport carbon emissions. However, the answer to this question is not straightforward because the effects of these polices depend on citizens' behavioral response.

Recent studies have applied microsimulation model or agent-based model to take into account citizens' behavioral response in policy evaluation. The common nature of these two modelling methods is the large-scale simulation of micro-level units (Mueller and de Haan, 2009). Using this modelling technique, studies have analyzed the effect of subsidy polices on the penetration of clean or new energy vehicles (de Haan et al., 2009; Eppstein et al., 2012; Musti and Kockelman, 2011; Zhang et al., 2011), and the policy effects on vehicle carbon emissions in the city (Hatzopoulou et al., 2011). However, these studies are mainly for the developed countries, and similar studies for China is not too many.

The main purpose of this study is to quantitatively evaluate the effect of key low carbon transport polices on carbon emission reduction. Microsimulation is used to evaluate the policy effects in Beijing in 2025. Beijing is at the forefront of development in China's cities, and transport related challenges in Beijing are also likely to reoccur in other cities with their further development. Therefore the study of Beijing will provide valuable lessons for other cities. Four key low carbon transport polices are selected, including the public transport improvement policy, public bike policy, energy efficiency improvement policy, and electric vehicle development policy. These polices are the guiding policies at the national level (State Council, 2013, 2014; MHURD, 2012), and have large potential in low carbon urban transport development. Moreover, these policies have interactions, for example

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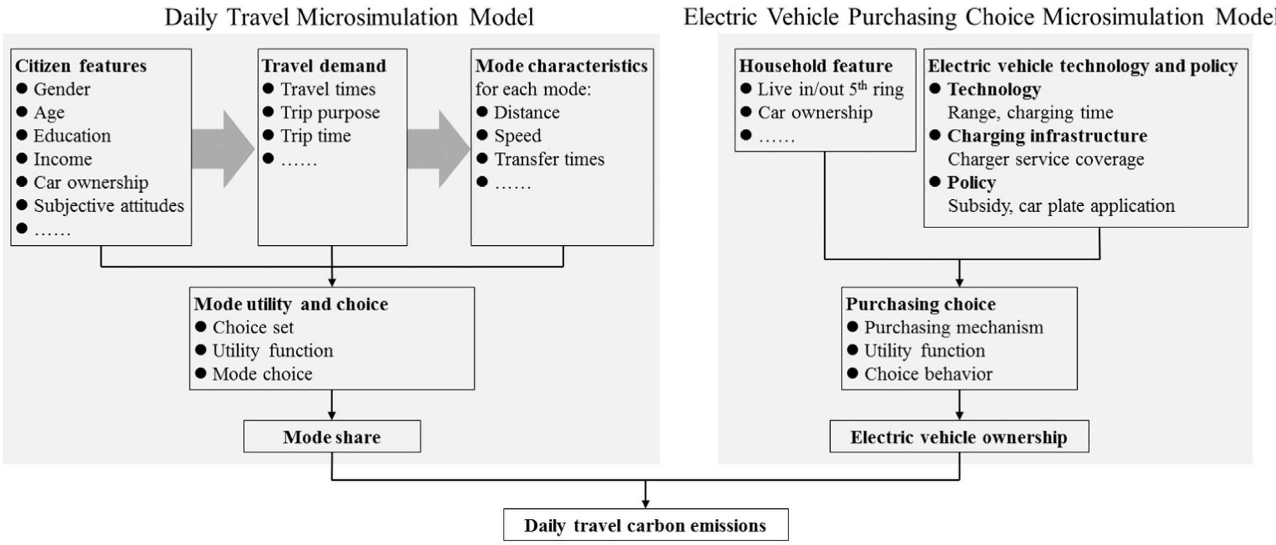

Fig. 1. Model structure.

public bikes facilitate citizens to connect with public transport. Therefore it is necessary to evaluate the policy effects under a comprehensive framework.

The main contribution of this study is that the microsimulation model is built on the concrete evidence of citizens' behavioral response, because these behavioral response are modeled using citizen survey data. Based on the behavioral evidence, our microsimulation model is able to simulate the behavioral change under a certain policy. Previous studies which have analyzed the low carbon development of the transport sector in China mainly focus on emission reduction resulting from technical improvement, but didn't pay much attention to emission reduction resulting from behavioral change (Zheng et al., 2015; Huo et al., 2012). Therefore, our study contributes to the existing studies on China's sustainable transport by simulating and estimating the emission reduction resulting from behavioral change under key policies.

The remainder of this paper is organized as follows. Section 2 describes the modelling methodology. Section 3 presents the simulation results of electric vehicle ownership. Section 4 presents the simulation results of daily travel carbon emissions and policy effects. Section 5 is conclusion.

2. Methodology

Microsimulation modelling is applied to simulate the carbon emissions from daily travel in Beijing. The Daily Travel Microsimulation Model (DTMM) is built to simulate the daily travel of Beijing citizens, and the output is the share of different transport modes in citizens' travel. In order to derive the carbon emissions from daily travel, another key factor is the proportion of electric vehicles in total private vehicles because the fast development of electric vehicles are expected to have a large influence on the emissions from private vehicles. Therefore, the Electric Vehicle Purchasing Choice Microsimulation Model (EVPCMM) is built to simulate the purchasing choice of electric vehicles by Beijing citizens, and the output is the share of electric vehicles in total private vehicles. Finally, the output from the two models are combined to derive the carbon emissions from daily travel in Beijing. Fig. 1 shows the model structure.

It is worth noting that the EVPCMM and the DTMM run separately and have different time scales. The EVPCMM runs on a year basis because the replacement of cars and the purchase decision of vehicles evolve with years. The DTMM simulates the daily travel carbon emissions on a weekday and a weekend, because the empirical data (Yang et al., 2016a) supporting the modelling is surveyed on a daily basis. The simulation of travel behavior in a longer time cycle requires travel data in a similar time cycle, which is hard to collect. The following section describes the model structure of EVPCMM first and then DTMM.

2.1. Electric vehicle purchasing choice microsimulation model

2.1.1. Model structure

The EVPCMM simulates the private electric vehicle ownership in Beijing from 2015 to 2025. The core part of the model is the vehicle purchase decision making by households, which is simulated according to the discrete choice model of Beijing citizens' electric vehicle purchasing choice (Yang et al., 2016b).

The simulating unit is households which are the units of vehicle purchasing choice generally. The time step is one year. The model simulates the replacement of existing cars and the purchase of additional cars (Fig. 2). If a car exceeds 12 years old,[1] the household needs to replace it. For households who want to replace existing cars or buy additional cars, if their needs cannot be satisfied by electric vehicles on sale, the household will buy a gasoline vehicle. Otherwise, their purchasing choice will be simulated by the discrete choice model in Yang et al. (2016a). However, because Beijing has restricted the increase of vehicles, the purchase of additional cars should not exceed the quota for electric cars and gasoline cars (Beijing Government, 2013). If the demand exceeds the quota, the quota is randomly allocated to the buyers, which is similar with the car plate lottery mechanism (Beijing Government, 2013).

2.1.1.1. Vehicle purchase choice. The vehicle purchase choice is the core part of the model, and is simulated by the discrete choice model of Beijing citizens' electric vehicle purchase choice (Yang et al., 2016b). The discrete choice model simulates the decision making procedure when consumers compare the characteristics of electric vehicles with a gasoline vehicle, and outputs the probability of choosing gasoline vehicles and electric vehicles. To transfer the probability into choosing result, a random sampling based on the probability is performed to determine the choice result. Therefore, the simulation is a random process in nature.

2.1.1.2. Parameter setting. The model needs to set parameters including population characteristics and car ownership. The base year is 2015. The population simulated is set to be 1% of Beijing.

[1] The average lifetime of cars in Beijing (Huo and Wang, 2012).