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Environmental benefits from ridesharing: A case of Beijing

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HIGHLIGHTS

- Findings from the big data of Didi ridesharing trips in Beijing are reported here.
- Ridesharing made substantial energy savings and air pollutant emission reductions.
- Ridesharing trips show very obvious regional and temporal characteristics.
- Ridesharing service mainly help meet the demand for mid- and long-length trips.
- Environmental benefits from ridesharing can be enhanced by the existing policies.

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ABSTRACT

Emerging ridesharing travel could be an effective way in China to reduce travel demand by cars, which can further seek to shift personal transportation choices from an owned asset to a service used on demand and lessen the traffic jam and emissions. Drawing on the raw observed ridesharing trip data provided by DiDi Chuxing company, this study evaluated the direct environmental benefits of ridesharing resulted from the travel mode shift and the indirect environmental benefits resulted from the attitude change towards car purchase behavior. The megacity Beijing is taken as the empirical context given its more serious situation of traffic congestion and difficulties for car purchase. Estimation results show that direct annual energy savings made by ridesharing are approximately 26.6 thousand tce, and annual emission reductions of CO_2 and NOx are approximately 46.2 thousand tons and 253.7 tons, respectively. Besides, using ridesharing service will lead to substantial energy savings and emission reductions from the long-term perspective attributing to the weakening willingness on purchasing new cars. Promoting EVs among ridesharing vehicles and switching to clean electricity generation as well as improving vehicle efficiency can further enhance the environmental benefits of ridesharing, with maximum effects amounting to 67% of energy savings and 57% of CO_2 emission reductions compared to 2016 level of the fuel-related energy consumption and emissions made by ridesharing.

1. Introduction

Transport energy consumption in China maintains an average annual growth of 11.14% in the past 10 years. And the resulting air pollutant emissions in the road transport sector is increasing year by year, mainly due to the rapid increase of the numbers of vehicles (at an average annual growth rate of up to 22%) [1] and the resulting heavy congestions. This further deteriorated the air quality, which in turn imposed unprecedented pressure on reducing air pollutants in the transport sector in China.

Many countermeasures have been implemented or planned in China for achieving sustainable road transport, such as promoting the public transport, applying TOD (Transit Oriented Development) mode, limiting the total number of vehicles by the license plate lottery, limiting the usage of vehicles by rotating driving privilege in weekday, and providing subsidies and privileges for EV (electric vehicle) purchase and usage. As it can be seen that, these measures are all designed and carried out by local

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government, i.e., government-dominant. In recent years, due to the difficult parking, insufficient taxies, and serious traffic congestion, the market-oriented ridesharing mode become increasingly popular among users in China, providing an alternative way to reach the sustainability in addition to the governmental efforts. On July 28, 2016, the Chinese Ministry of Transport took the lead in announcing the legitimacy of this sharing mode in the world. Ridesharing is thus recognized as a new travel mode in addition to traditional modes in China. The principle of ridesharing is quite simple that individuals gain the benefits of private vehicle use without the costs and responsibilities of ownership [2]. Unlike the traditional car-sharing mode that needs the vehicle stocks owned by the company, ridesharing promotes larger occupancy of the private vehicles and better utilization of the empty seats by encouraging the existing private car users to share their cars with travelers who have the same or close destination, thus save fuel consumption and travel costs per passenger, which can further mitigate the inner-city traffic, congestion, and environmental problems [3–8].

There is no doubt that ridesharing could be an effective way to reduce the travel demand by cars, and then the traffic jam and emissions. In light of this, many researchers have shed light on the social and environmental impacts of ridesharing. The most fruitful achievements come from UCTC (University of California Transportation Center) research team, who conducted very comprehensive analysis on the development of mobility-sharing modes [9] and the applications of car-sharing, ridesharing, ride-sourcing, and public bike-sharing [10]. However, most of the existing studies are mainly drawing on the survey data or the small-scale trip data instead of the raw observed order information.

Under such circumstance, we conducted a joint research with DiDi Chuxing, a Chinese transportation network company offering the largest peer-to-peer platform for private vehicles in China. By employing the raw big data on ridesharing trips which includes user and vehicle information provided by DiDi, we aim to answer three questions: (1) how the current ridesharing trips look like? (2) what is the environmental impacts of ridesharing (energy consumption and carbon dioxide (CO_2), primary PM2.5, sulfur dioxide (SO_2), and nitrogen oxide (NOx) emissions)? and (3) how to realize more environmental benefits for ridesharing travel? To this end, Beijing is taken as an empirical context in this study given its much more severe transport problems (e.g., vehicle purchasing constraints, plate number-based traffic rationing, insufficient public transport capacity, and parking difficulties). Based on the rich data, the spatial and temporal characteristics of ridesharing trips in Beijing is first explored and displayed. Building on the fuel lifecycle analysis and environmental input–output analysis, the comprehensive environmental impacts of ridesharing service on the whole road transport system are quantified with the support of a phone-based questionnaire survey conducted through the platform of DiDi. This survey was designed to capture the original travel mode if not choose ridesharing and the attitudes towards purchasing the cars in future if ridesharing is always available. On the basis of the accounted environmental impacts, the scenarios analysis is further implemented aiming to find effective ways to enlarge the environmental benefits of ridesharing travel.

The rest of the paper is organized as follows: The related literature review is briefly discussed in Section 2. The research framework and methods for calculating the energy consumption and emissions are presented in Section 3. Section 4 introduces the data and descriptive analysis of ridesharing trips. The environmental impacts of ridesharing travel and how to achieve more environmental benefits are interpreted in Section 5. Finally, conclusions and corresponding policy implications are discussed in Section 6.

2. Literature review

There are several previous studies arguing that the occurrence of ridesharing service might affect vehicle holdings and travel behavior, which may further act on the environment. For instance, Cervero and Tsai [11] estimated the extent to which ridesharing can reduce car ownership and traffic volume in San Francisco between mid-September and mid-October in 2002. The results show that, after using the ridesharing service, more than 60% of members would change their vehicular purchasing plan, but their mobility was enhanced and travel range of members would be enlarged around the city. Mishra and Clewlow [12,13] found that vehicle ownership of ridesharing members is significantly lower than that of people without a membership of ridesharing in the San Francisco area based on the subsample of the 2010–2012 California Household Travel Survey data. Furthermore, Shaheen et al. [14] believe that ridesharing service has the potential to impact the transportation sector by providing extra options to vehicle ownership in more geographic locations as well as increasing the interconnectivity between different travel modes, after interviewing 34 experts.

Some researchers paid direct attention to the environmental impacts including energy saving and emission reductions of ridesharing. For example, Jacobson and King [15] calculated the energy savings of ridesharing by using survey report data collected during 2005 and 2006 in National Health and Nutrition Examination Survey (NHANES). It is found that if 1% of vehicle owners choose to share their cars, the energy consumption could be reduced by 0.80–0.82 billion gallons of gasoline per year and the effect could reach 7.54–7.74 billion gallons per year when this ratio rises up to 10%. Another research conducted by Minett and Pearce [16] shows that ridesharing service has a positive influence on cities' transportation energy consumption with at least saving 1.7–3.5 million liters of gasoline per year and 200–400 L for each participant in San Francisco. This result is obtained based on three scenario comparison and the results of a survey with more than 700 valid questionnaires in San Francisco. Fagnant and Kockelman [6] developed an agent-based simulation model to evaluate the environmental benefits of carsharing services and conducted a case study in the context of Austin, Texas of the U.S. Their simulation results indicate that almost 11 conventional vehicles can be replaced by one ridesharing car. Though more than 10% of travel demand is stimulated by the ridesharing service, the overall impact is beneficial for the environment. Another example is Caulfield's research [17], which introduced COPERT4 model to evaluate the environmental benefits of ridesharing service by using the data of 2006 Census of Ireland. The analysis indicated that annually 12,674 tons of CO_2 emissions are saved by individuals' ridesharing. And a sizable annual saving in CO_2 emissions would be achieved, if respondents were to rideshare 3 or 4 times a week. Martin and Shaheen [18] evaluated the effect of ridesharing on greenhouse gas emissions by monitoring the lifestyle changes of ridesharing members with the support of a questionnaire survey. They surveyed 9635 ridesharing users registered in the North American's ridesharing service companies and 6281 final valid questionnaires were collected. Their results show that 27% decline of vehicle kilometers traveled (VKT) per year was observed.

As it can be seen that, the existing studies are more focused on the context of developed countries or cities. And majority of them did not apply raw trip data (only survey data or simulation data) and thus was not completely representative of the ridesharing market. What's more, they mainly considered the direct VMT related or fuel related impacts, in which the vehicle production related impacts caused by the change of vehicle purchasing behavior were not taken into account. To enrich the literature, this study aims to investigate the direct fuel-related and indirect industrial