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Impact of the built environment on the vehicle emission effects of road pricing policies: A simulation case study

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ABSTRACT

In order to develop a road pricing policy that is effective in reducing vehicle emissions, this paper explores the relationship between road pricing, the urban built environment, and vehicle emissions. Existing studies generally tend to choose a city or an entire region as the research object. For this reason, these kinds of studies can neither analyze the differences in the vehicle emission effects of road charging on regions with different built environment attributes, nor distinguish how different built environment attributes affect the vehicle emission effects of road user charging. To fill in the research gap, this paper focuses on the influences of road charging on the vehicle emissions of regions with different built environment characteristics. In order to achieve the above mentioned goal, this paper first applies a method which combines the land use and transport interaction model with a vehicle emission model to simulate the automobile emissions under different road pricing schemes. Then, using multiple regression analysis, this paper establishes the association between the built environment attributes and the vehicle emissions under different road charging levels. Additionally, using factor analysis and cluster analysis, this research further distinguishes the vehicle emission effects of road pricing based on attributes of the built environment. The results confirmed that road pricing affects vehicle emissions in different regions differently. More importantly, not every region will experience decreases in vehicle emissions after the implementation of a road charging policy. The presence of retail amenities, good street design, and public transportation, the more significant the effect of road pricing in reducing vehicle emissions. Furthermore, a healthy jobs-housing balance is also conducive to the decline of regional automobile emissions as well.

1. Introduction

Due to urban development and growing traffic demand, more and more cities around the world are facing serious traffic congestion problems (Rizzi and De La Maza, 2017), which can lead to significant reductions in quality of life and in the quality of urban environments. Indeed, motor vehicle pollution, as a major source of greenhouse gas emissions (GHGs), has become an urgent problem throughout the world and also is a serious obstacle to the sustainable development of cities (Coria et al., 2015). In response to growth in the use of motor vehicles, traffic congestion, and the resultant environmental degradation, scholars have proposed different technologies and approaches, including reducing traffic demand (by changing

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the spatial structure of urban land use), decreasing automobile use through vehicle use restriction policies (such as fuel taxes, road pricing, circulation bans by license plate or by engine size), development of green transportation options (e.g. public transport, walking, and bicycling), and the improvement in the road network and fuel efficiency (May et al., 2006). Among these technologies and methods, road charging has attracted extensive research as a travel demand management measure to control private car trips (Zhong et al., 2017).

The primary aim of road charging is to curb the excessive use of private vehicles. The introduction of a road pricing policy has two major effects. First, residents' short-term travel behavior will change, affecting regional vehicle emissions. Second, in the long-term, with the increase of the effect of road pricing on land use, a road charging policy will impact the (re)location choices of firms or households and once again influence residents' travel patterns and motor vehicle exhaust emissions in the region (Gibson and Carnovale, 2015; Tillema et al., 2010; Zhong et al., 2015). These road charging effects on vehicle emissions have gradually become the focus of scholars. Indeed, the existing literature has analyzed the vehicle emissions effects of road pricing at the aggregate level (metropolitan or region scale) (Guzman et al., 2016). Such research efforts, however, could not distinguish how different elements of the built environment may affect the impact of road pricing on vehicle emissions.

Many studies have demonstrated that the built environment or neighborhood type[1] has a significant effect on regional vehicle emissions (Aguiléra and Voisin, 2014; Hachem, 2016; Ma et al., 2015; Wang et al., 2017; Waygood et al., 2014). This is because the travel behavior of residents has a direct impact on automobile travel and emissions and is obviously affected differently by attributes of the local built environment. However, to the best of our knowledge, there is little research regarding the impact of the built environment on the effect of road pricing policies as they relate to and influence automobile emissions. It is important to understand the relationship between road pricing and emissions, as some cities, such as London, Stockholm, Milan, Beijing, and Shanghai, are using or intend to use road pricing policies to reduce vehicle emissions in their respective regions. However, after a series of analysis, this paper found that road pricing affects vehicle exhaust emissions in different regions[2] differently, i.e. not every region will experience decreases in vehicle emissions after the implementation of a road charging policy. This is due to the close associations between the effects of road pricing on vehicle emissions and the built environment of the region. In fact, the net effect of implementing road pricing strategies in some cases is to change the built environment attributes of the region, and finally lead to different vehicle emissions changes in different regions.

To fill in the research gap, this paper focuses on the influences of road charging on the vehicle emissions of regions with different built environment characteristics, so as to develop a road pricing policy more conducive to reducing vehicle emissions and reducing negative impacts to the environment. In order to achieve the above mentioned goals, this paper applies an integrated approach which combines the land use and transport interaction (LUTI) model, a vehicle emission model, multiple regression analysis, factor analysis, and cluster analysis. The relationships between these models and methods are provided in Fig. 1. These models and methods are related to each other, and the previous model or method will serve as the basis for the next model or method. Specifically, the first step was to use the LUTI model TRANUS to simulate the impact of road charging on urban land use and transportation systems (de la Barra, 1989; de la Barra et al., 1984). The predicted link-based traffic operation data derived from TRANUS was then inputted to the vehicle emission model (MOBILE 6) to obtain the vehicle emission conditions under different road pricing schemes (U.S. EPA, 2003). On this basis, the relationship between the built environment characteristics and the vehicle emissions under different road user charges schemes is established using multiple regression analysis. The authors finally used factor analysis and cluster analysis to quantitatively classify TAZs, so as to further distinguish the vehicle emission effects of road pricing based on the built environment attributes.

The remainder of this paper is structured into five parts. The second section analyzes and summarizes the existing research results. The third section describes the study area and the data source for the analysis. The fourth section presents the methodology. The fifth section discusses the impact of the built environment on the vehicle emission effect of road tolling policies. The conclusions are presented in the final section.

2. Review and summary of existing research

The authors argue that the impacts of road charges on vehicle emissions are not only related to road charging scheme (different toll schemes produce different travel patterns and vehicle emissions), but also related to the region's built environment. This is due to the fact that, by affecting the spatial distribution of various activities, the built environment elements may change the accessibility of the region, and thus (in)directly influence an individual's daily travel patterns (such as travel frequency, mode, time, and route), which ultimately affects the vehicle emissions of the region. Moreover, in the long-term, the combined accessibility effects of road pricing and the urban built environment will influence (re)location choices of residents and enterprises, and thus affect long-term travel patterns and vehicle emissions. Therefore, this paper summarizes the existing literature by examining (1) the relationship between the built environment, travel behavior, and vehicle emissions and (2) the influence of road pricing on travel behavior and vehicle emissions.

- Relationship between the built environment, travel behavior, and vehicle emissions

[1] The built environment or neighborhood type refers to density, diversity, street design, transit accessibility, and infrastructure accessibility.

[2] The traffic analysis zone (TAZ) was selected as the basic analysis unit in this study. Therefore, the regions in this paper refers to different TAZs.