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The spatial distribution of commuting CO_2 emissions and the influential factors: A case study in Xi'an, China

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Abstract

As the transport sector is a major source of greenhouse gas emissions, the effect of urbanization on transport CO_2 emissions in developing cities has become a key issue under global climate change. Examining the case of Xi'an, this paper aims to explore the spatial distribution of commuting CO_2 emissions and influencing factors in the new, urban industry zones and city centers considering Xi'an's transition from a monocentric to a polycentric city in the process of urbanization. Based on household survey data from 1501 respondents, there are obvious differences in commuting CO_2 emissions between new industry zones and city centers: City centers feature lower household emissions of 2.86 kg CO_2 per week, whereas new industry zones generally have higher household emissions of 3.20 kg CO_2 per week. Contrary to previous research results, not all new industry zones have high levels of CO_2 emissions; with the rapid development of various types of industries, even a minimum level of household emissions of 2.53 kg CO_2 per week is possible. The uneven distribution of commuting CO_2 emissions is not uniformly affected by spatial parameters such as job−housing balance, residential density, employment density, and land use diversity. Optimum combination of the spatial parameters and travel pattern along with corresponding transport infrastructure construction may be an appropriate path to reduction and control of emissions from commuting.

Keywords: Sustainable urbanization; Spatial distribution; Factors; Commuting CO_2 emissions; Xi'an

1. Introduction

Many recent researches have noted that urbanization has impacts on carbon emissions (Cole and Neumayer, 2004; Jones, 1991; Parikh and Shukla, 1995; York, 2007; Dhakal, 2010; Martínez-Zarzoso and Maruotti, 2011). The IPCC (2007) reported that more than 75% of CO_2 emissions are emitted from cities, and this statistic will increase exponentially in the foreseeable future with projections of an increase to 83% by 2030 (IEA, 2008).

As cities are the center for economic development and associated with continuous population growth as well as ever-increasing urbanization rates (Banister, 2005), carbon emissions have increased rapidly especially in developing countries featuring booming economic development and unprecedented urbanization (WB, 2005; Dhakal, 2009). China, one of the important developing countries in which carbon emission reductions are necessary, experienced an increase in its urbanization rate of 36.85% in the last 36 years from 17.92% in 1978 (NBSC, 2014).

With the rapid urbanization resulting from China's booming economic development, motorization developed rapidly, fostering a significant increase in vehicle kilometers traveled (VKT) and greenhouse gas (GHG) emissions (Zhao et al., 2011). The effect of urban expansion on transportation

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in growing megacities has become a key issue in the context of global climate change, as motorized mobility is a major source of domestic GHG emissions (Zhao, 2010). The transport sector contributes to 27% of energy-related CO_2 emissions (IEA, 2012) and is responsible for approximately 13% of GHG emissions. In developing countries, it is the fastest growing sector in terms of GHG emissions, driven mainly by rapid motorization. If no aggressive and sustained mitigation policies are implemented, CO_2 emissions from transport sector are expected to almost double by 2050 (IPCC, 2014). Moreover, in the context of rising motorization, the environmental effects of transport tend to be more detrimental (Zhao, 2010). Estimates from the United Nations in 2011 suggested that developing countries' share in global ownership of cars will rise from 25% in 1995 to 48% in 2050. During the period of 2001–2005, cars accounted for 7% of domestic CO_2 emissions; this percentage is forecasted to increase due to the rapid process of motorization (WB, 2007).

The process of urbanization has changed the spatial distribution of occupations, industries, and land use, which means that the larger the urban scale, the greater the reorganization of industries and the redistribution of residences and employment (Zhao, 2010; Zhao et al., 2011). Along with these changes, associated activities caused problems, such as backward infrastructure construction, uneven land development, a lower mix of land use (Deng and Huang, 2004; Pan et al., 2008), a higher use of motor vehicles (Cervero and Kockelman, 1997), and the consequent higher carbon emissions (King, 2007; Glaeser and Kahn, 2010).

Researchers have claimed that there is spatial difference in household transport carbon emissions between different regions in a city. In Adelaide, Australia, the families located in the outer suburbs generated more carbon emissions than those who lived near the center of the city (Troy et al., 2003). Similarly, in the capital area of Korea, the highest transport carbon emissions are from the families living in the urban fringe (Ko et al., 2011). Not all the results were consistent, however. In France, compared with the families in rural and suburb areas, those living in the city center and near the city generated more transport carbon emissions (Nicolas and David, 2009). However, in comparing transport energy consumption and transport carbon emissions between the inner and the outer suburbs in the five largest cities in Australia, the results showed that the level of transport energy consumption and transport carbon emissions of the two areas in each city are similar (Moriarty, 2002). Researches on the relationship between household transport carbon emissions and household locations in the city have suggested that household locations have impacts on the transport carbon emissions, but the impacts are not consistent.

In studies on urban spaces, the results showed that especially for transport energy consumption, there is a strong correlation between the urban form and energy consumption, and thus carbon emissions. There are many measurements for urban form spatial parameters such as job–housing balance, residential density, employment density and land use diversity. It is almost a foregone conclusion that when the job–housing balance is uneven, the longer the residential commuting distance and the greater travel demand will be (Cervero, 1989, 1991; Cervero and Duncan, 2006). A city of higher residential density is most likely a compact city, which may be a preferable city development pattern for decreasing transport CO_2 emissions by shortening commuting distance and commuting time (Cervero and Kockelman, 1997; Zheng et al., 2010). The higher employment density is usually related to shorter commuting distance, thus allowing for low-carbon travel modes, such as walking and cycling. The higher land use diversity (Zhao et al., 2007) is usually associated with the greater probability of short distance travel, which may help in reducing the use of high-carbon vehicles such as cars.

Realignment in the arrangement of urban spatial parameters could reduce GHG emissions because urban form influences the volume of GHG emissions generated by households (Grazi et al., 2008; Hankey and Marshall, 2010). This influence is felt in part through the way that compact urban forms are associated with lower transport energy use and carbon emissions (Wang et al., 2013; Hankey and Marshall, 2010). There is general acknowledgement among researchers that land use change can influence the use of certain transportation modes (Zhang, 2004; Zahabi et al., 2012), and that the reduction of travel and the modal split are relevant to GHG emissions control (Mishalani et al., 2014a, 2014b).

In fast urbanizing countries such as China, urban forms evolve rapidly as they develop rings of new suburbs and new industry zones. The question of urbanization with relation to travel and transport emissions, and particularly, the relative impact of spatial parameters on household transport carbon emissions, needs further empirical research in different spatial context.

Many monocentric cities, such as Xi'an, the case city in this paper, are gradually developing into polycentric cities as urbanization increases, with the formation of new districts to share functions and deflect pressure from the city center. Meanwhile, urbanization has brought about uneven development areas in a city, with concomitant uneven transport carbon emissions according to the above review of the relationship between the household locations and transport carbon emissions. Given the scale of the task of addressing global warming, no means of reducing CO_2 emissions (and by implication, GHG emissions) should be overlooked. Considering the uneven development and carbon emissions caused by the formation of new districts in the process of urbanization for monocentric cities, Xi'an is used as a case study to answer the following three questions:

1) How are transport carbon emissions distributed in urban spaces with the formation of new districts in the process of urbanization for monocentric cities?
2) What is the cause of this distribution?
3) What should we do to decrease and control the transport carbon emissions in new urban spaces?