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# Modeling vehicle emissions in different types of Chinese cities: Importance of vehicle fleet and local features

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ABSTRACT

We propose a method to simulate vehicle emissions in Chinese cities of different sizes and development stages. Twenty two cities are examined in this study. The target year is 2007. Among the cities, the vehicle emission factors were remarkably different (the highest is 50–90% higher than the lowest) owing to their distinct local features and vehicle technology levels, and the major contributors to total vehicle emissions were also different. A substantial increase in vehicle emissions is foreseeable unless stronger measures are implemented because the benefit of current policies can be quickly offset by the vehicle growth. Major efforts should be focused on all cities, especially developing cities where the requirements are lenient. This work aims a better understanding of vehicle emissions in all types of Chinese cities. The proposed method could benefit national emission inventory studies in improving accuracy and help in designing national and local policies for vehicle emission control.



## 1. Introduction

China's vehicle population has increased explosively during the past two decades, with an accelerated growth rate. In particular, China exceeded the U.S. in vehicle sales in 2009, becoming the largest vehicle market in the world. As a result, vehicle emissions have become a growing environmental concern of mega-cities since the 1990s in China (He et al., 2002; Chan and Yao, 2008). In the meantime, as the number of vehicles has also increased dramatically in medium and small cities, the concern over vehicle pollution is not confined to mega-cities any more. Vehicle emissions are becoming a major environmental issue in cities of all sizes in China.

For a long time, mega-cities (such as Beijing, Shanghai, and Guangzhou) have been the focus of vehicle emission studies and control strategies (Fu et al., 2001; Hao et al., 2000; Wang et al., 2008a, 2005, 2010; Huo et al., 2009). Although there have been several studies that provided estimates of vehicle emissions for those mega-cities, few studies focused on other cities. Because of lack of necessary data at city level, vehicle emissions were usually estimated as provincial totals in national or regional emission inventories, then downscaled to cities or grids by socioeconomic or population data (Cai and Xie, 2007; Zhang et al., 2009). A comprehensive picture of vehicle emissions covering all sizes of cities in China is absent.

Information on vehicle emissions at city level is not only of great importance for improving the accuracy of national vehicle emission inventories, but also important for vehicle emission control policies. In a rapidly developing and urbanizing country like China, city numbers, urban areas, and vehicle population will continuously increase in the future. Given the fact that the vehicle fleet turnover is a slow process (e.g., 15 years for cars), policymakers have to accelerate the progress of emission control policies to offset this large potential increase in vehicle emissions. A better understanding of vehicle emissions at city level would help policymakers to make efficient and effective policies at both national and local levels.

This work first develops a common methodology of estimating vehicle emissions of all types of Chinese cities. The characteristics

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of the vehicle fleets in Chinese cities differ significantly, for instance, passenger cars occupy a larger proportion of the fleet in mega-cities than in medium and small cities, southern cities usually have more motorcycles than northern cities, and northern industrialized cities have more heavy-duty trucks for transporting coal, materials, and other industrial items. Therefore, it is important to select cities that can cover the different characteristics of the vehicle fleets as much as possible. We selected 22 Chinese cities as cases for this work. Fig. 1 illustrates the locations and socioeconomic information of the 22 cities in 2007 (State Statistical Bureau of China, 2008). As shown, the selected cities are located all over China and cover all city sizes, including all four municipalities (Beijing, Shanghai, Tianjin, and Chongqing), seven provincial capitals, nine mid-size cities, and two small-size cities (or perhaps more precisely, towns). Vehicle emissions from those cities are then estimated and analyzed, to explore the vehicle emission patterns of cities of various sizes and development stages in China. The 22 cities are selected from both rapidly developing regions (Beijing and Tianjian in the Jing-Jin-Tang region, Shanghai and Ningbo in the Yangtze River Delta region, and Zhuhai, Shenzhen, Foshan and Dongguan in the Pearl River Delta region) and western regions where economic development is relatively slow. In this study, we estimated vehicle emissions of carbon monoxide (CO), volatile organic compounds (VOCs), nitrogen oxide ($NO_x$), particulate matter with diameters of 10 μm or less ($PM_{10}$), and carbon dioxide ($CO_2$) in each city in 2007, based on city-specific analysis of vehicle types, driving patterns, technology distribution etc.

## 2. Methodology and data

For each city, the total amount of pollutant $j$ emitted from vehicles is calculated using the following equation:

$$E_j = \sum_i (VP_i \times EF_{i,j} \times VKT_i) \quad (1)$$

where $j$ represents pollutant type (CO, VOCs, $NO_x$, $PM_{10}$, and $CO_2$); $E_j$ is the amount of emissions of pollutant $j$; $i$ represents vehicle type (in this study, vehicles are classified into five categories, light-duty passenger vehicles [LDVs], light-duty trucks [LDTs], heavy-duty passenger vehicles [HDVs], heavy-duty trucks [HDTs], and motorcycles [MCs]); $VP_i$ represents the vehicle population of vehicle $i$; $EF_{i,j}$ is the emission factor of pollutant $j$ for vehicle $i$; and $VKT_i$ is vehicle kilometers traveled (VKT) of vehicle $i$ in 2007.

### 2.1. Vehicle population by type

China's transportation statistics contain vehicle population data for most cities, which are directly adopted in this study. As for the cities whose vehicle populations are not reported by China's statistics – there are three of them: Zitong, Jiutai, and Urumqi – we estimated their vehicle population by using the Gompertz curve, which relates vehicle ownership growth to per capita gross domestic production (GDP) growth (Wang et al., 2006). For each of the three cities, a Gompertz curve is established based on the socioeconomic information of its province (State Statistical Bureau of China, 2002–2009), and then it is used to calculate the city's vehicle population using urban socioeconomic information. For the cities that don't have data on vehicle population by type in statistics, the shares of each vehicle type of total vehicle

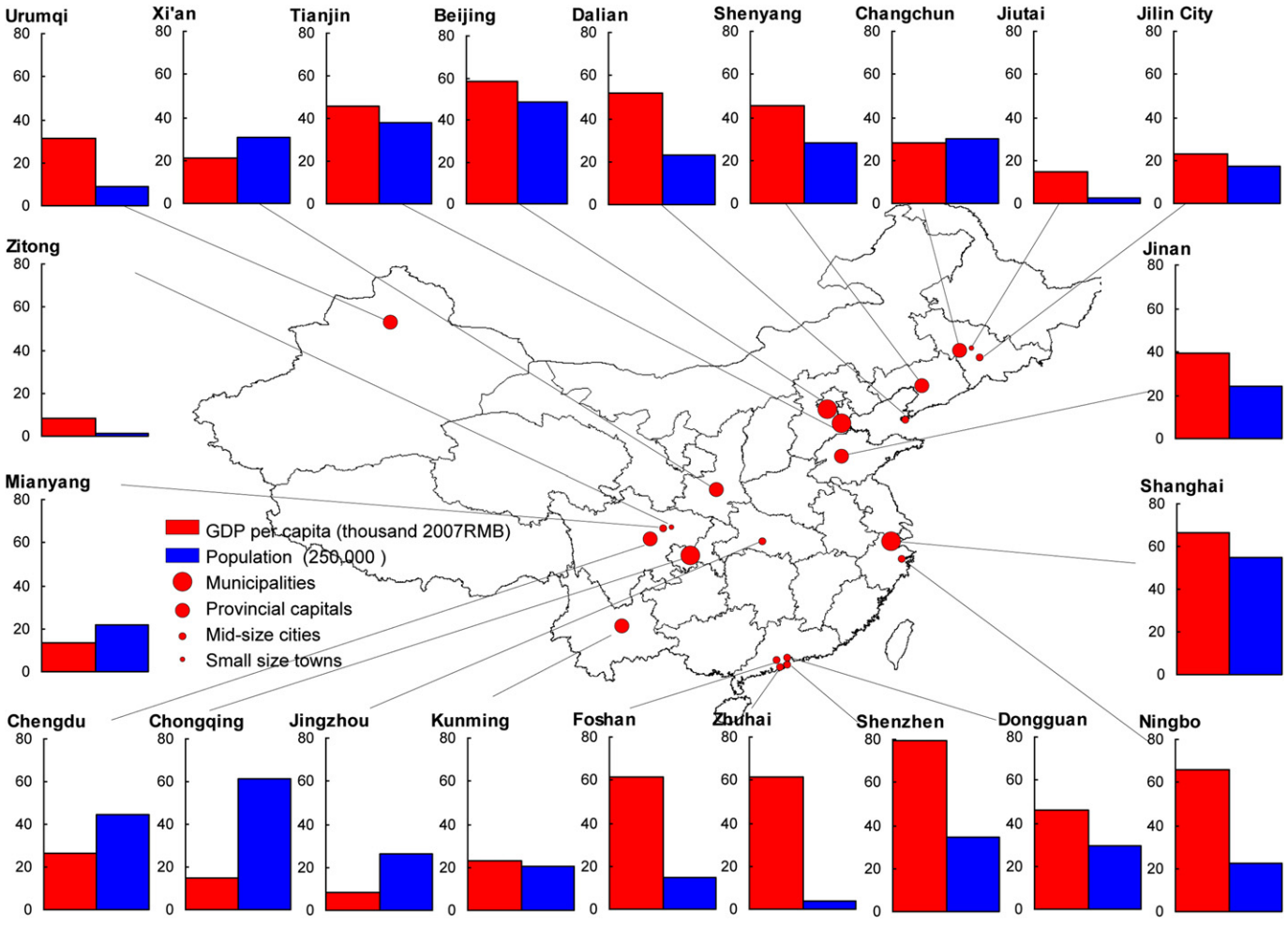


**Fig. 1.** Location and socioeconomic information of the 22 selected Chinese cities in 2007.