

Urban Transport Infrastructure and Air Quality Characteristics: a Comparative Analysis of China and India

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Abstract

India and China are the most populous nations in the world. Most population forecasts agree that the three largest cities in both countries will be among the twenty most populous cities in the world. Measurements of ambient air quality and transportation capacity indicate that these are already among the most congested and polluted cities of the world. Cities in both countries continue to attract migrants from rural areas. Thus, it is vital that policy makers in both countries study ways in which the problems that plague these cities are addressed in an integrated manner. In this paper we use analysis of variance (ANOVA) and principal component factor analysis (PCA) to understand the dimensions of the differences and similarities within and across countries with respect to transport infrastructure, air quality and land use features. The results indicate that both China's and India's urban transport infrastructure display geographical variations, particularly between cities on the coast and inland. Such variations result, in part, from the financing structure of transportation infrastructure. Pollutants tend to be associated with urban transport in both Chinese and Indian cities. Growth in transportation infrastructure almost inevitably places demands on land and air pollution from urban transportation sources becomes of increasing concern. Therefore, integrated transportation, land use and environmental planning of cities in India and China is vital to sustainable growth.

INTRODUCTION

China and India are the world's most populous with populations both in excess of one billion. China is the fourth largest country in terms of area – nearly three times that of India (the seventh largest area). However, the population densities in both countries are roughly the same (and very high) as most of the Chinese population lives on a little more than 30% of the land area. Both countries face rapid land use change on the urban peripheries. Zhou and Ma (1) note that a survey using satellite images shows that urbanized areas in the 31 largest cities in China expanded by 50-200% between 1986 and 1996. In 2001 the urban population in India was 28% of the total population with 35 cities having a population over a million as compared to 23 cities with population over a million in 1991 (2). The total number of vehicles in India increased 11 times during the period between 1970 and 1990, approaching 21 million vehicles. The number of registered vehicles has also grown from about 37 million in 1997 to an estimated vehicle fleet of over 50 million vehicles in 2001 (3). In the past ten years, the total number of vehicles in China has tripled, and the number of motorcycles nationwide has increased more than five fold (2). The increasing gap between transportation demand and supply in both countries has caused increasingly congested traffic conditions. For instance, in China's megacities (i.e., cities with 1 million population and up) per capita road space averaged only 6.6 square meters (4). Travel speeds were less than 20 kilometers per hour.

Poor transport infrastructure in contrast to rapid motorization and urban growth, has increasingly offset advances in pollution control from stationary sources, causing poor air quality. Particulate pollution is severe in both Chinese and Indian cities. UNESCAP/ADB (5) named Delhi as the most polluted city in the world in terms of suspended particulate matter. According to the World Health Organization in 1998, seven of the ten most polluted (with respect to air quality) cities in the world were in China (6). While air quality has improved in the national capitals of Beijing and New Delhi, it remains poor by international standards. Further, an estimated 30% of the primary fine particulate (PM10) emissions are from transportation sources (7). Thus, urbanization and motorization are creating a complex mix of problems affecting, ultimately, the environment.

COMPARATIVE STUDIES OF CHINA AND INDIA

The earliest studies on the economic and political differences between India and China (8) suggest that both countries were very similar in 1956 – both countries were primarily agricultural economies with over 80% of their population living in rural areas. Another study (9) also notes that between the late 1800s and the early 1950s both countries had experienced near stagnation with very low annual growth rates. Both countries have since then followed a centralized planning model for their economy though the implementation of their models, especially in terms of the political structure of its implementation, has differed considerably. In a paper written in 1972, Murphey (10) notes that, in both countries the impact of urbanization had been felt in every rural area and that there was a growing urban-rural tension. Even thirty years ago, the author suggests that, most Indian and Chinese cities lacked infrastructure with chronic unemployment and under-employment. Desai and Gurley (11) suggest that while China's social development was ahead of India this may be a function of history rather than the lack of economic or political will on the part of the Indians. Both countries implemented economic reforms that continued the opening up of their economies in the 1990s. A more recent paper by Bhalla (12) notes that China's reforms were an extension of the economic changes that began in 1979 involving further liberalization. However, he notes, India's reforms were a break with its

socialist past. Furthermore, India's reforms have not included its rural sector and have been hindered by political instability. Most researchers comparing the countries have focused on the social and political economies of the two countries and do not address the effects on cities, their growth and infrastructure. In this paper we compare the two countries at national and provincial/state levels with respect to transport infrastructure, land use, and air quality characteristics.

DATA AND METHODOLOGY

This study has assembled a database that includes data describing various characteristics like population and area, transport infrastructure (road length, public transport) and air quality (annual ambient average pollutant concentrations) characteristics of about seventy cities in China and eight-seven in India (See Figure 1) from various sources. These include for India – the Central Pollution Control Board, RITES, India, the World Bank, the National Institute for Urban Affairs and State Transportation Boards. For China, City-level data are compiled from the China urban transportation center (CUTC) affiliated with the Ministry of Construction (MOC) and the provincial level data are extracted from the provincial and transportation yearbooks. China's air quality data were extracted from the environmental yearbook for the 1998 air concentrations. The analytical tools include basic descriptive statistics, analysis of variance (ANOVA) and multivariate analysis using principal component factor analysis (PCA) to understand the dimensions of the differences and similarities within and across countries. We have also used land use and transport infrastructure data at the province (China) and state level (India) to conduct a comparison in order to confirm the trends in similarities as well as differences at different scales.

[Insert FIGURE 1]

Data availability is a major issue in developing countries like China and India. Most of the data used in this study come from published reports and statistical yearbooks. The quality of the data remains in question. Even between the two countries there are major differences in data availability and quality. China official statistics bureau collects and publishes data by city, province, and sector every year, and is a central source for data. India does not have a similar organized central source collecting transportation and land use data within cities and therefore data are scattered and have to be assembled from various sources. Due to the difficulty in getting compatible datasets for the two countries, our analyses can only be a first step towards a comparison of land use, air quality and transportation characteristics at the provincial/state, and city levels.

TRANSPORT INFRASTRUCTURE IN CHINA AND INDIA

India has witnessed a gradual transformation from rail-dominated transport to road-dominated one in the past few decades (13). The share of railways decreased from 36.9% of total passenger kilometers (PKM) in 1980-81 to 16.4% in 1993-94. Freight transport by railways dropped from 61.9% to 42.3% during the same period. At the same time, road transport grew tremendously. India's road network in 1996 totaled over 3.3 million kilometers, of which 57.7 thousand kilometers were national highways (14). National highways constituted only 2% of the total road network but carried 40% of the total road traffic. This huge growth in road transport was attributed to a rapid growth in the population of vehicles (13). China experienced a similar trend in mode shares. In the early 1950s railways were the dominant means for transporting passengers (84% of total PKM) and goods (71% of total freight ton kilometers, TKM). By 1999,

the percentage of the total PKM by road increased to 55.3% while railways dropped to 36.1%. Freight transport by railways declined to 31% in 1999 and waterways carried 53% of the freight transport (15). At the end of 1999, China's total road length reached 1.35 million kilometers and the road density was 14.1 kilometers per hundred square kilometers, a 50% increase since 1978. However, China is far ahead of India in terms of passenger and ton km transported by road as demonstrated in Table 1. China's road PKM almost doubled and TKM was six times that of India.

[Insert TABLE 1]

Transport infrastructure is not equally distributed in both countries, even across cities. The disparity is especially evident between coastal and interior locations. In China, the total road length in 1999 in the east, central, and west regions were almost identical but the road densities with respect to area differed substantially (Table 2). That is, road length density in East China was more than twice as that of Central China and almost five times higher than the western region. A coastal effect on road length on the state/provincial level is seen significant for India but not China (Table 3). The ANOVA results in Table 3 indicate a statistically significant variation between the coastal and interior states in India at the 0.1 significance level while no significant difference is found between the coastal and interior China ($p=0.4$). However, as Table 4 shows China's city level transport infrastructure displays large variability by region. Coastal cities not only have much higher road length and larger public transportation and taxi fleets but also differences are statistically significant in terms of road length ($p=0.01$) and the number of taxis ($p=0.04$). Such regional variations are, in part, a reflection of regionally divergent economic conditions in both countries. Sachs *et al.* find increasingly a coastal-interior and urban-rural divide in the economy amongst Indian states (16). They attribute this lack of convergence in India to large geographical differences in policies of the national and state governments. Similar studies in China also observe that geographical location is one of the many factors that account for significant regional disparities in China, noting a coastal versus non-coastal gap in transportation infrastructure across provinces (17; 18).

[Insert TABLES 2&3]

Despite the remarkable growth in India's road transport, there has not been equivalent investment in road infrastructure to keep up with the drastic growth of road vehicles and road usage (13). In India, the road sector has traditionally relied almost exclusively on funds provided through the government's budgetary process (14). However, the level of financial support for transport infrastructure from the government has been reduced steadily in the past few decades. As a result, the share of the road sector in terms of outlay has been constantly declining and budgetary support may not be adequate for road infrastructure in the country (19). *India Infrastructure Report 2003* notes that "for the first time emphasis is being laid upon the continuous maintenance of highways and private sector participation is being encouraged in financing construction of roads which includes cost of maintaining roads over the concession period or a predetermined period given in the concession" (20).

China is ahead of India with respect to privatizing transport infrastructure finance. Historically the Chinese central government has financed transport infrastructure and owned all of the revenues. Since the 1978 economic reforms, China has gradually decentralized its fiscal system and fiscal management. The share of budgetary investment (i.e., state budgetary appropriation) decreased from 78% in 1977 to 9% in 1992 and the difference in share was picked up by extra-budgetary investment (i.e., amount invested by entities other than the central government). This extra-budgetary investment increased from 22% in 1977 to 91% in 1992 (21).

Beginning in 1985, the government adopted the “beneficiary-pay” concept and tailored it to suit its financing system for transport infrastructure. Hayashi *et al.* (21) also note other features of China’s transport infrastructure financial system including a earmarked tax/road maintenance fee for inter-city road finance and the land market revenue for intra-city road infrastructure. Because of the beneficiary-pay system, China has seen tremendous improvement in road infrastructure and road transport in the past two decades or so.

CHARACTERIZATION OF URBAN TRANSPORT AND AIR QUALITY IN CHINESE AND INDIAN CITIES

In our dataset, the variables include

population density

transport infrastructure (*road length, number of public transport, and number of taxis*)

ambient concentrations (1998 annual average) (three major pollutants: *total suspended particles – TSP, sulfur dioxide – SO₂, and nitrogen oxides – NO_x*)

As shown in Table 4, the average per capita road length (in kilometers) of Indian megacities (i.e., cities with over one million population) is almost four times greater than other Indian cities. Average per capita road length is about the same in Chinese megacities as in other Chinese cities. However, air pollution has quite different pictures in the two countries. In India, the pollutants’ concentrations in megacities are at about the same level as in the less populous cities while Chinese megacities are more polluted than other Chinese cities, having almost doubled SO₂ and NO_x concentrations.

[Insert TABLE 4]

We computed the two-tailed Pearson correlation matrices of these variables for Chinese and Indian cities separately (Table 5). In the China data *population density* are found to be significantly and positively correlated with transport infrastructure parameters, i.e., road length, and public transport and taxi fleet. So are the transport infrastructure parameters among themselves. Another important finding in the China data is the appearance of strong connection between NO_x concentration and road length, public transport and taxi fleet, i.e., transport infrastructure parameters (all at the 0.01 significance level). That is consistent with recent studies that indicate that in China NO_x increasingly originates from urban sources (22, 23). The significant correlations between dummy variable *coastal* and *road length* and *TSP* indicate again the coastal effects on urban transport infrastructure and urban source pollution.

The Indian cities have quite different scenarios. No statistical evidence connects population density with transport infrastructure characteristics. While the concentrations of the three pollutants are coherent (significant at the 0.01 level) there is no correspondence between pollutants and urban transport in India cities. Although research has indicated vehicular pollution is a major contributing source (24), we suspect that annual average pollutant concentration is not an adequate correspondent to the drastic meteorological conditions in India. Nonetheless, the correlation matrix does imply a coastal effect on TSP and SO₂ pollutant concentrations.

[Insert TABLE 5]

Finally, we identify the key urban features of Chinese and Indian cities together using these variables. There were a total of fifty-seven valid cases of cities (i.e., without missing data), forty-seven Chinese cities and ten Indian cities. Principal component analysis (PCA) was used and the resulting factors are shown in Figure 2. Our PCA result confirms that population density

is a key factor characterizing both Chinese and Indian urban land use and transport scenarios. The other two factors are related to urban transport infrastructure and urban air quality.

[Insert FIGURE 2]

POLICY RELATED CONCLUSIONS

In comparing transport infrastructure features between China and India we find that, while both countries have improved dramatically in transport infrastructure, there are huge differences between the countries in terms of road passenger kilometers traveled and goods transported (in tons kilometers). In both countries, there are significant differences in transport infrastructure between the coastal and inland cities. This may be due to the imbalanced economic growth across regions and the financing structure of transport infrastructure. Coastal regions, in general, have the advantage of attracting foreign enterprises. Thus regional and national planning agencies should address these differences in ability to attract foreign investments.

We also find that the major pollutants like TSP, SO₂, and NO_x are associated with urban transport. As air pollution increasingly originates from urban sources such as on-road vehicle exhaust, there is an increasing need to establish a transportation compliance framework with air quality standards so that transportation investments do not worsen the environment. Thus planning agencies must establish a formal coordinating mechanism amongst themselves and enforce compliance.

This study also indicates the need for better data collection, especially in the case of Indian cities. While the 2001 Census included questions on transportation there are no other centralized attempts to collect transportation and land use data. The lack of reliable data is a major drawback to the planning efforts in India. Such data are available in China though they are often not fully utilized in part due to institutional barriers among agencies.

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TABLE 1 Comparing Rail and Road Characteristics

	India	China	U.S.
Railways			
Passenger kilometers	195,355	82,693	1,020
Ton kilometers	136,165	260,427	352,942
Road			
Passenger kilometers (billion)	400	705	2,500
Ton kilometers (billion)	958	572,430	1,534,430

Data sources: World Bank Development Report, 2001 and CIA database, 2000

TABLE 2 Road Length and Density by Region in China (year 1999)

	Road length (km)	Road length density (km/100 sq kms)
East	479,258	37.2
Central	454,981	16.7
West	417,448	7.9
Total	1,351,691	14.1

Data source: 1999 China Transportation Yearbook

TABLE 3 Provincial/State Level ANOVA Comparisons by Region

	Average road length (km)	F-stat	P value
China			
Coastal province	36,741	0.714	0.4
Interior province	43,716		
India			
Coastal state	113,091	3.10	0.09
Interior state	54,909		

Data sources: 1997 China Transportation Yearbook, and Pocketbook of Transport Statistics in India (1997)

TABLE 4 Descriptive Statistics at City Level by Population Size

		Per Capita Road			
		length (km)	TSP ($\mu\text{g}/\text{m}^3$)	SO ₂ ($\mu\text{g}/\text{m}^3$)	NO _x ($\mu\text{g}/\text{m}^3$)
India					
Megacities	Mean	7.01	231.5	15.3	23.7
	Std. Dev.	9.07	158.9	13.3	17.0
Others	Mean	1.87	195.1	20.2	26.8
	Std. Dev.	0.33	109.5	20.3	20.6
China					
Megacities	Mean	7.48	299.8	77.0	60.2
	Std. Dev.	2.55	134.8	55.6	24.4
Others	Mean	6.78	286.2	39.3	33.3
	Std. Dev.	2.92	146.6	23.9	15.6

Data sources: China urban transportation center, MOC, and RITES, India

TABLE 5 Consolidated Correlation Matrices for Chinese and Indian City Data

	COASTAL	POP DENSITY	RDLEN	PUBTRANS	TAXI	TSP	SO ₂	NO _x
COASTAL	1	.141	.369**	.209	.292	-.444**	-.205	.220
POP DENSITY	-0.111	1	.461**	.339*	.291*	-.111	.210	.110
RDLEN	-.130	.058	1	.721**	.883**	.002	.235	.619**
PUBTRANS	.068	-.150	.355	1	.752**	-.101	-.013	.513**
TAXI	-.218	-.087	.960**	.372	1	.068	.121	.676**
TSP	-.391**	.216	.125	-.231	.211	1	.424**	.136
SO₂	-.233*	-.111	.302	-.272	.357	.348**	1	.204
NO_x	-.189	-.051	.073	-.216	.301	.351**	.712**	1

Note: 1. Upper triangle of the matrix is for China and the lower triangle (shaded) for India.

** Correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed).

2. Variables: coastal=1 if coastal and 0 otherwise; pop density—population density; rdlen—road length; pubtrans—public transport fleet size; taxi—number of taxis; TSP, SO₂ and NO_x—pollutant concentrations.

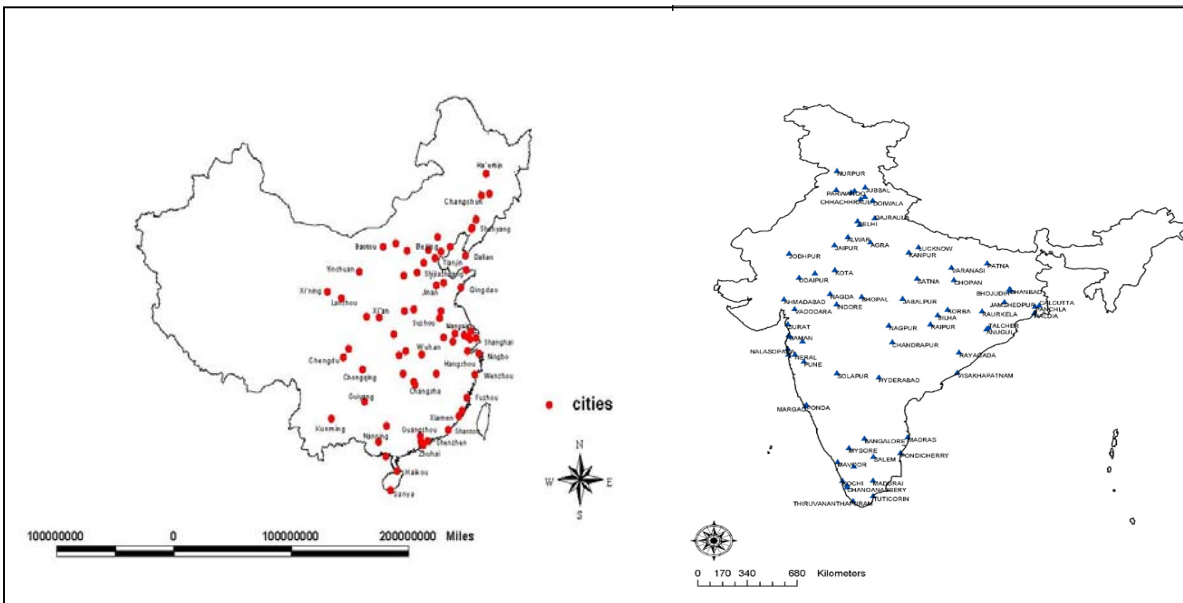


FIGURE 1 Case cities in India and China.

(Sources: China Data Center, University of Michigan, and CPCB, 1998)

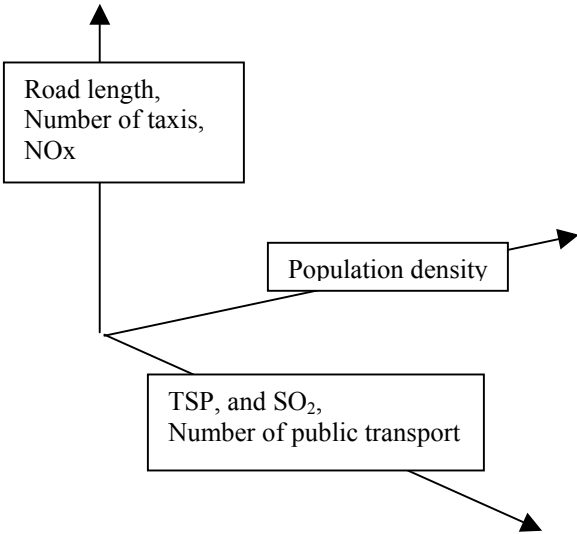


FIGURE 2 PCA result for all cities.