Engineering 2 (2016) 29–32

Contents lists available at ScienceDirect

Engineering

journal homepage: www.elsevier.com/locate/eng

Views & Comments

China's Urban Infrastructure Challenges

Yunhe Pan

Former Executive Vice President, Chinese Academy of Engineering

1. Introduction

To meet people's needs in daily life, production, and recreation, city infrastructure including a wide variety of structures, such as stores, factories, office buildings, houses, roads, and pipelines, have been built. The rapid growth of urban populations, along with people's pursuit of a better life, have led to a greater demand for buses, railways, airways, cars, and subways; to larger scales of production, logistics, transportation, and waste; and to the establishment of service facilities, such as malls, banks, sewage treatment facilities, telecommunication infrastructures, data centers, healthcare centers, and senior care centers. As a result, cities expand rapidly and urban physical systems become increasingly complicated. Poor urban planning and management inevitably result in traffic congestion, pollution, unemployment, monotonous building, and other "urban malaises." The current issues confronting Chinese cities primarily arise from a misunderstanding and poor management of the complexity of physical systems in the process of industrialization and urbanization, bringing great challenges to economic and social development.

2. Urban traffic congestion: Situation and solutions

2.1. Challenges in urban transport

For countries experiencing an upsurge of urbanization, traffic congestion is common. However, traffic congestion in China is steadily growing worse. In 1990, there were only 800 000 private cars in China. By 2012, this number had surprisingly increased by 110 times, to a total of 90 million cars. This dramatic increase in the number of private cars has caused severe traffic congestion (Fig. 1). In Beijing, the average time to drive to work was 52 min in 2012, with an average speed of approximately 15 $km\cdot h^{-1}$ [1]. Similar situations are occurring in other cities across China.

Traffic congestion does not only lead to wasted time on the road; it also causes increased fuel consumption, air pollution, and noise pollution; decreased traffic safety; and other issues. Relevant studies indicate that traffic congestion comes at a huge cost in Beijing, accounting for approximately 4.2% of the city's annual gross domestic product (GDP) [2].

2.2. Solutions to urban traffic congestion

At present, the main solution to traffic congestion is to rely on real-time traffic sensor information to disperse and manage traffic. When serious traffic congestion exists, a traffic restriction policy can be applied. However, this is a shallow and temporary means that cannot solve the issues at the root of traffic congestion. Three more effective solutions are suggested below.

Improving urban street networks. Loose networks with excessively wide streets comprise the majority of China's urban street networks. Table 1 [3] displays a comparison of street networks in different blocks. In the table, "Beijing New Area" refers to the part of Beijing located outside of the second and third rings. The average number of intersections per square kilometer in this area is 14, while in Shanghai, this number is approximately 17. In contrast, Turin, Italy has roughly 150 intersections per square kilometer, a number similar to that of Paris, France. Thus, urban streets in China typically have fewer intersections and are wider than those in other large cities. For example, Chang'an Avenue in Beijing has 10 to 12 lanes, but very few intersections.

As Table 2 [3] shows, the distance between intersections in a

Fig. 1. A typical traffic situation during rush hour in Beijing.

http://dx.doi.org/10.1016/J.ENG.2016.01.007

Table 1
A comparison analysis of street networks in different cities [3].

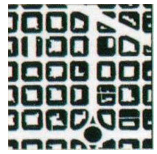
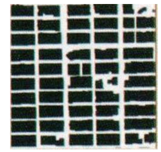
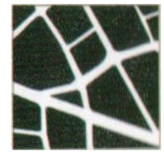
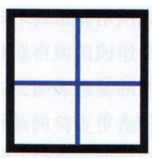
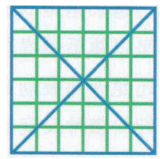
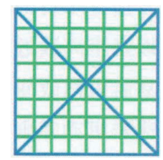
	Turin, Italy	Barcelona, Spain	Paris, France	Pudong, Shanghai, China	Beijing New Area, China
Urban street network					
Number of intersections per square kilometer	152	103	133	17	14
Average length between intersections (m)	80	130	150	280	400

Table 2
A comparison analysis of new and dense blocks per square kilometer [3].

Venue	New block in Beijing	Medium block	Dense block
	Distance between intersections: 500 m	Distance between intersections: 170 m	Distance between intersections: 130 m
Block type			
Motorized street description	Black line: 10-way motorized street Dark blue line: 6-way motorized street	Light blue line: 4-way motorized street Green line: 2-way motorized street	Light blue line: 4-way motorized street Green line: 2-way motorized street
Street length (by type)	Motorway: 32 000 m Bikeway: 8 000 m Walkway: 8 000 m	Motorway: 39 200 m Bikeway: 29 600 m Walkway: 29 600 m	Motorway: 472 000 m Bikeway: 37 600 m Walkway: 37 600 m
Population density (work + residence)	7 500 persons·km^{-2}	15 000 persons·km^{-2}	20 000 persons·km^{-2}
Street cost	5 514 CNY per person	4 033 CNY per person	3 700 CNY per person

new block in Beijing is 500 m, compared with 130 m in a dense block. Congestion is less persistent in a dense block, since vehicles can move to other roads to avoid it. The total street length varies greatly between different block types: In a dense block, the total motorway is 472 000 m·km^{-2}, while in a block with wide streets and a loose street network, it is only 32 000 m·km^{-2}. This difference explains why congestion is less prone to occur in dense blocks. The population density of a new block in Beijing is 7500 persons·km^{-2}; this number is far lower than that of a dense block, which is 20 000 persons·km^{-2}. Thus, a dense block has a greater population tolerance, which is related to the fact that the urban street cost per capita in a dense block is far less than that of a loose block. To sum up, if the issue of urban traffic congestion is not solved by city planning, it cannot be resolved from the root by only controlling transport and vehicles.

Using intelligent logistics management. China has a huge logistics capability. Logistics costs have increased dramatically with an average annual logistics growth rate of over 12% (as shown in Fig. 2), generating a large quantity of exhaust emissions. In addition, logistics costs in China are extremely high, making up 18% of the annual GDP and 20%–40% of sales; in Europe and the US, the respective percentages are 10% and 10%–15%.

Research reveals that freight vehicles contribute 76% of the particulate matter and 36% of the carbon monoxide produced by all vehicles. According to statistics, 40% of trucks on roads are unladed and there is an average 72 h waiting time for the next loading of a truck in China. Therefore, the average daily mileage of a truck is only 300 km in China, compared with 1000 km in the US, indicating low transport efficiency in China [4,5]. To tackle these problems, the China Transfar Group takes an active part in intelligent logistics, from both an online and offline perspective. For online logistics, the group has created a logistics information platform; for offline logistics, Transfar has built a logistics transfer center. After a period of development, more than 2 million of the approximately 12 million commercial

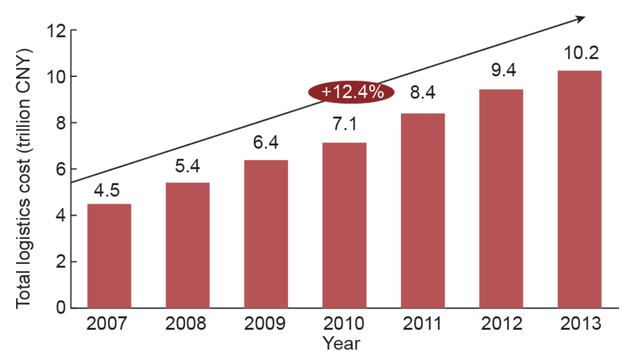


Fig. 2. Total logistics cost in China from 2007 to 2013 in trillion CNY, with an average logistics growth rate of 12.4%.

freight trucks in China (16.6%) are now included in Transfar's logistics information system, which possesses the functions of freight matching, capacity scheduling, and real-time monitoring nationwide. Transfar also constructs logistics handling and transferring centers, centralizing goods-to-truck and truck-to-truck handovers, as well as providing various service facilities in 68 hub cities across China. By these means, the sorting time has decreased from 72 h to 9 h, and the number of unladed trucks has also decreased significantly. Transportation costs decreased by an average of 40%. These results show that information technology can play a huge part in logistics and relevant discharge reduction.

Using intelligent traffic management. common traffic management practices in many countries involve traffic information display and the Internet of vehicles. Researchers in China, however, have a new idea, based on the increasing popularity of electric bicycles here. Compared to cars, electric bicycles have many unique advantages in urban transportation.

As shown in Table 3, electric bicycles occupy about oneeighth the space of cars. Thus, if half the cars in Beijing were exchanged for electric bicycles, traffic would clear up considerably. Electric bicycles also have strong advantages over cars in terms of price and environmental pollution. Furthermore, electric bicycles in the city are not significantly inferior to cars in terms of speed. In fact, the only drawback of electric bicycles is that their safety and comfort levels are much lower than those of cars. However, an electric bicycle can be transformed—reinforced and covered with a hood—to make it safer and more comfortable. The resulting electric mini car will probably be a major transportation vehicle in Chinese cities in the future. An academician of the US National Academy of Engineering once commented on the current situation of China's cities, saying: "China's electric bicycle has a promising future if combined with new energy technology and new safety technology. It could to be a good way to replace the car in the city." Tomorrow's electric mini car will likely be light and small, having two seats and running at a medium speed. It must be safe and comfortable, and will probably possess some of the qualities of cars and some of electric bicycles.

3. Urban PM2.5: Source monitoring and solutions

As China's urbanization accelerates, urban environmental pollution such as solid waste, water, air, noise, and other pollutions become increasingly severe. Garbage classification (i.e., into decomposition, combustion, or reuse) is widely adopted in Chinese cities in order to deal with the garbage problem. To deal with water pollution, a comprehensive prevention and control method is applied, such as the Five-Waters Project in Zhejiang Province, which includes wastewater treatment, flood water control, storm water drainage, potable water security, and water use efficiency. To reduce air pollution, such as fine particulate matter (PM2.5), the Chinese government usually suspends the production of some companies, gives public holidays, and/or sets traffic restrictions, as was done during the "APEC Blue" program. This program was a temporary campaign conducted by the government in the fall of 2014 in order to rapidly reduce emissions for the Asia-Pacific Economic Cooperation (APEC) meeting in Beijing. These measures have a certain degree of impact, to different extents. The "APEC Blue" program showed that PM2.5 pollution could be quickly reduced, but at a huge cost. After the APEC meeting, the air pollution in Beijing was still severe, albeit with a slight improvement in the PM2.5 level.

Table 3
A comparison of various aspects of cars and electric bicycles.

	Car	Electric bicycle
Road area occupancy (length × width)	5 m × 1.8 m = 9 m^2	1.8 m × 0.65 m = 1.17 m^2 (about 1/8)
Price	120 000 CNY	3 000 CNY (1/40)
Speed	120 $km \cdot h^{-1}$	20–40 $km \cdot h^{-1}$
Environmental pollution	Poor	Good
Comfort and safety	Good	Poor

The primary requirement to seriously address the problem of air pollution in China is to understand the sources of PM2.5. However, experts are not yet in agreement regarding PM2.5 sources. An analysis of the causes of PM2.5 pollution in Beijing, Tianjing, and Hebei, based on relevant reports in 2013 [6], reveals that floating dust contributes 17% of the pollution; coal-fired power plants and heating boilers account for 30%; and steel, cement, petrochemical, and other industries account for 25%; motor vehicles and daily life activities contribute 18% and 10%, respectively. However, a different analysis in a report by the World Bank and Development Research Center of the State Council in 2014 [2] provides a different result. As shown in Table 4 [3], this report lists vehicle emissions as accounting for 22% of the pollution, and a different part of the report states that the large number of new cars contributes 30% of the PM2.5 in the air.

The inconsistency in the data analyses of PM2.5 is due to the scarcity of sampling points. For example, there are only about 40 sampling points in Beijing, while the number in Hangzhou is just over 10. Thus, analyses conducted by experts are usually based on data from a relatively small number of sampling points. However, the level of PM2.5 is time- and location-sensitive. Therefore, it is necessary to conduct high-resolution real-time monitoring in order to accurately determine its sources. Three solutions to this issue are listed below, for comparison.

Increasing sampling points. For example, the number of sampling points for PM2.5 could be increased to 1000. However, this solution would be extremely expensive.

Recruiting volunteers. Portable PM2.5 sensors could be given out to volunteers. A real-time collection of PM2.5 data could then be achieved that would be extensive both in terms of time and space and would provide a better data set for analysis. Hundreds of volunteers were once recruited in Paris to collect similar data.

Designing new products. New mobile phones or cars could be designed with inbuilt PM2.5 sensors. By crowdsourcing in this way, an extremely large data set could be collected, which could then be used to analyze the connections between individual health, environmental conditions, and urban air pollution. This is the best solution. The relevant products have been successfully developed and will hopefully be widely and successfully used both at home and abroad.

4. Concluding remarks

Urban infrastructures face many challenges in addition to traffic congestion and air pollution. Other challenges include dealing with natural disasters, terrorism, and urban safety; setting up education, science, culture, and health facilities; and establishing energy and resource support systems. Cities today are no longer

Table 4
Analysis of sources of PM2.5 from Ref. [3].

Sources	Nationwide PM2.5	Beijing PM2.5
Floating dust	34% (North China) 29% (South China)	17% (suspended) 7% (buildings)
Coal burning	10%–30% (in cities)	16.7% (in cities); 24.5% (outside cities) (The level outside the city is 47% higher than that in the city)
Industrial dust (steel, cement)	Increased by 32% (mainly cement, increased by 27%)	
Vehicle emissions	8%–30% 15% (North China) 20% (South China)	22%
Straw burning	5%–46% 14% (North China) 20% (South China)	9%

purely dual spaces, in which humans interact with their physical environments; rather, cities have been upgraded to ternary spaces, in which humans interact both with their physical environments and with information in cyberspace (Fig. 3). This shift is closely related to the emergence of big data, the Internet of Things, and so forth. A modern city is a massive and complicated system. To make it run efficiently and to provide people with better services, a layer of "nerves" should be added. This is the goal of an Intelligent City (iCity): the intelligent development of a city.

China is now undergoing simultaneous development in many areas: industrialization, informationization, urbanization, agricultural modernization, and greenization. The development of an iCity involves unique tasks, however, to realize intelligent development in urban construction, information infrastructure, industrial development, management and services, human resources, and so forth. At present, judging from China's development path (Fig. 4), the first step is to create various intelligent applied mid-level systems, including intelligent healthcare, an intelligent grid, and intelligent transport. Next, these systems can each be expanded in both an upward and a downward direction: upward through the development of big data platforms, which allow isolated data to be accessed and combined in order to use big data to promote intelligent predictions, decision-making, and planning; and downward through the construction of the Internet of things, forming a network of efficient sensors to perceive the city. These development steps will improve the city environment, transportation, urban management, people flow, logistics, and information flow, and will realize a combined ternary space consisting of humans, their physical environment, and information.

To date, more than 300 Chinese cities have initiated their iCity development. I am confident that the coming decade will witness more efficient, more habitable, greener, and more beautiful Chinese cities.

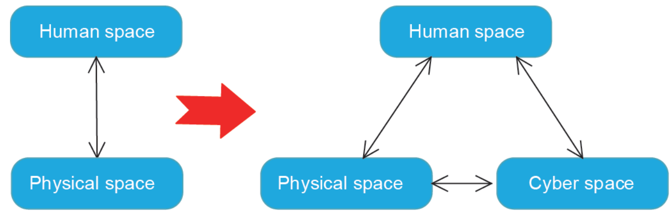


Fig. 3. Upgrading a city from dual space to ternary space.

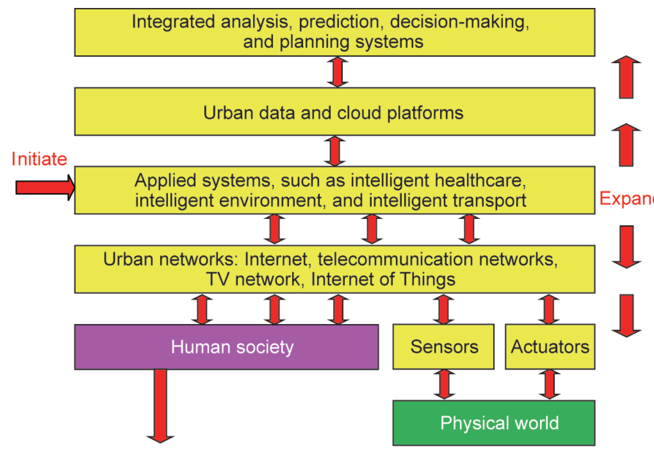


Fig. 4. The development path of an iCity in China.

References

[1] Niu WY, Liu YJ. China's new urbanization report of 2012. Beijing: Science Press; 2012. Chinese.
[2] Pan Y. "Beijing average running 15 kilometers per hour" will be changed? China Youth Daily. 2015 Sep 22; Sect.: 6. Chinese.
[3] The World Bank, Development Research Center of the State Council. China: a new approach for efficient, inclusive, sustainable urbanization. Beijing: China Development Press; 2014. Chinese.
[4] Economic Operation and Regulation Bureau of National Development and Reform Commission, Modern Logistics Research Center of Nankai University. Report of China logistics development (2011). Beijing: China Fortune Press; 2011. Chinese.
[5] China Federation of Logistics and Purchasing. China logistics yearbook 2013. Beijing: China Fortune Press; 2013. Chinese.
[6] Report of the CPPCC National Committee: Analysis of PM2.5 pollution in Beijing, Tianjin and Hebei Province. 2013. Chinese.