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Policy Forum Article

Curbing Congestion and Vehicular Emissions in China: A Call for Economic Measures[1]

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Abstract

With the exponential growth of the national vehicle fleet in the last three decades, most cities in China are facing mounting pressure to tackle congestion and air pollution problems caused by motor vehicles. Beijing, the capital city, is a good case to study how municipal governments address those issues. To alleviate road congestion and pollution, the government has invested heavily in road infrastructure, advanced traffic management technology and also introduced stringent standards on vehicular emissions. However, city planners have been over-relying on command and control measures including travel demand management, which have proven to be costly and inefficient in controlling motor vehicle ownership and usage—the fundamental causes of congestion and emissions. Economic measures including road pricing and vehicle registration auction schemes are superior and should be adopted in travel demand management in the future.

Key words: congestion, air pollution, motor vehicles, China, travel demand management

1. Introduction

Fuelled by unprecedented economic growth and consequent rises in income, China has been undergoing rapid motorisation since the mid-1980s. As shown in Figure 1, the number of motor vehicles[2] rose from 3.2 million in 1985 to 146 million in 2014. This is mainly driven by the exponential growth in private vehicles, jumping from a mere 285,000 to a staggering 123 million during this period—a stunning average annual growth rate of more than 35% over the 20-year period (National Bureau of Statistics of China (NBSC) 2014).

Not surprisingly, this increase in motor vehicles on the road has meant that vehicle emissions and traffic congestion have become increasingly common in many Chinese cities. Beijing, China's capital, has repeatedly hit the headlines because of its severe air pollution and city-wide traffic standstills.

From an economic perspective, congestion is an outcome of excessive demand for limited road space. Emissions are a function of the technical specifications of the vehicle engine and the distance travelled. There are four basic solutions for congestion: improve the efficiency of transportation infrastructure to better match the demand for and supply of road space, increase the supply of road infrastructure, provide more alternative or efficient travel modes and manage the demand. City planners in China have mainly

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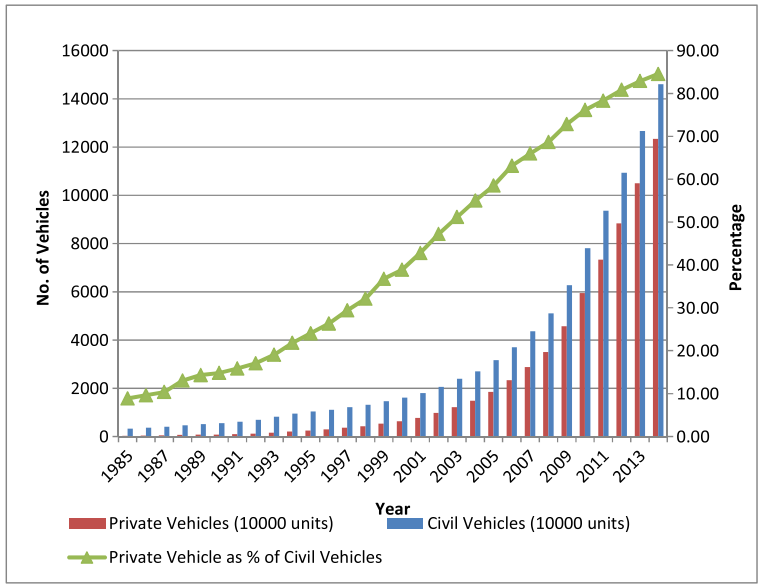
[1]The author thanks Mr Christopher O'Grady for assistance with editing this paper. All errors remain to be the author's responsibility.

2. China does not publish data of military vehicles; thus, the data on civil vehicles are utilised as a proxy for motor vehicles.

Figure 1 Number of Civil and Private Vehicles in China between 1985 and 2014.



Source: National Bureau of Statistics of China (2014 and 2000)

focused on the first three solutions and relied on command and control measures to control congestion and manage the demand. Setting emission standards and measures designed to control vehicle ownership and usage are the main tools to address vehicular emissions in China. Similarly, command and control measures prevail in emission control policy.

This article uses Beijing as a case to provide a snapshot of the municipal government's effort to tackle congestion and air pollution, highlights the high costs of command and control measures and advocates for more economic measures in the future.

2. Beijing's Effort to Curb Congestion and Air Pollution

Despite its poor reputation for air quality and congestion, the Beijing municipal government has performed tremendous work to mitigate congestion and air pollution. Initially, the focus was on the supply side: road construction and public transport. Later, travel demand management (TDM) was introduced: first, as a temporary measure for the Beijing Olympic Games and later, as a permanent measure. This first section mainly discusses other measures and leaves TDM for discussion in the next section.

Infrastructure construction was the first measure introduced to ease congestion when it first appeared in the mid-1980s (Guo *et al.* 2015). Investment on road infrastructure amounted to 105 billion RMB over a 5-year period between 2001 and 2005, and doubled in the next 5 years to 211.8 billion (Beijing Municipal Commission of Transport 2006; Beijing Municipal Commission of Transport 2012). As a result of heavy investment, the area of paved road in Beijing increased steadily from 49.21 million m^2 in 2000 to 138.84 million m^2 in 2013 (National Bureau of Statistics of China (NBSC) 2014). However, this massive road development program failed to catch up with the demand for road space, driven by a fivefold expansion in the motor vehicle fleet during the same period.

Recognising the limit of road construction, the city planners then turned to public transportation. In 2005, prioritising public transport was formally listed as one of the five top transportation strategies, and Beijing entered an era of rapid development of public transport (Beijing Municipal Commission of Transport 2006). Nearly 10 years of implementation of the public

transport priority policy has transformed Beijing's public transport from a system dominated by buses to a system backboned by light rail and subways. By 2013, 17 light rail/subway lines cover all metropolitan areas in Beijing, carrying 8.7 million passengers in a typical weekday, while 813 bus lines and 23,592 buses serve 13.2 million passengers every day (Guo *et al.* 2015). More importantly, public transport has become the dominant transport mode in Beijing. As shown in Figure 2, the share of public transport rose from 28.2 per cent in 1986 to 46 per cent in 2013, mainly driven by a leap in subway travel.

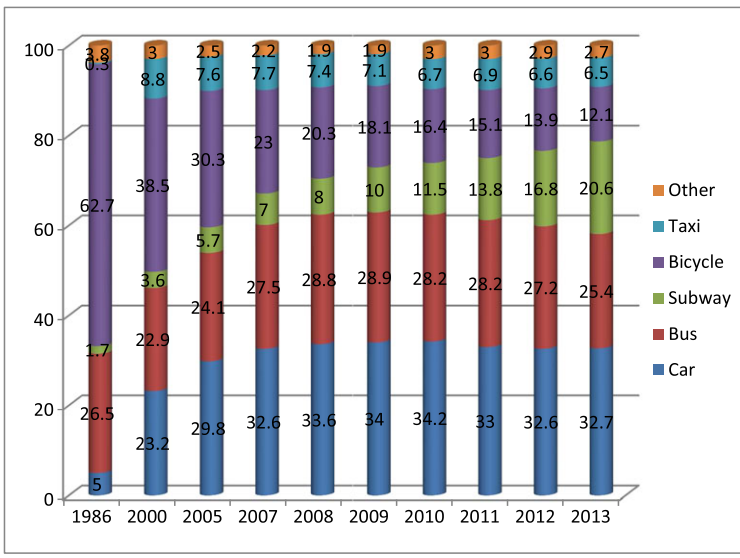
Raising emission standards and scrapping old vehicles have been the two major measures adapted by the city planners to tackle vehicular emissions in Beijing. As shown in Table 1, Beijing has been at least 2 years ahead of the national agenda in adopting new emission standards, reflecting the city planners' determination to tackle air pollution problems as well as the mounting public pressure caused by poor air quality. The aggressive adoption of stricter emission standards on new vehicles was also accompanied by an accelerated vehicle retirement scheme on old vehicles. One million vehicles are planned to be scrapped between 2013 and 2017 (Beijing Municipal Government 2012).

3. Travel Demand Management

Despite painstaking efforts in raising emission standards, improving transport facilities and continuing investment in road infrastructure, congestion and air pollution hardly improved in Beijing and even deteriorated. TDM was eventually put on the agenda in 2008 as the Olympic Games approached. Road space rationing was put in place first, and a number plate lottery scheme was introduced later on.

In order to significantly improve air quality and relieve traffic congestion in the city, between July and September 2008, the authorities temporarily introduced a road space rationing policy based on plate numbers: vehicles with odd number plates were only allowed to drive on odd dates, and even number plates were only allowed on even dates. A modified restriction policy was made permanent after the games in October 2008, banning 20 per cent of the vehicles on a given weekday instead of the 50 per cent restriction policy implemented during the Olympics. Vehicles with number plates ending with the two digits published by the authority on a daily basis were not allowed on the road. Additionally, under the revised policy, non-Beijing licenced trucks were prohibited from entering the city during the

Figure 2 Beijing Transport Mode Structure: 1986 to 2013.



Source: Guo et al (2015)

Table 1 Implementation Dates of Emission Standard

Stage	*Beijing*	*Shanghai*	*Guangzhou and others*	*Nationwide*[‡]
China 1[†]	1 Jan 1999	1 Jul 1999	n/a	1 Jul 2000
China 2	1 Jan 2003	1 Mar 2003	1 Jul 2005	1 Jul 2005
China 3	31 Dec 2005	HDV: phased-in over 2007	1 Sep 2006	1 Jul 2008
China 4	LDV: 1 Dec 2008 HDV: 1 Jul 2008	1 Nov 2009	1 Jun 2010 (GZ + 9 cities in Guangdong Province)	1 Jul 2011
China 5	1 Feb 2013	1 May 2014	31 Dec 2015 (GZ + 8 cities in Guangdong Province)	1 Jan 2018

Notes:
[†]China's emissions standards are nearly identical to Europe's standard. China 1 is equivalent to Euro1, and China 2 is equivalent to Euro 2.
[‡]Implementation dates vary with different types of vehicles. The dates shown in this column are the earliest dates when the standard applied to new vehicle sales and registrations.
HDV, Heavy Duty Vehicle; LDV, Light Duty Vehicle.
Source: Transport Policy.Net (2015).

day, and heavily-polluting cars[3] were banned from entering the city area within the fifth ring road (Guo *et al.* 2015) area (basically, the whole area of and around the inner city/Central Business District).

In 2011, a number plate lottery scheme was instituted in the city as a further measure. Only residents who had won the lottery were allowed to purchase a car. By capping the number of number plates available for the lottery, the government effectively controls the number of newly registered vehicles, which was halved in the first year of implementing the scheme and has been tightly controlled under 600,000 per year since 2011. The objective was to control the total number of motor vehicles to under 6 million by 2017 (Beijing Municipal Government 2012).

While the majority of the TDM measures are command and control type, one economic measure was introduced in 2010. Parking charges in highly congested areas were doubled from 2.5 RMB per half hour to 5 RMB during the peak time (7am to 9pm), and the charge was raised to 7.5 RMB per hour after the first hour (Beijing Municipal Commission of Development and Reform 2010). It was reported that parking in central areas in weekdays and weekends fell 13 and 17 per cent, respectively, as a result of introducing the charges (Guo *et al.* 2015). Despite the initial success of these measures, the impact waned because of weak enforcement as many vehicle owners managed to avoid the high charges by paying cash to car parking attendants.

The use of command and control measures reached a new height in November 2014 creating 2 weeks of blue sky in Beijing around the time of the Asia Pacific Economic Cooperation (APEC) meeting. The so-called APEC Blue was an outcome of concerted effort involving six provinces to remove the embarrassing scene of smog-filled skies and traffic jams in Beijing to impress the world leaders who gathered to attend the APEC meeting. According to the official report from the Municipal Bureau of Environmental Protection, half of all motor vehicles were ordered off the roads each day to cut exhaust emissions; 14,000 factories were closed down or had operational restrictions imposed; more than 40,000 construction sites were closed; and millions of civil servants, employees at the state-owned enterprises, as well as all schools were forced to take a six-day vacation (Beijing Municipal Environmental Protection Bureau 2015).

4. A Critical Evaluation of Command and Control Measures

With a 30-year history of a planned economy and a one-party political system, it is not difficult to understand why command and control measures are favoured by city planners in

3. Those are the vehicles that failed to meet the China 1 emission standards.

China. They are easy to design and implement, and the impact can be clearly seen almost immediately. The road space rationing policy introduced for the 2008 Olympics resulted in a 26.9 and 22.8 per cent improvement in network speed during the morning and afternoon rush hours (Guo *et al.* 2015). Apart from 'APEC blue', similar measures were used for the Nanjing Youth Olympic Games in 2014 and ahead of the Asian Games in Guangzhou and Shanghai Expo in 2010. Despite the early (expected) benefits, the drawbacks are too obvious to be ignored.

Firstly, the measures are extremely costly. Credit Suisse estimated the factory shutdowns to create 'APEC blue' alone lead to a one-quarter drop in China's steel production, a 13 per cent decline in cement production and 3 per cent loss of total industrial output. Added together, that shaved 0.2 to 0.4 percentage points off China's November industrial production figures (Huang 2014). The implicit costs are even higher. The road space rationing policy introduced in April 2009 removed 900,000 vehicles each workday from the roads (Guo *et al.* 2015). The welfare loss caused by such a ban is significant, considering the length of time that the policy has been in place. The forced vacations for civil servants and employees at state-owned enterprises represent a huge loss of productivity. There was widespread dissent among ordinary Chinese regarding the price tag for the 2 weeks of blue sky to impress some foreign leaders. The costs of scrapping old vehicles can be large as well. It was reported that 476,000 vehicles were denied registration in 2014 alone (McDonell 2015), which is nearly 10 per cent of the total fleet. Considering the fact that there were 481,300 vehicles in Beijing in 1994, the majority of the vehicles denied registration are less than 10 years old. Needless to say, the costs of complying with the centralised command and control measures are borne by vehicle owners and other ordinary citizens, and these costs were not taken into account by the city planners when decisions were made. However, they are costs imposed on society and are a waste of resources, thus, should not be dismissed by policy makers.

Secondly, the impact is usually short-lived. Despite the huge effort behind 'APEC blue', 5 days after the lifting of the ban, Beijing returned to a dense, suffocating smoggy sky. The improvement in air quality and traffic congestion disappeared as soon as the traffic ban was lifted after Olympic Games. Indeed, the city planners had to resort to permanent road space rationing within months to curb the congestion and emissions. Again, the impact of such policy was soon offset by the ongoing surge in car ownership. Sensing that the policy had not solved the problem, the municipal government looked to the number plate lottery to tackle the issue in 2011.

Thirdly, the measures often result in undesirable side effects. A direct impact of the road space rationing policy based on number plates has been a jump in the number of new cars purchased, as people felt they needed to have two cars with both even and odd numbers so that they can in fact use their cars every day. This rush to get around the policy meant that the number of newly-registered private vehicles in Beijing went from under 400,000 prior to 2008 to 468,000 in 2008, then skyrocketed to 675,000 and 870,000 in the next 2 years (National Bureau of Statistics of China (NBSC) 2014). Unsurprisingly, the air quality and traffic congestion also got worse in the same period. The number plate lottery scheme successfully pushed the number of new vehicle registrations back to 400,000 in 2011, but another side effect was created: a black market. The municipal government initially awarded plates to 1 in 10 people who were hoping to get a car. But faced with rising demand and increasing pressure to curb car ownership, it cut the allocation of new number plates by 40 per cent to 150,000 in 2014, meaning only 1 in 150 got a plate. By 2015, there were 2.47 million bidders trying their luck for 17,600 number plates in a typical auction (Beijing Municipal Government 2015). The long odds have created a thriving black market, where anecdotal evidence suggests it costs as high as 200,000 yuan (AUD $40,000) to get a number plate despite repeated warning from the government that it is illegal to transfer number plate under lease

or other arrangement (Beijing Municipal Government 2015).

Fourthly, the measures lack flexibility. The road space rationing policy allocates road space based on the last digit of registration plates, and the lottery scheme allocates cars based purely on luck. Unfortunately, peoples' travel needs do not depend on the numerical qualities of their registration plates, and their demand for vehicle usage is unlikely to be matched with their propensity for luck. Users who need cars may not get one and those who do win the lottery may in fact have no need. There are also numerous ways to rort the system. Both systems provide little flexibility in meeting the needs of the traveller, thus reduce the overall efficiency of the transport system.

In short, the previously mentioned drawbacks of command and control measures highlight three facts: first, the costs of those measures may far outweigh their benefits. While we do not have precise figures, a loss of 0.2 per cent of national industrial output appears to be a very high price tag for 2 weeks of Beijing blue sky, not to mention all the loss caused by compulsory holidays and factory closures. Second, the measures were primarily used to temporarily impress outsiders, instead of addressing the fundamental issues leading to congestion and emissions. Third, those measures are not effective in changing traveller's behaviours as desired by policy makers. As shown in Figure 2, the proportion of car trips as a share of travel mode has hardly changed in the last 10 years, and government effort has mainly led to higher utilisation of the subway system. It is perhaps time to explore other measures that can achieve the goal in a sustainable way and have fewer side effects.

5. Call for More Economic Measures

The year 2000 marked the one millionth motor vehicle in Beijing. It took only 5 years to add another million, 3 years for the third million and less than 2 years for the fourth million. It is obvious that the transport system cannot accommodate such a rapid growth no matter how much additional money can be invested to build roads, as the area of land is limited. Even technology advances such as transportation monitoring and coordination systems will eventually have limited benefits. TDM, or managing vehicle ownership and usage, is likely to be the main way of addressing congestion and emissions in the longer term, and economic measures should form an important part of TDM not only because of the drawbacks of the command and control measures discussed previously but also because they are more efficient in terms of achieving policy goals. Beijing has certainly realised the need to introduce economic measures but is yet to take a substantial step forward to make this happen (Beijing Municipal Government 2012).

The efficiency of market mechanism rests on the ability to allocate resources to those who can use them most efficiently. Price is used to direct the resources; in another words, those who are willing to pay for the highest price get the resources. There are debates as to whether those with limited means are denied their fair share of resources under the market system, but there is widespread consensus that equity issues needs to be addressed via the social welfare system, while the market system should be allowed to operate with minimum government intervention. It is also possible to address some equity concerns while implementing the economic measures: for example, certain number of number plates or parking spaces can be allocated to people who have special needs (such as medical conditions).

There are several economic measures that can better address Beijing's problems.

5.1. Road Pricing Scheme

Both Singapore and London have implemented successful road pricing scheme, but city planners have been reluctant to introduce such schemes in China for fear that it may cause public disturbance and equalitarian concerns. Roads are traditionally considered as public goods, thus need to be accessed equally by all members of society. Pricing means relatively wealthy consumers will be allocated more road space as they can afford to pay, therefore is seen as unfair and potentially causes social unrest.

While such concerns are not ungrounded, there are a few ways of dealing with them. First, a gradual approach can be adopted to address equalitarian concerns. A fee-paying express lane can be trialled in the area where the congestion is the worst. Vehicles equipped with electronic toll collection device can choose to pay to use the express lane, while other vehicles can still have access to free lanes. That way, the choice of using the fee-paying express lane is a voluntary decision, and access to roads is still made available for people who do not wish to pay. Once the tolled express lane has gained acceptance among road users, similar practices can be rolled over to other areas. Second, educate the public. Road is not significantly different from other public or quasi-public goods such as hospitals and schools. If private hospitals and schools are widely accepted in China, it is possible to apply the same logic to road. A public campaign can be launched prior to the introduction of a road pricing scheme to publicise the benefits of toll lanes. Last, transparency of toll revenue accounts. Much of dissent of tolled road is caused by lack of transparency in using the toll revenue. If municipal government can ensure the funds raised by the road pricing scheme are used to improve road infrastructure and that the pricing is set for managing demand instead of generating revenue, then it is more likely to gain a support from the public.

Road pricing schemes are superior to road space rationing schemes because they can achieve similar results in a more efficient manner: the scarce road space will be allocated to those who are willing to pay a price, hence to those that need the roads the most. In addition, it can address the equalitarian concerns by granting those in need free access to express lanes, and it has the potential to adjust road prices should they expect a surge or a drop in demand.

5.2. *Number Plate Auction Scheme*

This is a measure that has been in place in Singapore and Shanghai for more than 20 years. Instead of drawing one lucky applicant out of hundreds, the number plate is allocated to the person who is willing to pay the highest price in the auction.

This type of scheme is superior to the number lottery scheme in four ways: first, it reduces the transaction costs significantly. It provides no incentive for those who do not need a car to bid in the auction, so it stops unnecessary bidding and associated costs. For people who need a car but miss out in the lottery, it saves their costs of searching and negotiating a deal in the black market. Second, it is more efficient. Resources (cars) are allocated to those who most need them (expressed as the ones who are willing to pay the highest price). The lottery scheme appears 'fair' on the surface as theoretically, everyone who enters the lottery is facing the same odds. However, it is 'unfair' in the sense that the demands of those who really need a vehicle are not met. Therefore, it is an inefficient mechanism in allocating resources. Third, it generates revenue to the government (instead of traders in a black market), which can be used to invest in road infrastructure and improving the transport system. Lastly, it essentially removes the black market for number plate. Because it is unlikely to be profitable to bid a number plate in the auction and sell it to car owners in the presence of an auction market, there is no incentive to trade in the black market.

Similar to road pricing scheme, equalitarian concerns can be addressed via free or discount number plate for those in need.

5.3. *Flexible Parking Pricing Scheme*

Current parking charges for on-road parking spaces are set by Beijing Municipal Commission of Development and Reform, and private parking operators are not allowed to charge a price that is higher than the charges set by the commission. There are only two different pricing schemes for the whole city: one applies to the Central Business District and another applies to the rest of the city. The pricing set by the commission is too rigid and does not reflect the fluctuations of demand for the parking spaces at different times of the day in the different regions. More variations in terms of parking prices to reflect the dynamics of

demand and supply of the parking spaces would allow the rationing function of price to take effect.

It is worth noting that economic measures will not tackle the problem properly unless they are well-designed to target specific issues. In other words, the price needs to be set to provide adequate incentive to change vehicle owner and traveller's behaviour. It requires in-depth research to understand the underlying motivations and needs of travellers so as to develop effective price schemes to achieve the policy goals. Despite the extra work required, it is time for Beijing to abandon highly inefficient command and control measures and to take a step to adopt economic measures to address congestion and emissions. Otherwise, we will be seeing the city and other Chinese cities trapped in congestion and air pollution with no hope in horizon.

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