Abstract

China’s car ownership has been expanding at a staggering pace in the past two decades. The rapid motorization brought unprecedented level of traffic to its densely populated cities unprepared to accommodate it, causing severe congestion and air pollution problems. Chinese cities have responded to these challenges with sweeping travel demand management (TDM) measures. The practice of TDM in China is unique not only because it is large in scale and broad in scope, but also because it occurs against the backdrop of a fast and historical transition of the most populous country on earth. The objective of this note is to review and document this practice, discuss its outcomes and lessons, and examine what the rest of the world could learn from it.

Keywords: China; motorization; travel demand management; car ownership

1 Introduction

The internal combustion engine is one of the greatest inventions of all time (Gordon, 2017). It unleashed, at the dawn of the 20th century, the explosive growth of the automobile industry, which has forever transformed human mobility. By 2010, the number of automobiles in operation has surpassed 1 billion worldwide (Sousanis, 2011), and that number is expected to double by 2020 (Sperling and Gordon, 2010). As humans increasingly plan their lives around the ownership and use of cars, the world soon discovered the steep price of this dependency. Cars are a major user of energy. Worldwide the transport sector consumed more than a quarter of the total energy, of which 60% is in the form of petroleum (NRS, 2010). Consequently, transportation is responsible for roughly 30% of the world’s greenhouse gas emissions, making it the largest contributor of all industries (USEPA, 2017). The growth in car use also subject residents in big cities around the world to the infamous symptoms of traffic congestion: lost time, disrupted schedules, wasted fuel, deteriorating air quality, and discomfort (Garling and Schuijtema, 2007). In the United States
alone, the economy loses more than $100 billion a year to traffic congestion (Schrank et al., 2015). It is widely acknowledged that a car-dependent transportation system is unsustainable and that policy measures are necessary to decrease the demand for car use (OECD, 1996). This note is concerned with such travel demand management (TDM) measures (Kitamura et al., 1997) and their implementation in major Chinese cities.

A latecomer to motorization, China’s car ownership has been expanding at a staggering pace in the past two decades. In 1994, China sold 1.4 million vehicles. 15 years later, its new vehicle market has grown to 18 million a year, the largest in the world (Wang et al., 2011). By the end of 2017, China has more than 300 million motor vehicles in stock, of which about 217 million are light duty cars and trucks (Dai and Liu, 2017). The rapid motorization brought unprecedented level of traffic to densely populated cities unprepared to accommodate it, causing severe congestion and air pollution problems. The notorious haze pollution has been linked to vehicular emissions (notably volatile organic compounds and nitrogen oxides, see e.g., Guo et al., 2014). According to AutoNavi (2018), the ten most congested Chinese cities consistently have a travel time index close to 2, meaning the travel time in the peak time is almost twice as long as the free flow travel time. In comparison, the travel time index is averaged at 1.32 for the 15 major US metropolitan areas, with the highest (Los Angeles) being 1.43 (Schrank et al., 2015). The rising private auto ownership also stretches the nation’s energy supply to the limit: in 2016, nearly two thirds of its oil consumption had to be met by import.\footnote{http://www.ecns.cn/business/2017/01-13/241517.shtml.}

Chinese mega cities have responded to these challenges with sweeping TDM measures, some of which would have faced strong and crippling opposition elsewhere. The practice of TDM in China is unique not only because it is large in scale and broad in scope, but also because it occurs against the backdrop of a fast and historical transition of the most populous country in the world. The objective of this note is to document this practice, discuss its outcomes and lessons, and examine what the rest of the world could learn from it.

For the remainder, Section 2 formally introduces the TDM concept and review commonly used TDM measures. Section 3 summarizes the TDM measures that have been implemented by seven representative cities in China. Section 4 focuses on Beijing and Shanghai, the two Chinese mega cities that arguably have the most TDM experience. Section 5 summarizes the findings.

2 Travel demand management

To be clear, technology is and will continue to be part of the solutions to sustainable transportation. For example, cars powered by electricity generated from renewable energy could potentially address the concerns about the energy security and environmental impacts. However, technology may not on its own solve the puzzle of traffic congestion. Take autonomous driving as an example. The technology’s potential to improve transportation is enormous, but many are predicting it will make our streets more congested than they are today (Harb et al., 2018; Levin and Boyles, 2015; Simoni et al., 2019).

A typical reaction to the rising level of congestion is expanding road capacities. For one thing, such an approach has its physical limits. More important, as new capacities usually induce new demands, the congestion relief brought by them is often short-lived (Vickrey, 1969). Therefore, satisfying all the “latent demand” for car use is not only inefficient but also infeasible, especially in crowded urban areas. Keeping this demand at a desirable level is the central mission of
travel demand management (TDM). In this note, we classify TDM measures as mandatory and voluntary, depending on whether they directly affect the cost and/or availability of private car use or not.

2.1 Voluntary TDM measures

Since travel is a derived demand, the most effective way to manage this demand seems to keep it at a low level in the first place. This would require land use planning that properly balances employment, commercial and residential development so that long-distance trips can be largely avoided (Gärling and Schuitema, 2007). An example is transit-oriented development that centers on an area within walking distance from a major public transport hub (Dittmar and Ohland, 2012). Unfortunately, few cities are built from scratch with a clear vision for TDM, and the planner in charge often has to operate within many constraints unrelated to transportation. Therefore, although preemptive land use planning is an effective tool in theory, it is not always available when needed.

Another broad strategy aims to encourage travelers to voluntarily shift from driving to more sustainable travel modes, such as mass transit systems, walking/biking/e-scooting, and carpool/ride-sharing. It can be achieved by enhancing alternative modes—including both improving the level of service and lowering the cost—and “nudging” travelers about the consequences of their choices (Gärling and Schuitema, 2007). For transit, the enhancements may result from adding new capacities (e.g. mass rapid transit, park-and-ride facilities), providing preferential control treatment (e.g. bus only lanes or transit priority signals), and subsidizing transit fares with public resources. To make carpool/ride-sharing more attractive, a longstanding measure is to designate High-Occupancy-Vehicle (HOV) lanes reserved to be used by carpool vehicles (Chan and Shaheen, 2012). Finally, providing dedicated bike lanes and bike-share programs are among the effective strategies to promote biking (Shaheen et al., 2010; Fishman, 2016).

2.2 Mandatory TDM measures

Mandatory TDM measures come with various levels of coercive power. The least coercive measures employ the pricing tool, whereas the more coercive ones directly control the use and ownership of cars.

For almost a century, economists have argued (see e.g. Pigou, 1920) that travelers inflict an “external cost” on the rest of society, which creates excessive congestion if not internalized. The best way to internalize this travel externality is to have the road owner, in most cases the government, impose a congestion toll equal to the discrepancy between the average and marginal travel costs (see e.g., Beckmann et al., 1956; Vickrey, 1963; Lindsey and Verhoef, 2001; Yang and Huang, 2005; Lindsey, 2006; Duranton and Turner, 2009; Isekeris and Vos, 2009; de Palma and Lindsey, 2011). Despite its strong theoretical appeal, however, congestion pricing has not been received well by the public in most parts of the world. Opponents argued that the policy not only is expensive and complex to implement (Niskanen and Nash, 2008), but also creates regressive welfare effects (Evans, 1992; Arnott et al., 1994; Hau, 1998; Taylor and Kalauskas, 2010). An alternative designed to overcome some of the shortcomings is the tradable credit scheme (TCS). TCS replaces tolls with market-priced tradable credits that are distributed to traveler by the authority (Verhoef et al., 1997; Yang and Wang, 2011; Nie, 2012; Wang and Yang, 2012; Nie, 2015; Nie and Yin, 2013; Xiao et al., 2013; Ye and Yang, 2013). It offers a market mechanism through
which the poor who are “priced out” can be compensated by selling their credits to the rich. Hitherto only a handful of cities (e.g., Singapore, London and Stockholm, Lindsey et al. [2012] have successfully enacted a congestion pricing policy, and to the best of our knowledge, TCS has not been considered for implementation in any major city.

A related but much less studied pricing tool concerns parking. Verhoef et al. [1995] note that, whereas regulatory parking polices are less efficient than congestion pricing, they are more readily acceptable to the public given the ubiquitous existence. Calthrop et al. [2000] show that pricing parking spaces inside a central business district (CBD) with a lump-sum fee leads to higher welfare gains than cordon-based congestion pricing. Yet, a parking fee per unit time may incentivize travellers to park for a shorter time, hence increasing traffic to CBD, in the absence of optimal road pricing (Glazer and Niskanen [1992]). Arnott and Inci [2006] argue that the optimal on-street parking fee should be set to simultaneously saturate parking spaces and eliminate cruising for parking. Marsden [2006] asserts no empirical evidence supports the belief that parking policies could damage the attractiveness of CBD to businesses.

Restricting car use is often achieved through license plate rationing (LPR). Mexico City’s “No Circulating Day” scheme is one of the earliest and probably also the best documented LPR schemes. Introduced in 1989, the scheme bans each car from driving on a specific day of week, based on the last digit of its license plate number (CA, 2007). Similar schemes have since been implemented in Manila, Philippine (started in 1996, GUETA and GUETA, 2013), Sao Paulo, Brazil (started in 1997, CA, 2007) and Bogota, Columbia (started in 2000, CA, 2007). During 2008 Olympic Games, Beijing adopted a highly restrictive form of LPR known as odd-even rationing, which basically bans a car from driving every other weekday. Its positive effects on congestion reduction and air quality improvement in the short-term (see e.g. Wang et al. [2009]) have convinced the government to permanently adopt LPR later. Despite its wide use, LPR’s long-term effectiveness in reducing car use has been repeatedly questioned in the literature (Eskeland and Feyzioglu, 1997; Davis, 2008; GUETA and GUETA, 2013). Additionally, even under the best circumstance, it is still a second-best policy and displays a regressive welfare effect (Nie, 2017b).

The most restrictive TDM measure directly controls auto ownership. Often known as the vehicle quota system (VQS), it caps the number of cars registered each year according to a projected growth curve. This policy was first implemented in Singapore (Koh and Lee, 1994; Chin and Smith, 1997), and subsequently adopted by a number of Chinese cities. Beijing enacted the policy in 2010, followed by Guangzhou in 2012, Tianjin in 2013, and Hangzhou and Shenzhen in 2014 (Xiao et al., 2017). Unlike Singapore’s VQS, which sells new licenses through auction, most Chinese VQS schemes distribute licenses entirely or partially through lottery to address the concerns about inequality. An exception is Shanghai, whose VQS program started much earlier and closely resembled Singapore’s scheme. It has been argued that VQS may be less effective in China than in Singapore, because a city not isolated from the surrounding areas cannot completely ban vehicles registered elsewhere from driving on its streets (Wang, 2010). Also, limiting vehicle fleet growth may induce more intensive use, thanks to congestion relief (Yang et al., 2014). Thus, determining a quota to achieve an optimal level of car use is difficult, and often a source of welfare loss (Xiao et al., 2017). Finally, under VQS buyers tend to favor larger and less fuel efficient vehicles, which not only distorts the vehicle market but also generates negative environmental and energy impacts (Wang, 2010).
Table 1: Statistics of the seven representative large cities in China.

<table>
<thead>
<tr>
<th></th>
<th>Beijing</th>
<th>Shanghai</th>
<th>Guangzhou</th>
<th>Shenzhen</th>
<th>Chengdu</th>
<th>Hangzhou</th>
<th>Harbin</th>
</tr>
</thead>
<tbody>
<tr>
<td>GDP/ billion *</td>
<td>3031.998</td>
<td>3267.987</td>
<td>2285.935</td>
<td>2422.198</td>
<td>1534.27</td>
<td>1350.9</td>
<td>630.05</td>
</tr>
<tr>
<td>Car ownership/ thousand +</td>
<td>267.94</td>
<td>169.56</td>
<td>171.85</td>
<td>216.04</td>
<td>318.96</td>
<td>295</td>
<td>158.23</td>
</tr>
<tr>
<td>Built-up area size/ km² *</td>
<td>912</td>
<td>565</td>
<td>381</td>
<td>181</td>
<td>326</td>
<td>397</td>
<td>337</td>
</tr>
<tr>
<td>Road mileage in built-up area/km *</td>
<td>5143</td>
<td>4038</td>
<td>2692</td>
<td>1719</td>
<td>2632</td>
<td>2773</td>
<td>1664</td>
</tr>
<tr>
<td>Urban railway mileage/km +</td>
<td>608</td>
<td>666.4</td>
<td>398.3</td>
<td>297.64</td>
<td>175.1</td>
<td>138.5</td>
<td>12.8</td>
</tr>
</tbody>
</table>

*: 2018 data, +: 2017 data

Data source: population and GDP from https://en.wikipedia.org/wiki/wiki; built-up area size and Road mileage in built-up area from MOHURD et al. [2019]; Car ownership and Subway operating from MMPS [2017].

3 Overview of TDM practice in China

The history of TDM practice in modern China may be traced back to Shanghai’s vehicle quota system (VQS). Remarkably, the city began to set a quota on newly issued licenses as early as 1994, when private car ownership was literally still in its infancy and its adverse effect was largely unknown to the country.

In the following, we provide an overview of the development of the various TDM measures in seven major Chinese cities since the rapid motorization began to run its course in China. As shown in Table 1, all cities considered herein have a population close to or over 10 million, and the largest two, Beijing and Shanghai, have more than 20 million. In terms of economy, Beijing, Shanghai, Guangzhou and Shenzhen are the so-called “big-four”, widely considered the Tier-I mega cities in China. In 2018, each of the big-four has a GDP over ¥2 trillion (about $300 billion), with Shanghai’s GDP exceeding ¥3.2 trillion (about $470 billion). Chengdu and Hangzhou are among the top Tier-II large cities, with a GDP ranging between ¥1 and ¥2 trillion. Located in Northeastern China, Harbin is a provincial capital city that has experienced a relatively low growth rate, especially in recent years. The size of its economy is about 1/6 of Beijing’s in 2018.

Among the seven cities, the highway length per million people ranges between 130 and 300 km. In Hangzhou, this index is about 293, whereas in Shenzhen it is only 132.2. In terms of the total highway supply, Beijing is the largest at 5143 km, followed by Shanghai’s 4030 km. Beijing and Shanghai also have the most extensive urban railway systems in China, operating 608 and 666.4 km railways, respectively. These are translated to roughly 27 km urban railway per million people. The two Tier-II cities, Chengdu and Hangzhou, are lagging behind in this aspect. They each have built a little over 10 km urban railway for each million people by 2017. Incidentally, these two cities also have the highest car ownership per thousand people in this group, significantly higher than that of their Tier-I counterparts whose economies are much larger.

Figure 1 summarizes the main TDM measures adopted by the seven cities following a chronological order. Of the six measures included here, two are voluntary measures (flexible work hours and priority of transit development) and four are mandatory measures (license plate rationing, vehicle quote system, parking pricing and external traffic control). Both license plate rationing and external traffic control aim directly at reducing car use. The difference between the two is that the former focuses on the vehicles that are registered in the city, whereas the latter targets vehicles that are not. We call those vehicles that don’t have a local license external vehicles.
All seven cities restrict the use of their streets by external vehicles. In fact, external control is the only measure adopted universally in this group. The second most popular measures, each implemented in six cities, is priority of transit development and parking pricing. Direct restriction on car ownership is being practiced by all big-four cities plus Hangzhou. The least popular measure appears to be license plate rationing, possible due to public resistance. Only three cities, Beijing, Chengdu and Harbin, have implemented it on a regular base. We should note other cities have used license plate rationing on special occasions. For example, Hangzhou has an odd-even rationing policy for one of its most crowded tourist attraction (West Lake area). Shenzhen had used, on and off, a similar policy on a very small number of roads close to its ports with Hong Kong.

Beijing is the only city that had implemented all six polices, which speaks to the pressure it faces to manage traffic congestion. Harbin had only adopted two, the least of the group, and it completely focused on direct restriction on car use (i.e. license plate rationing and external traffic control).

4 Case studies

In this section, we pick Beijing and Shanghai to conduct in-depth case studies of their TDM measures. Both cities are among the largest in the world in term of population and economic activities, and as a result, face similarly daunting challenges to meet the travel demand, especially for car use, of their residents. These two cities have, however, followed quite different paths towards the adoption of TDM policies. In what follows, we review these policies for each city, classified according to the taxonomy introduced in Sections 2 and 3.
4.1 Beijing

Located in northern China, Beijing is the capital of the nation, and the world’s third most populous city. It has a total area of 16,410.54 square km, including a built-up area of about 912 square km. Figure 2 shows the city’s population continued to grow since 2003, until peaked in 2016, when it reached just shy of 22 million. In 2003, privately owned vehicles numbered less than 1 million in Beijing. This number was quadrupled in merely 10 years, reaching more than 4 million in 2013 (Guo et al., 2015). To alleviate traffic congestion, Beijing implemented the following TDM measures: prioritizing transit development; flexible work hours; restricting vehicle use through license plate rationing and external traffic control; new vehicle quota system; and differentiated parking pricing. We discuss these measures in details next.

4.1.1 Voluntary measures


These policy guidelines have greatly expanded the capacity of Beijing’s transit systems. Between 2005 and 2017, Beijing’s urban railway system has increased its total service distance from just over 100 km to almost 600 km, forming a backbone high-capacity railway network that consists of 17 lines. In 2018, this system carries more than 8.537 million passengers each day and during the rush hour the busiest lines operate with headway close to two minutes. In the same period, Beijing has also overhauled its fixed-route bus system and made significant investment in Bus Rapid Transit (four lines were in use by the end of 2013, see Guo et al., 2015), as well as innovative transit services, such as mini buses (solution to the first- and last-mile problem), commuter express buses, and customized buses (on-demand made-to-order fixed route service). In 2013, more than 13 million passengers were served by Beijing’s bus system that operates more than 800 lines and 20,000 buses (Guo et al., 2015).

Not only did Beijing prioritize transit in its transportation planning, it also heavily subsides transit fare in order to attract passengers. Despite the high living cost in Beijing compared to the rest of the country, Beijing’s bus and railway fares are among the lowest among Chinese big cities. For example, railway ticket fare has been kept at ¥2 as late as 2014.

![Figure 2: The population of Beijing and Shanghai (Million). Data sources: http://calendar.hexun.com/area/dqzb_110000_D0060000.shtml](http://calendar.hexun.com/area/dqzb_110000_D0060000.shtml)
Flexible work hour  In 2010, Beijing implemented a flexible work hour policy in order to reduce the peak demand during the morning and evening rush hours. The policy enacted on April 12, 2010 shifts the work hours of most government workers by half an hour, from 8:30 AM - 5:30 PM to 9:00 AM - 6:00 PM. According to Baidu, this is the first implementation of such a policy for the purpose of travel demand management in China.

4.1.2 Mandatory measures

Vehicle quota system  In 2011, Beijing introduced its own vehicle quota system, limiting the total number of new vehicles allowed to be registered in the city in that year to 240,000 (about 88% are for private owners). As a comparison, between 2005 and 2010, roughly 400,000 vehicles were added into the city’s vehicle fleet on average annually. Unlike Shanghai’s VQS, Beijing’s new licenses are distributed using a lottery system among all eligible residents of the city. This design is primarily driven by the political concerns about equal access to mobility. The policy’s impact on the growth of car ownership is predictable and dramatic: it reversed the growth trend for the first time since 1984, cutting the growth rate from 14% in 2010 to 5% in 2011.

Beijing’s 2013-2017 Clean Air Action Plan states that by 2017 the city should keep its total vehicle population under six million. Accordingly, the quota of the VQS is reduced to 150,000—of which 20,000 are reserved for alternative fuel vehicles—in 2014. Four year later, in 2018, it is further reduced to 100,000, of which 60% are for alternative fuel vehicles. Thus, in the matter of less than a decade, Beijing suppressed the annual demand for new regular internal combustion engine cars by more than 90% (from more than 400,000 in 2010 to 40,000 in 2018), all through regulation.

For those who really need to own a car in Beijing, VQS has created a severe hurdle that can only be cleared by pure luck. The likelihood of winning a lottery was about 1 in 883 towards the end of 2017. By the end of 2018, the chance has become one in 2,000. Give that there are only six lotteries per year, this gloomy statistics means an average resident would literary have to wait for more than 300 years before she can win a license!

License plate rationing  Beijing first implemented license plate rationing in 2008, initially as an accommodation to the Olympics Games. The scheme adopted during the event was a drastic odd-even rationing, which basically takes away half of the vehicle fleet off the road. After the Olympics Games, Beijing introduced a less restrictive temporary rationing scheme starting on October 1st, 2008. The new scheme restricts access, based on the last digit of license plates, to the area inside the fifth ring road during the peak time (6 AM to 9 PM). Each weekday, two of the ten digits (0-9) are restricted (e.g., 1 and 6 for Monday), which means on average 20% of the vehicles cannot be used in the restricted area. Every thirteen weeks, the restriction rule is updated. In 2009, the peak time window was redefined as 7 AM to 8 PM. Another significant change was made in 2015, which gives exemptions to battery electrical vehicles. It should be noted that license plate rationing remains a “temporary” TDM measure in Beijing. The rule has to be renewed once a while, justified by the need to mitigate traffic congestion and air pollution.

\[\text{https://bkso.baidu.com/item/%E9%94%99%E5%8E%BB%E6%88%A6%E4%B8%8B%E7%8F%AD}\]
\[\text{https://finance.ifeng.com/a/20171226/15888587_0.shtml?_cpb_pindaotj5}\]
\[\text{http://www.yfyc.tv/qiche/yaohao/35967.html}\]
**External traffic control**  Beijing began to limit the access of external vehicles to the city’s core areas in 2011. The initial rule requires every external vehicle acquire a special temporary pass. In addition, external vehicles are banned from driving within the fifth ring during the rush hours (weekday 7 — 9 AM and 5 — 8 PM). They are also subject to the same license plate rationing rule applied to local vehicles.

The control on the external access has become increasingly harsh over the years, in part because the external temporary passes had become a loop hole exploited by the desperate residents who seek to bypass the VQS restriction. In 2019, a special temporary pass only lasts 7 days and a vehicle can get at most 12 passes a year[5](sources). Effectively, an owner of an external vehicle can only drive it 84 days in a year.

**Parking pricing**  The experiment of using parking price as a TDM measure started in 2011, when a differentiated parking pricing scheme was proposed to discourage access to the city’s central areas and on-street parking. The parking fee in highly congested areas during the peak time (7 AM to 9 PM) was increased to ¥5 per half an hour in the first hour, and to ¥7.5 per half an 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%, respectively, right after the new pricing structure was introduced (Guo et al. 2015).

Shortly after the initial rule was implemented, the area that implements the new rule was expanded and the price incremental time was adjusted from 30 minutes to 15. Studies suggest that the new parking rule has positively affected traffic conditions in the restricted area. Two months after the updated rule went into effect, it was reported that traffic flow in some of the most congested areas fell 11% to 12% (Guo et al. 2015). The gains, however, were not sustained, partly due to pervasive illegal parking behaviors (Guo et al. 2015).

### 4.2 Shanghai

Located in the Yangtze River Delta, Shanghai is the largest city in China by population, with a population of about 25 million as of 2018. A global financial center and maritime transport hub, Shanghai is located in one of the most developed regions of the country, with per capita GDP exceeding $20,000 in 2018. Similar to Beijing, Shanghai has continued to gain population at a fast pace since 2003, but the growth has slowed down after 2010 (see Figure 2). Since 2013, its population has peaked and stabilized. In many ways, Shanghai has been leading the TDM policy making in the country. It is the first to implement many of the measure considered in this note. We review these efforts in what follows.

#### 4.2.1 Voluntary measures

**Priority of transit development**  In "Urban Transportation White Paper" published in 2002, Shanghai first proposed to prioritize transit development. In 2007, the city government passed "Resolution on Prioritizing Urban Transit Development" and "Shanghai Three Year Action on Urban Transit Development 2007 – 2009". These regulations set in motion massive expansion of the urban railway system and significant improvement to the existing bus system. Between 2005 and 2017, the length of urban railway quadrupled from 148 km to 617 km. By the end of 2017,

the city operates about 1500 bus routes that amount to almost 25,000 km in operating millage. The length of transit-priority lanes had increased from about 160 km in 2011 to close to 400 km in 2017. Shanghai also subsides transit fare in order to attract riders, albeit to a lesser extent compared to Beijing. In 2007, it began to give discount to transferred riders and free access to senior riders\textsuperscript{6}.

4.2.2 Mandatory measures

Vehicle quota system As mentioned before, Shanghai began to restrict car ownership in 1994 by selling licenses through auction. Initially, the licenses were sold in a sealed bid reserve price auction (meaning no bids under a preannounced price would be accepted). In 2000, a new rule issued by Shanghai Municipal People’s Congress abandoned the reserve price (Xiao et al., 2017). The number of licenses sold via auction was modest in the first few years, totaling 11,000 between 1994 and 2000 (Xiao et al., 2017). The market began to take off after 2000, aligned with the rapid motorization in China. Between 2002 and 2013, the price of a license rose from about ¥20,000 to ¥80,000, earning for Shanghai’s vehicle license plate the reputation of “the most expensive piece of steel sheet in the world”.

In response to the public outcry, the city introduced the so-called “advisory price” in 2013, which is set as the weighted average of the market prices in the past three months (after removing outliers). The new rule dictates that the price proposed by a bidder cannot exceed the advisory price in the first bidding round. This rule has effectively slowed the price increase at the auction. The cost of acquiring a license in the May of 2019 was still kept below ¥90,000, a mere 12% increase in a period of six year.

Unlike Beijing, Shanghai does not have a rigid annual quota. Instead, the number of license sold varies by month. For example, in January of 2018, 12,183 licenses were sold in an auction participated by 226,316 bidders\textsuperscript{7}. In May of 2019, 170,794 residents competed to win 9,626 licenses in total. In fact, up until early 2019, the number of total licenses sold each year has been gradually increasing in Shanghai. In 2018, the total number of licenses sold through auction rose to its peak of about 130,000. Since the beginning of 2019, however, the monthly transaction began to drop below 10,000, likely because the government’s promotion of alternative fuel vehicles (especially electric cars) has finally reached a tipping point (Ge et al., 2018). Winning a license through an auction is still an unlikely event (with a probability of about 3% to 8%), and the willingness to pay only plays a relatively small role here due to the advisory price. Nevertheless, the chance is almost two orders of magnitude greater than winning a lottery in Beijing.

External traffic control Shanghai was a pioneer in terms of restricting access of external vehicles. This is probably not a coincidence, given its radically early implementation of vehicle ownership restriction. If an external vehicle can be used freely in the city, the VQS would have no effect at all. Shanghai controls external traffic by time and roads. In weekday, external vehicles are banned mostly from using the elevated expressways (including major bridges and tunnels) during the peak time, defined as 7-10 AM and 3-8 PM. In addition, Shanghai issues a special license (so-called ”C” license) for the residents living outside the Outer Ring Road. Vehicles with ”C” license are not allowed to be driven inside the Outer Ring Road.

\textsuperscript{6}https://wenku.baidu.com/view/a3550418f18583d049645969.html
\textsuperscript{7}http://www.51chepai.com.cn/paizhaojiage/
Parking pricing  The “Urban Transportation White Paper” of 2002 named the parking policy as a TDM measure, emphasizing the role of price differentiation based on areas. In 2013, an updated version of the White Paper further emphasizes the role of parking in traffic management. It specifically suggests area-based parking supply, pricing and management should be used to manage the demand for car use. However, we have not found direct evidence that these high level policy objectives have not been fully translated to tangible TDM policies.

4.3 Comparison

Figure 3 compares several metrics of the two cities to gauge the outcomes of their TDM policies. Figure 3 (a) shows that the per capita car ownership in Beijing is more than doubled that in Shanghai before 2015. This is the clearest evidence that Shanghai’s early adoption of VQS had worked. On the other hand, Beijing’s vehicle ownership growth had significantly slowed down in recent years, thanks to its increasingly aggressive VQS policy. Yet, by the end of 2018, Beijing still has 100 more vehicles for every thousand people than Shanghai does, a gap that will take a long time to close. This discrepancy might explain, at least partially, why Beijing’s congestion is consistently worse (see Figure 3 (d)).

Figure 3(b) shows the two cities’ urban railway systems had gone through an almost identical rapid development phase. Between 2006 and 2016, each city added roughly 2 km railway per million people per year. Interestingly, the trend for the bus system is quite different in the two cities (see Figure 3 (c)). Whereas Shanghai’s bus operating millage saw a modest but steady growth between 2011 and 2017, Beijing’s has been declining at a faster rate during the same period. In 2011, Shanghai has only a negligible lead (about 1%) in terms of bus operating millage per million people. By the end of 2017, the gap has grown to more than 10%. It is unclear what has contributed to this rather significant downturn in the provision of bus services in Beijing.

5 Discussions

The most popular TDM policy solution in Chinese mega cities is the combination of (1) priority of transit development (with a strong focus on urban railway system), (2) vehicle quota system and (3) external traffic control. The fact that all big-four (Beijing, Shanghai, Guangzhou and Shenzhen) chose this solution suggests that it may be the most effective among all that are politically feasible and technologically practical in China. This solution does make sense, at least from the point view of a central planner who is eager to alleviate traffic congestion. Together, the second and third measures directly control the root of congestion: the unsustainable growth of car population in the city. On the other hand, the first measure aims to fulfill the travel need of the residents, whose ability to own a car is now severely limited, by making better public transportation available.

When implemented in the above package, VQS was indeed a very effective tool to curtail the unsustainable growth of motorization. It clearly explains why the average per capita vehicle ownership is about 30% lower in the big-four than in some of the smaller and poorer Tier-II cities (e.g. Chengdu). In hindsight, Shanghai did the right thing to follow Singapore’s lead and adopt this strategy at a time when it might well have been perceived as an overreaction. The early action gave Shanghai more flexibility to manage its motorization process, and might have

8http://www.tranbbs.com/application/Parking/application_160867.shtml
Figure 3: Key transportation metrics: Beijing vs. Shanghai. Data sources: car ownership from [http://calendar.hexun.com/area/dqzb_110000_D0940000.shtml](http://calendar.hexun.com/area/dqzb_110000_D0940000.shtml); congestion index is from [https://report.amap.com/download.do](https://report.amap.com/download.do)
“primed” and prepared its residents better for what was coming. Instead of being forced to progressively tighten the control (as in Beijing), Shanghai was able to gradually adjust its quota upwards in later years to meet the demand of a growing population. This ability is largely due to the “reservoir” created by the brake applied in the early phase of motorization. As a result, a resident in Shanghai is almost 100 times more likely to own a car than her counterpart in Beijing, despite the fact that Shanghai has a larger population and economy. The difference that a forward-looking TDM policy can make on citizens’ welfare seems rather striking in this case.

Interestingly, the policy that has been universally praised by experts—congestion pricing—is currently missing from the Chinese TDM practice. In fact, both Beijing and Shanghai had considered congestion pricing policies seriously. Beijing began to study congestion pricing in 2010. “Beijing Transportation Development Plan in the 12th Five Year Period”, published in 2012, proposed to implement congestion pricing in the 12th five year period (i.e. 2011 - 2015). This proposal was reaffirmed in Beijing’s 2013 - 2017 Clean Air Action Plan. In Shanghai, the policy has been on the radar since 2002, and a widely reported attempt to promote it occurred in 2013, when it was included as one of the TDM measures in a white paper on transportation. These efforts have yet to produce any actual policies, however. In 2016, the World Resource Institute (WRI) and Beijing Jiaotong University (BJTU) conducted a survey on the public opinion about congestion pricing. They found almost half of the respondents oppose such a measure, more than doubling the number of supporters.

The anecdotes that the authors gathered from talking to practitioners and academics in China suggest that congestion pricing is deeply unpopular politically there, so much so it is considered by some decision makers as “politically incorrect”. For a country known for its strong executive power, this cautious attitude towards congestion pricing is surprising if not puzzling at the first glance, especially since more coercive measures such as license plate rationing have been pushed through successfully, despite the public opposition. The failure of congestion pricing in China may be attributed to three reasons. First, there is a legitimate concern about the inequality created by the policy, as it has the reputation of benefiting the rich at the expense of the poor. The government, under the pressure to maintain social harmony, prefers perceived equity over efficiency in policy making. Second, implementing congestion pricing is a more delicate effort than the other measures. It is no easy feat to design a pricing scheme to deliver a desired relief to traffic congestion, while ensuring it does not agonize too many users. In addition, collecting tolls not only is expensive, but also threatens infringement of privacy. Third, congestion pricing is a less straightforward concept to the general public. It is difficult for a layman to not mistake it with “yet another tax” and question what he has to gain from it. Consequently, the misconception about the logic and intention behind the policy exacerbates suspicion and resistance.

We close by noting that none of the three obstacles should prevent Chinese cities from including congestion pricing in their TDM toolkit in the future. There are many ways to address the regressive welfare effect, such as providing travel allowance and creating a cap-and-trade market for mobility credits. For the cities that have already implemented license plate rationing, turning the “right to drive on a day” into a tradable commodity is economically sound, technologically feasible and politically acceptable, as demonstrated in Nie (2017a). In addition, mobile computing and social platforms have made it possible to develop individualized TDM measures that can

---


deliver incentives and nudges, as well as tolls, to influence travel behaviors in real time. These technologies, along with the theories that are being developed to harness their power, promise a comprehensive and sophisticated TDM platform that includes congestion pricing as an integral component. Last but not least, the aforementioned WRI-BJTU survey shows those who are more knowledgeable about congestion pricing tend to like it better. Thus, education and outreach play an important role in shaping the public opinion and should be given more considerations when the next Chinese city decides to take up this challenge.

References


URL https://www.epa.gov/ghgemissions


