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Article

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Abstract
Peak car has happened in most developed cities, but for the 1.5 °C agenda the world also needs emerging cities to go through this transition. Data on Beijing shows that it has reached peak car over the past decade. Evidence is provided for peak car in Beijing from traffic supply (freeway length per capita and parking bays per private car) and traffic demand (private car ownership, automobile modal split, and Vehicle Kilometres Travelled per capita). Most importantly the data show Beijing has reduced car use absolutely whilst its GDP has continued to grow. Significant growth in electric vehicles and bikes is also happening. Beijing's transition is explained in terms of changing government policies and emerging cultural trends, with a focus on urban fabrics theory. The implications for other emerging cities are developed out of this case study. Beijing's on-going issues with the car and oil will remain a challenge but the first important transition is well underway.

Keywords
Beijing; emerging cities; peak car; traffic demand; traffic supply; urban fabrics

Issue
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1. Introduction

Some developed cities witnessed a plateau in per capita car use in the early part of this century, which became known as 'peak car' (Headicar, 2013; Newman & Kenworthy, 2011; Puentes & Tomer, 2008; Stanley & Barrett, 2010). The phenomenon of peak car provides hope for reductions in oil consumption and greenhouse gas (GHG) emissions (Goodwin, 2012; Millard-Ball & Schipper, 2011; Newman, Beatley, & Boyer, 2017). However, it will not help agendas like the UNFCCC agenda to reach 1.5 °C, unless the vast mega cities of the emerging world also undergo peak car. This article will examine the extent to which Beijing is demonstrating peak car as an example of how close the emerging world could be to contributing positively to the 1.5 °C agenda. The question underlying this article therefore is whether peak car is happening in one of the world's largest and fastest growing emerging cities.

China was well known as the 'kingdom of the bicycle' in the 1980s. The modal split of daily trips by bicycles was as high as 63% in Beijing in 1986 (BJTRC, 2015). Beijing was then recognized as a Non-Motorized Mode City (NMM) in 1995 in a global cluster analysis (Priester, Kenworthy, & Wulfhorst, 2013). However, the Chinese bicycle culture had started to decline by the end of 20th century as a direct result of Chinese economic growth, urban development and the prosperity of the Chinese automotive industry (Gao & Kenworthy, 2016). China replaced the US as the largest automobile producer and consumer from 2009 (Gao, Kenworthy, & Newman, 2014). The resulting affordability and availability of automobiles facilitated rapid growth in car use across Chinese cities. Beijing is an example of how the bicycle was rapidly replaced with automobiles: automobile modal split went from a meager 5% in 1986 to 34% by 2010. The resulting traffic did not suggest that Beijing had much hope of contributing to any agenda on reducing automobile-based emissions.

The popularity of automobiles in China undoubtedly facilitated economic growth and urban mobility. However, it also generated negative impacts upon the Chinese economy, society and environment, especially in relation to oil consumption, GHG emissions and smog emissions, some of the most pressing problems for urban sustainability. The potential to reduce such environmental impact was not seen to be very high as the economic conditions leading to reduced environmental impacts in the developed world happened at much higher levels of per capita economic development (Asian Development Bank, 2012). However, the theory of what brings such change suggested that rapid urbanization could also bring about a new set of priorities that enable higher environmental concern and priority. As China's built-up area increased six-fold in 28 years from 1987 (Ministry of Housing's China Urban Construction, 2015), it was quite clear that rapid urbanization was a Chinese characteristic.

Part of the response that leads to change of priorities in cities is how quickly governments respond to the new needs of such rapidly growing cities. Part of the necessary government change happened in recent times due to the global climate debate. China has been a strong part of the global climate change agenda for over a decade. The Paris Agreement came into force in 2016 and aims to 'keep a global temperature rise this century well below 2 °C above pre-industrial level and to pursue efforts to limit the temperature increase even further to 1.5 degree Celsius' (United Nations, 2015). China signed the agreement and took a strong stand that it will meet their commitments of 60–65% reduction in carbon dioxide emissions per unit of GDP (Gross Domestic Products) by 2030 from the 2005 level (NPC, 2016). Beijing, as the national center of politics, culture and foreign relations, was necessarily a major part of the new climate agenda and, its transition will be a live demonstration of how cities can take a bold step towards creating a more sustainable urban environment.

The transition to peak car should not therefore have been a great surprise but indeed the changes are still quite remarkably fast and thus the data will be set out showing trends in car ownership and car use, transit trends and traffic infrastructure, as well as GDP data and electric vehicle trends. An attempt will then be made to explain the phenomenon through government policies and urban planning theories.

2. Traffic Demand, Private Car Ownership and Use

Chinese cities, along with their respective provinces, have increased their car ownership over recent years and now provincially range in car ownership from a meager 51 per 1,000 persons in Tibet, up to 198 per 1,000 in Beijing, with a national average of 93 per 1,000 persons (see Figure 1). This national level of car ownership is less than countries such as Swaziland, El Salvador, Honduras, Guyana and Azerbaijan (NationMaster Online Database, 2016). These levels are nowhere near the car ownership levels found in cities in more developed countries. For example, in 2005–2006, cities in the US averaged 640 cars per 1,000 persons, Australian cities 647, Canadian cities 522, and European cities 463 per 1,000 persons (Newman & Kenworthy, 2015). Thus, Chinese provinces and cities, even during what could be called a rampant period of motorization, had by 2015 not even come close to car ownership rates in more automobile dependent regions, and were even less nationally than in some significantly less developed countries.

Private ownership of motor vehicles especially small- and mini-sized passenger cars stimulated the growth of the total number of motor vehicles to some degree as shown in Figure 2. A fear of the consequences of China's growing vehicle ownership on traffic and air quality led to dramatic restrictions on car ownership and use. Beijing has rationed road space in 2008 to limit car travel and deployed an unpaid lottery system in 2010 to distribute license plates to public applicants to cap the number of new car registrations (BMCT, 2010). Besides these, the other Transportation Demand Management (TDM) policies like the termination of national pro-car policies designed to assist the economy during the global financial crisis (GFC) (Ministry of Finance, 2011a, 2011b, 2011c) have also accelerated the sharp drop in the growth rate of private car ownership (see Figure 2). There was just a 3% growth rate in 2011 compared to 2010 level of 23%.

The actual car use, different from car ownership, is reflected by per capita Vehicle Kilometres Travelled (VKT) and modal split of daily trips by automobiles. Per capita, VKT has increased steadily through the beginning of the 2000s and then peaked in 2010 before sharply declining despite the continuing economic growth (see Figure 3). It is set out showing how the decline is not caused by a decline in economic growth; on the contrary car use has declined during a period of substantial economic growth in Beijing. This is 'peak car' as seen in most developed cities and now clearly evident in Beijing, though a little delayed from the peak around 2004 in US and Australian cities (Newman & Kenworthy, 2015).

The GDP increasing is an important parallel result for the global agenda which is seeking to eliminate extreme poverty and other important social objectives through the SDGs. The 1.5 °C agenda is unlikely to be met unless emerging cities are going to begin a peak car transition whilst also achieving economic and social development goals. Figure 3 suggests that this may be possible. It is important therefore to see how Beijing seems to have achieved this.

The data on Beijing's modal split show a similar critical turning point to peak car around 2010 when the pro-

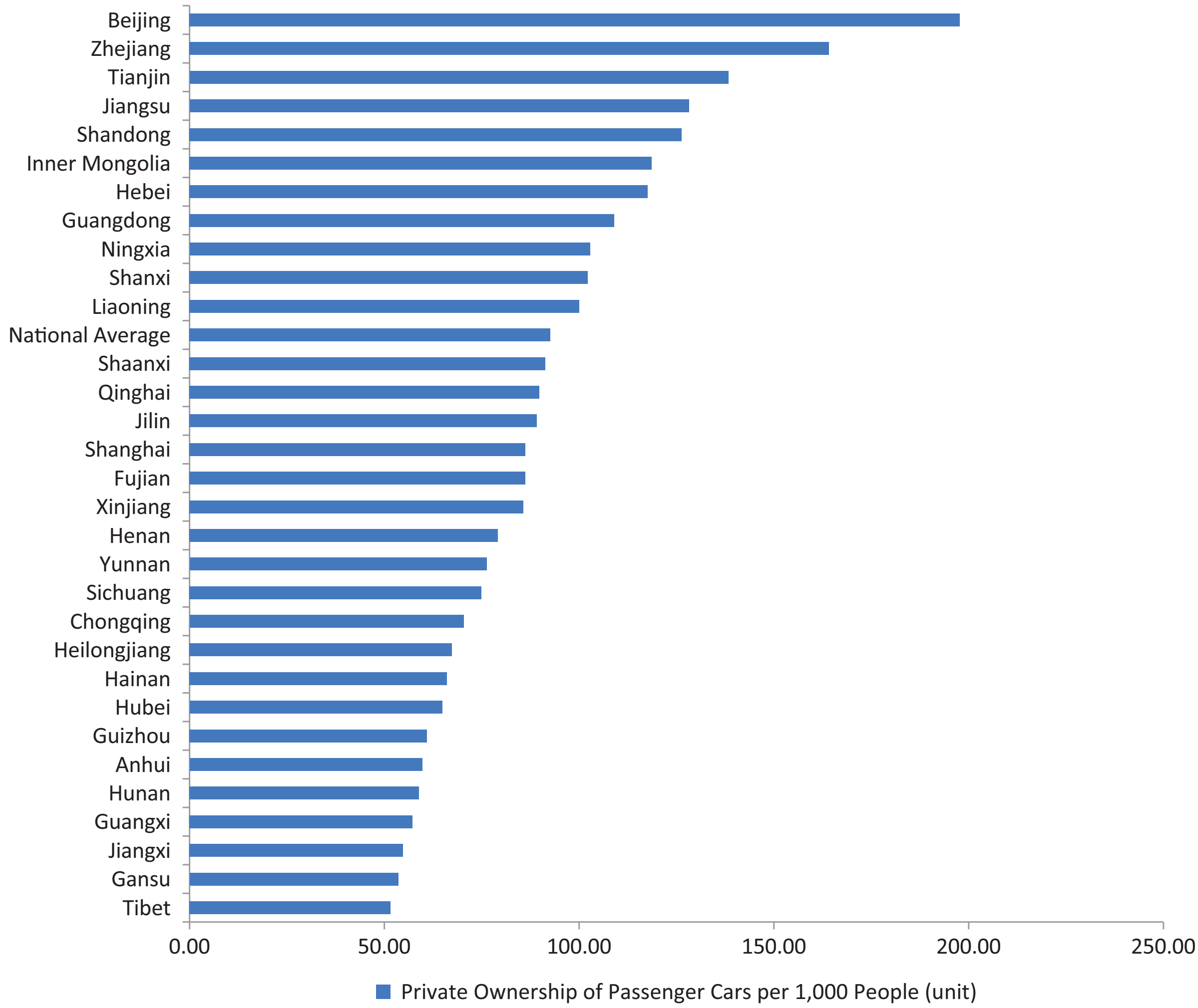

Figure 1. Private ownership of passenger cars per 1,000 people across China in 2015 (unit). Source: Compiled based on data provided by the National Bureau of Statistics of the People's Republic of China (NBSC, 2016).

portion of transit use began to increase sharply and the proportion of car use began to go down after initially replacing bicycle use (see Figure 4).

The switch to transit is due to a rapid growth in the provision of urban rail through municipal and national support especially the Five-Year Plan, a package of incentives to assist the national economy and social development. The Tenth Five-Year Plan in China 2001–2005 was the first to embrace 'developing urban rail transport' and then the Twelfth Five-Year Plan (2011–2015) started strong encouragement of the public transport system, including the dramatic growth of Metro systems across the nation's cities. Quality transit appears to be the first clear policy to assist in achieving peak car goals. Further data on how this was done is therefore examined in terms of investment trends in road and rail.

3. Changing Development Trends in Infrastructure

Beijing operated its first metro line in 1969 and it took 33 years to complete two more lines (BJMBS, 2016). The Metro system in Beijing since then has undergone rapid development, starting with the 2008 Olympics with 3 new lines constructed from 2007 to 2008 and then continuous expansion until the present. The expansion of the Metro is clearly shown in Figure 5 below from 2 lines, 54 km of track and 469 million passengers a year in 2001 to 18 lines, 554 km of track and around 3,324 million passengers a year in 2015 (around 9 million passengers a day). Bus patronage share has declined as the rail system grew (see Figure 5).

At the same time as investment in rail grew, there has been a reduction in the priority given to freeways and parking infrastructure for cars in Beijing despite continuous increase in economic capacity (see Figure 3) and traffic demand, both of which decline in per capita terms in the period leading up to the decline in per capita car use (see Figure 6). This is significant for any emerging city wanting to reduce its car use.

4. Spatial Distribution of Population

In Beijing there are 16 different sub-divisions governed directly by the Beijing Municipality (BJMBS, 2016). These

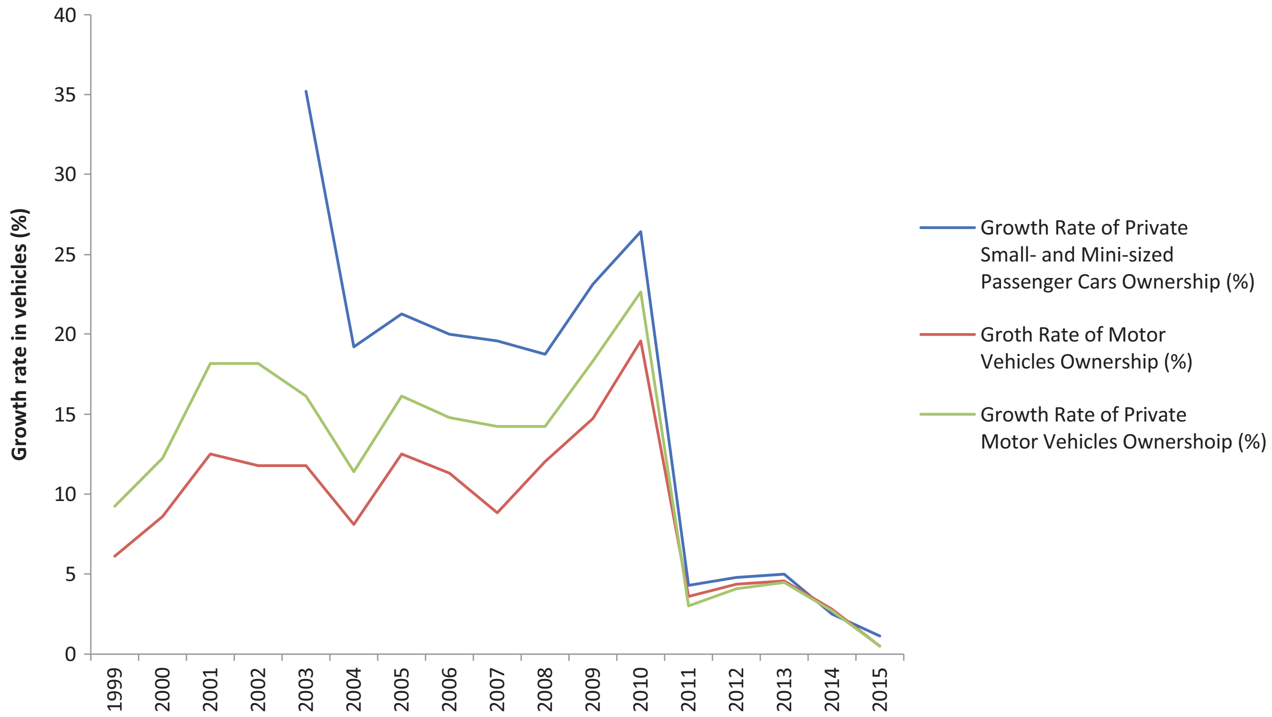

Figure 2. Comparisons of growth rate of ownership between motor vehicles, private vehicles and cars in Beijing from 1999 to 2015. Source: Compiled from data provided by the Beijing Transportation Research Centre (BJTRC, 2002–2015, 2016).

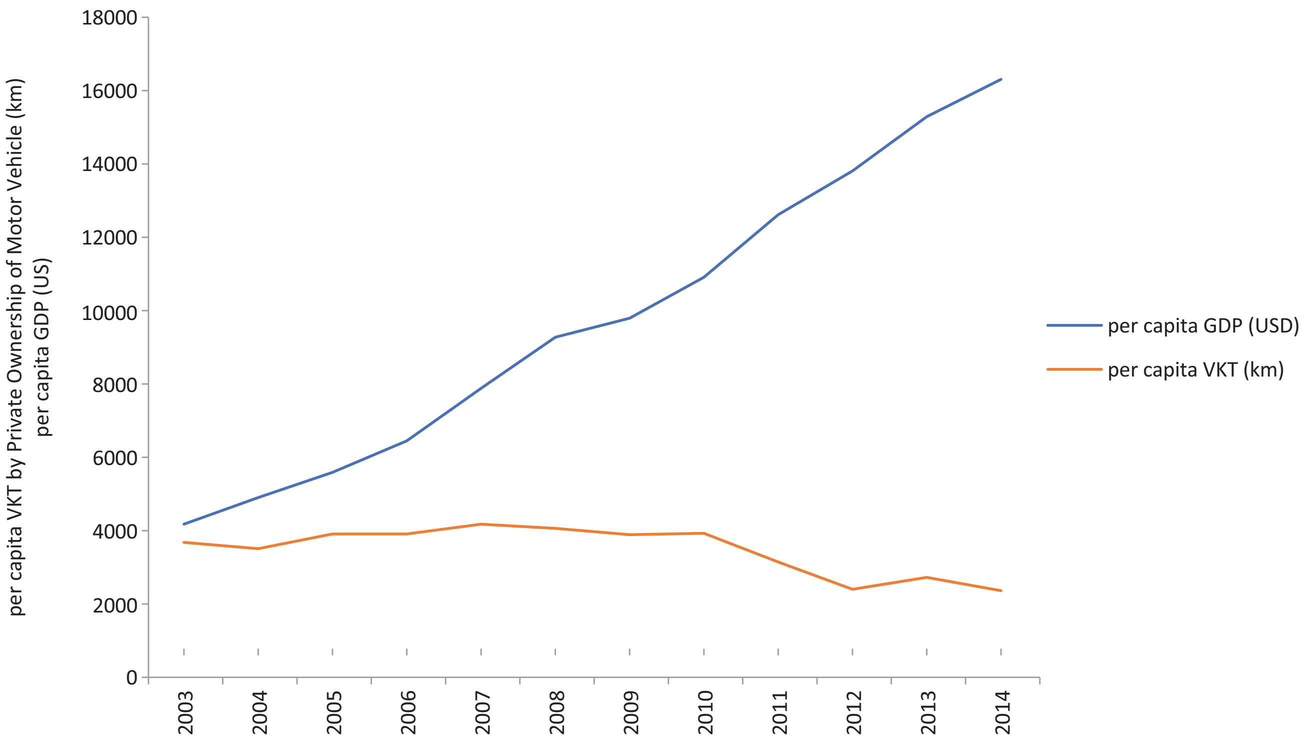

Figure 3. Peak car in Beijing: relationships between economic performance and private automobile use in Beijing from 1986 to 2014. Source: Compiled based on data provided by the Beijing Municipal Bureau of Statistics (BJMBS, 1982–2015, 2016) and the Beijing Transportation Research Centre (BJTRC, 2002–2014, 2015).

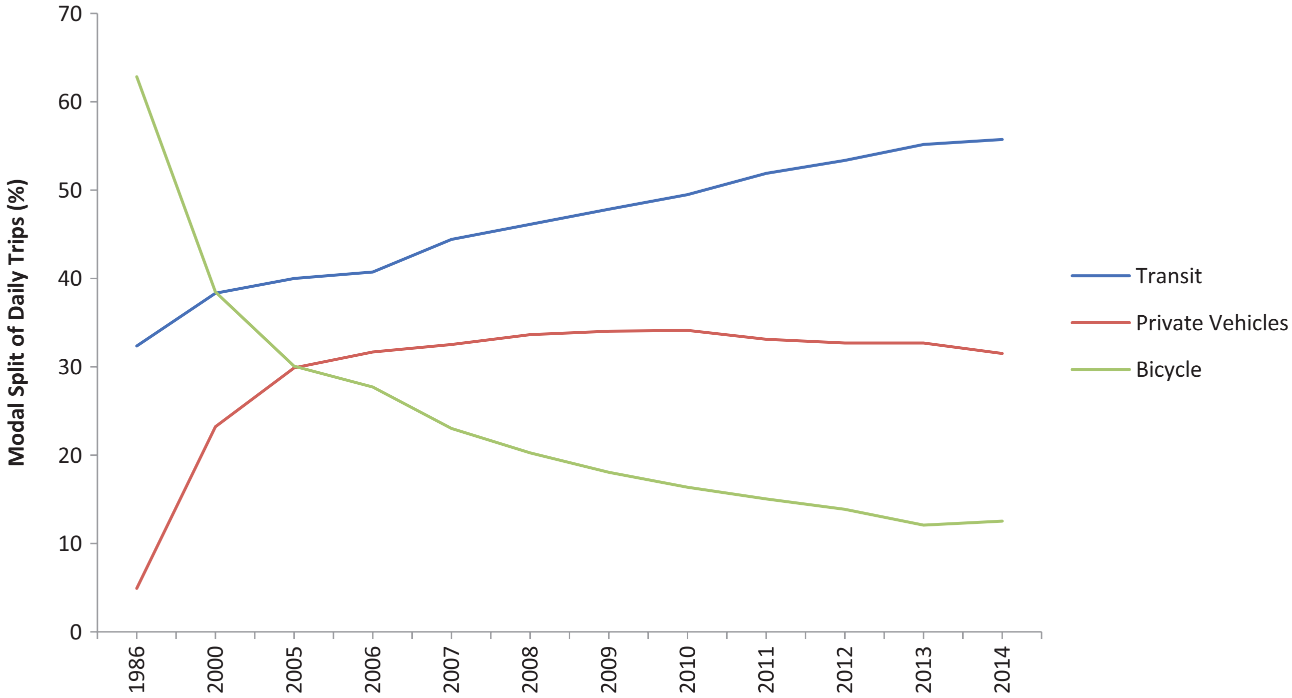

Figure 4. Modal split of daily trips in Beijing (excluding walking). Source: Compiled based on data provided by the Beijing Transportation Research Centre (BJTRC, 2002–2014, 2015).

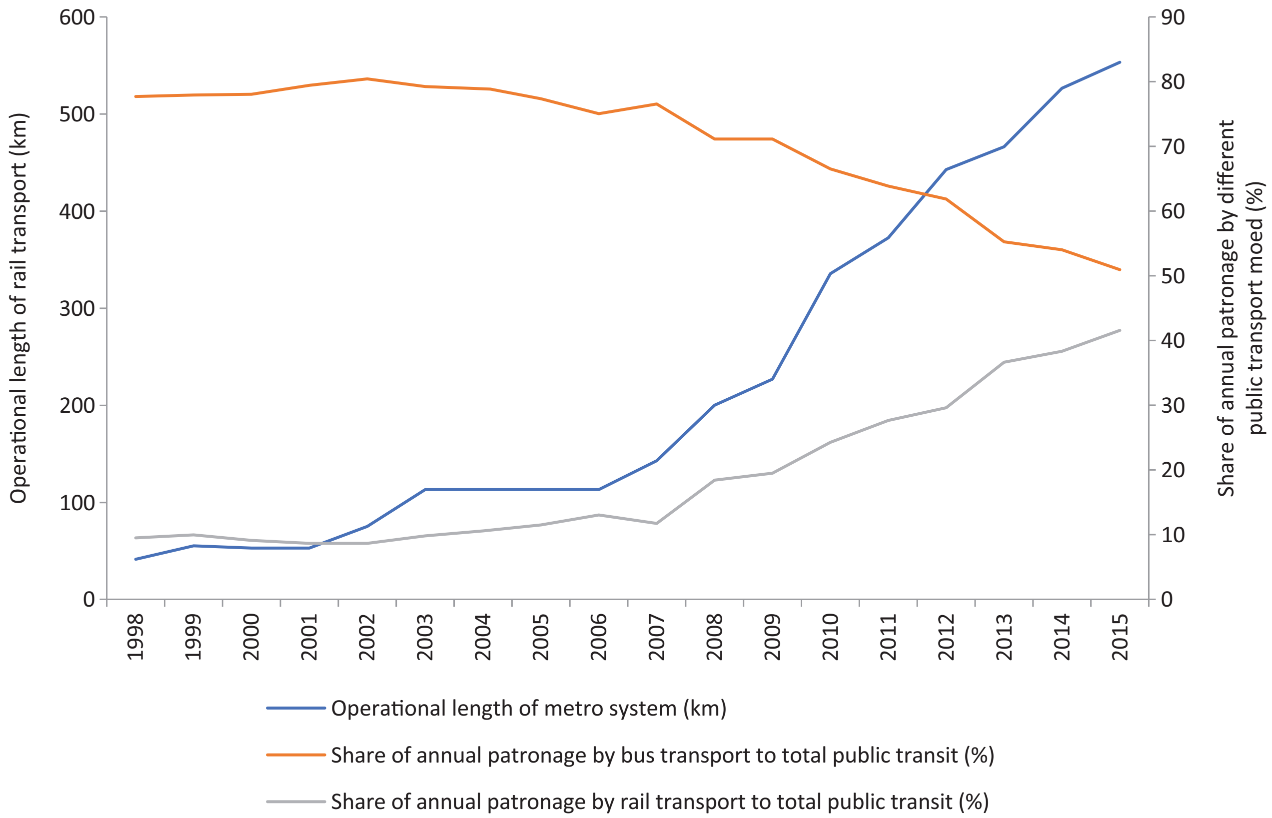

Figure 5. Operational length of rail transport and the share of annual patronage by rail transport to total public transport modes in Beijing (including rail transport, taxi, bus and trolley bus). Source: Compiled based on data provided by the Beijing Transportation Research Centre (BJTRC, 2002–2014, 2015).

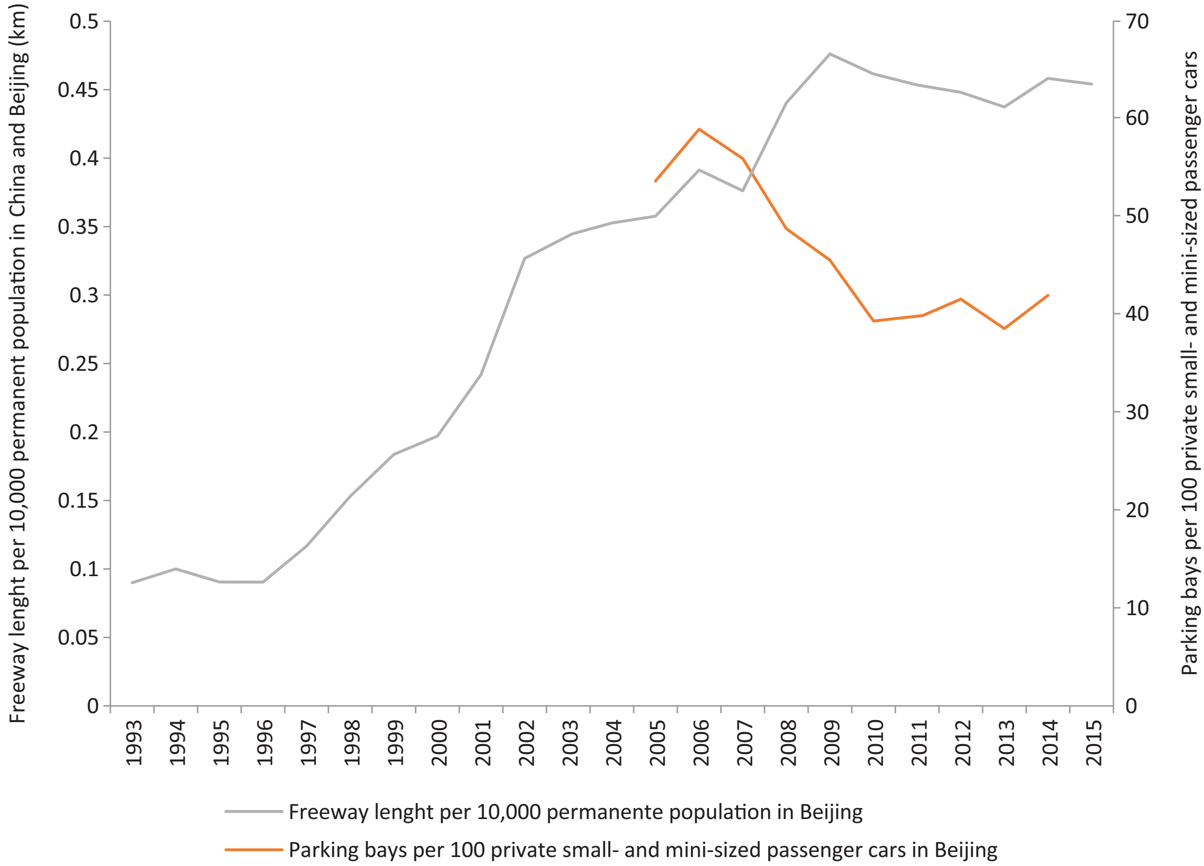

Figure 6. Trend of freeway length per 10,000 permanent population (km) and parking bays per 100 private small- and mini-sized passenger cars in Beijing. Source: Compiled based on data provided by the Beijing Transportation Research Centre (BJTRC, 2015) and (BJMBS, 1994–2015, 2016).

16 districts are also categorized into four different types for economic development and environmental protection perspectives. Table 1 defines the three different types of districts according to their distinct urban fabric (see Table 1).

The spatial distribution of the population plays an important role in per capita car use (Headicar, 2013). Usually the outer suburbs have much higher car use than the inner and central areas (Newman & Kenworthy, 2015). In Figure 7 the central city has remained static in population over the past decades but the inner and outer areas have both grown substantially. The data would suggest that the inner area growth has enabled low car use destinations to be able to grow more swiftly than the higher car using areas and together with Metro lines going to all parts of the city, the overall result is reduced car use.

5. Urban Density and Urban Fabric

The data on transport and infrastructure are clearly suggesting a major discontinuity between the growth in car use that would have been expected in an emerging city like Beijing and the actually observed peak car use. The difference is likely to be a combination of these transport and infrastructure priority changes and the fundamental land use in the city.

The 'Theory of Urban Fabrics' explains the interactive relationship between urban transport and urban form (Newman, Kosonen, & Kenworthy, 2016). It identifies three distinct urban fabrics by the priority of transport infrastructure systems: Walking city (pre-history to the 1850s), Transit city (1850s to the 1950s) and Automobile city (from the 1950s). Car use declines exponentially with urban density increases (Newman & Kenworthy, 2015) and thus as the densities declined in each of these three phases the amount of car use has tended to go up. However, in recent years in all developed cities people began to move back into walking and transit urban fabric and hence densities began to go up again leading to a decrease in car use.

The spatial data would suggest that the transit fabric of inner areas, where most growth has happened, has been a factor in these reduced car use levels. However, there is another factor as even the outer areas have substantial density levels that make transit and walking options much easier. In China, the cities were very dense during the historic walking city period and the transit city period as well with high-rise buildings stretching along corridors. The recent rapid urbanization period has continued to build at high densities as extra layers around the old cities were built. The density was thus significantly higher than in developed world cities.

Table 1. Different categories of districts in Beijing. Source: Compiled based on data provided by the Beijing Municipal Bureau of Statistics (BJMBS, 2016).

Administrative Division	Four Different Types of Functional Zones	Three Different Types of Districts with Different Urban Fabrics
DongCheng Xicheng	Capital Economy Code Zone	Central City
Haidian Chaoyang Fengtai Shijingshan	Municipal Development Zone	Inner Area
Tongzhou Shunyi Fangshan Daxing Changping	Municipal Development New Zone	Outer Area
Huairou Pinggu Mentougou Miyun Yanqing	Ecosystem Development Zone	

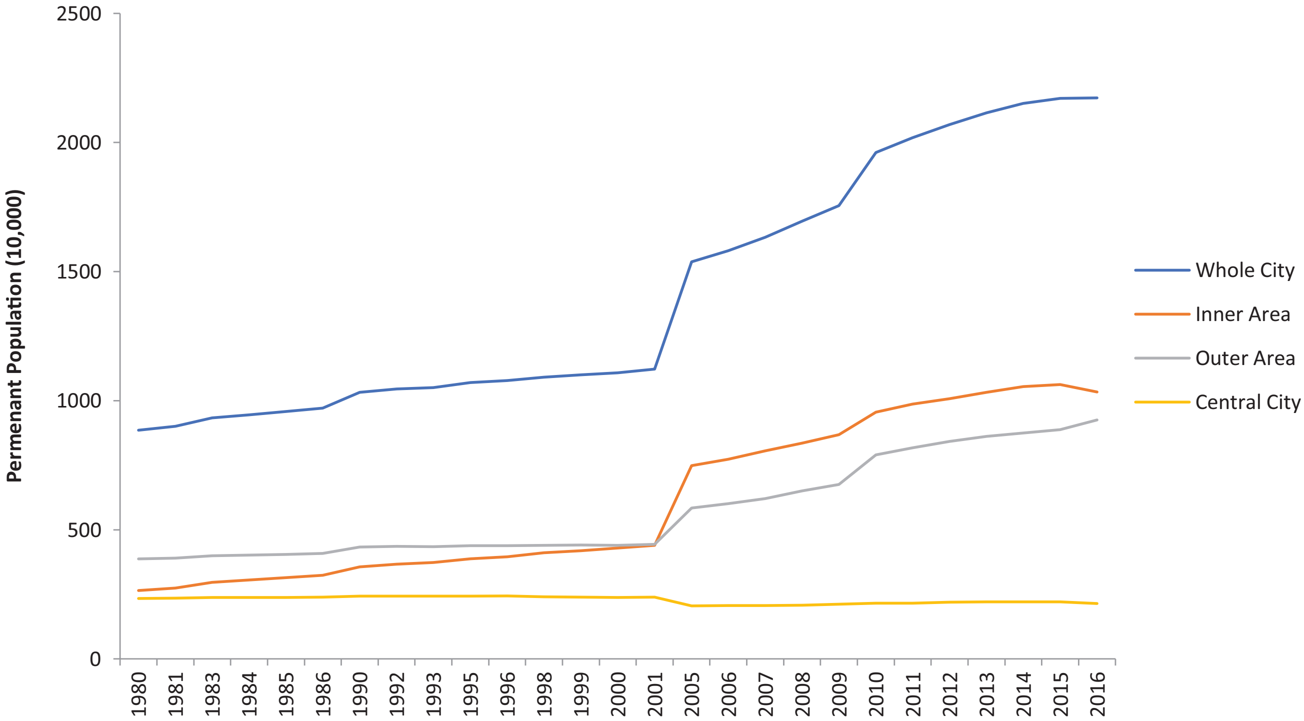

Figure 7. Changing spatial distribution of population in Beijing (10,000) from 1980 to 2016. Source: Compiled based on data provided by the Beijing Municipal Bureau of Statistics (BJMBS, 1982–2015, 2016).

The central city in Beijing features typical walking city fabric, with urban density of close to 250 persons per ha (see Table 2). The inner area is less dense but it is still in favour for walking and cycling. The whole city becomes denser despite the urban expansion, typical of European transit-oriented regions (see Figure 8). The outer area features the lowest urban density in Beijing, but still the high end of automobile city fabric found in Australian and US cities.

From an international comparison perceptive, Beijing is not an automobile city even in the rapid course of urban development and automotive industry prosperity. It features walking and transit urban fabrics, with increasing urban density.

Table 2. Urban density (persons/ha) by different districts in Beijing from 1980 to 2013. Source: Compiled based on data provided by the Beijing Municipal Bureau of Statistics (BJMBS, 1982–2015, 2016).

	Central City	Inner Area	Outer Area	Whole City
2009	229.08	94.93	21.86	42.86
2010	234.61	103.11	25.15	47.16
2011	233.31	105.70	25.75	48.07
2012	238.19	107.46	26.29	48.90
2013	240.04	109.51	26.69	49.62
2014	240.15	111.17	27.00	50.23
2015	239.06	111.51	27.29	50.50

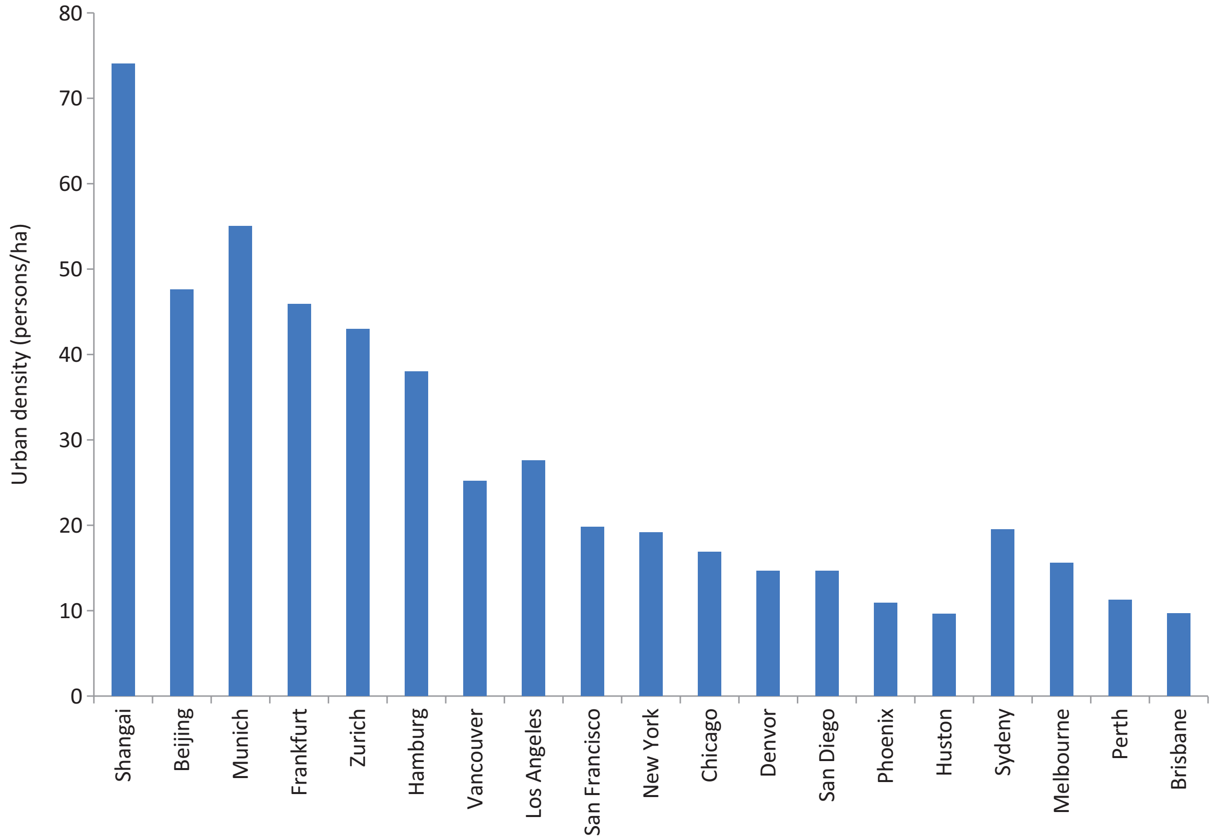

Figure 8. Comparisons of urban densities between Beijing and other cities in the developed world in 2005. Source: Compiled based on data provided by the Beijing Municipal Bureau of Statistics (BJMBS, 1982–2015, 2016) and Newman and Kenworthy (2015).

This difference in density can be explained in terms of different cultural traditions about urban space with the anti-density tradition of Anglo-Saxon countries (including the UK, the US, Australia, Canada and New Zealand) (Newman & Kenworthy, 1999), whilst in Chinese cities the cultural tradition is much more pro-density (Gaubatz, 1999; Lin, 2007) leading to traditional compact urban form. This traditional urban form has paved the foundation for a lower level of car use and peak car in Beijing.

The low rise, high density blocks which characterize China's traditional way of building local neighborhoods rather than the western-style low-density and single-family detached houses, facilitate the walking-scale environments typical of Chinese cities. In particular, the mixture of residential, commercial and recreational land use within these traditional Chinese communities provides local shops, small public spaces (squares or playgrounds) and other community services. It enables these local areas to cater for their daily necessities within walking distance. The close proximity generated by the short blocks also shortens the pedestrian walking distance (Ewing & Cervero, 2010). Finally, this type of urban form helps to facilitate and operate more efficient public transport for these communities.

As well as the organic density of traditional Chinese cities there has been a long commitment to planning the city into a central square with dense linear corridors leading to the centre. This is known as the imperial-centred and axisymmetric urban form, which is affected by the Doctrine of the Mean (Sit, 2010). The Kao Gong Ji document presents a city centre based on a square or rectangular shape, a pattern that was developed during the Dynasty of Western Zhou (1046BC–771BC) and led to the traditional road grid. This chessboard-like urban form based on small block sizes with multiple route choices is ideally suited to walking which has dominated Chinese urban transport for thousands of years. It also laid the foundation for the later construction and development of efficient public transport corridors across many Chinese cities and because it was dense and had relatively clear roadways it was also suitable for the bicycle that grew rapidly in China from the end of the 19th century (Gao, Newman, & Webster, 2015). Then when trams came they followed these roads and took them further out into longer corridors.

When this road structure is combined with high density and mixed land uses, as it is in China, it means that the major parts of Chinese cities were fundamentally Walking and Transit City fabrics and became an entrenched part of how cities were built in the Chinese cultural and political landscape. Automobile fabric only develops where a new kind of urban form is sought further out from the fabric already there and at considerably lowers densities. This did not happen very much in China, instead the city fabric from the walking and transit eras were rebuilt at much higher density and followed the same corridor-based form into new areas.

Beijing has served as the capital for six dynasties, and also for New China since it was established in 1949. The Forbidden City has been at the heart of the whole city, with other important buildings symmetrically distributed around the central axis. Until today, its traffic corridors such as the Metro system and highway loop roads are still following the urban pattern (the red building in the centre of the Beijing subway system shown in Figure 9 is The Palace Museum).

6. Future of Beijing, Other Chinese Cities and Emerging Global Cities

Sustainable development is listed as one of seven main strategies for Chinese national development in the latest 19th National Congress of the Communist Party of China (NPC, 2017). The Five-Year Plan has evolved from encouraging private vehicles to propel economic growth towards 'Prioritising Public Transport' since the Twelfth FYP, 2011–2015 (NPC, 2011). China has adopted limitations to control private car ownership and use and to continue to prioritize urban public transport at the national and municipal levels. Thus, it is not expected that peak car in Beijing is likely to reverse and begin growing again.

In addition to legislation aiming to make automobile travel less needed or encouraged, changing social trends are in favour of alternative modes over automobiles. In China, the docked public bicycle program is supported by local government and a dockless shared bicycle system is being operated by a market for over 200 million shared bikes across urban China. They provide a gateway for casual users and tourists and increase the access and uptake for bicycle users (Mason, Fulton, & McDonald, 2015). The lightly motorized mode, e-bikes, has replaced the normal bicycle as the dominant cycling mode with over 250 million e-bikes now operating across the country. In Shanghai, the e-bike modal split soared from 3% in 1995 to just over 20% in 2014, while bicycle use dropped from 39% to 7% (SCCTPI, 2016).

The peak car phenomenon in Beijing is a powerful signal that 1.5 °C agenda can be approached in such emerging cities. The other part of the 1.5 °C agenda is electric transport. This is being done for air quality reasons as well as climate emissions. China is the largest electric car market around the world in 2016, with 336,000 new-registered cars—doubling the sale in the US. It has

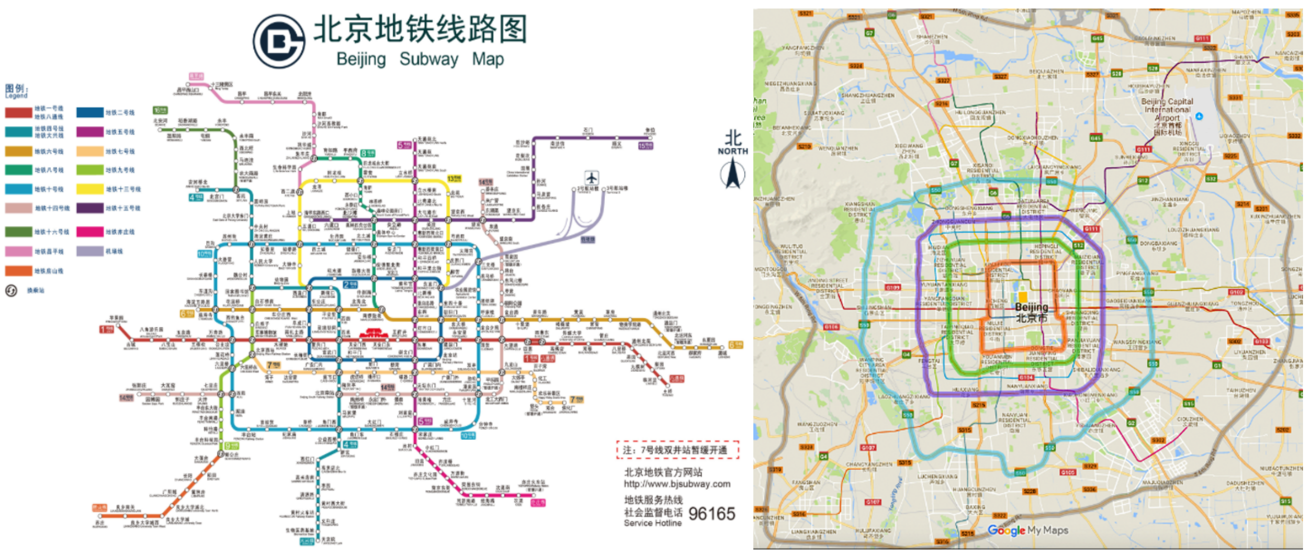

Figure 9. Beijing subway map, updated to 2017 (left), and map of ring roads in Beijing (right). Source: Compiled based on data provided by the Beijing Subway Official Website (2017) and Google Maps.

also exceeded the US with the largest electric car stock since 2016 (International Energy Agency, 2017). In China, an app-based car-sharing program has also emerged since 2012 with total passengers dramatically increasing up to 300 million in 2015. Such trends would suggest Chinese cities would continue to decline in transport-related GHG.

Beijing has also provided a model for the emerging cities around the world with similar conditions. But there are some other emerging cities, which struggle financially to invest in urban rail development and/or face the challenge of urban sprawl. Newman and Kenworthy (2015) have examined several other emerging cities in Latin America and Eastern Europe where the first signs of peak car can be seen. Similar results will no doubt depend on the extent of transit building compared to roads as well as the extent to which walking city and transit city fabric is where the focus of development is provided.

7. Conclusion

Beijing, as the capital of the largest emerging economy, represents and leads China's development and evolution. Hence, its peak car transition is of great importance for China and the entire world. The decline in VKT per capita was not expected based just on GDP levels associated with peak car in other parts of the world. But Beijing has made the transition without reducing its economic agenda and perhaps even suggesting, because of it. The changes can be seen to be related to a combination of investment priorities changing and inner urban fabric priority being a focus for development. Direct policies that favour rail over road with reduced per capita freeway growth and reduced parking provision as well as some travel demand management policies, have been implemented. Beijing features Chinese traditional urban fabrics of walking centres with transit linear corridors all with dense, mixed land use patterns that favour public transport and walking and cycling. These areas are where the major job growth and urban activity is focused, and thus private vehicle use has decoupled from wealth and has now peaked. The positive signs for achieving the 1.5 °C agenda in terms of oil are being supplemented by vehicles powered by renewable energy and lightly motorized modes (e-bikes and e-cars). Beijing is now providing a model of how an emerging city can begin to reduce its car-based greenhouse emissions. The future is likely to see this trend continue.

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Conflict of Interest

The authors declare no conflict of interests.

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