

**Curtin University Sustainability Policy (CUSP) Institute**

**Motorisation of Chinese Cities: Pathways to Sustainable Urban Mobility**

**Yuan Gao**

**This thesis is presented for the Degree of**

**Doctor of Philosophy**

**of**

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## **DECLARATION**

To the best of my knowledge and belief this thesis contains no material previously published by any other person except where due acknowledgment has been made.

This thesis contains no material which has been accepted for the award of any other degree or diploma in any university.

A handwritten signature in black ink, appearing to read 'Yuan Gao', enclosed within a thin black rectangular border.

Yuan Gao,

PhD Candidate

Date: 14/10/2016

## ABSTRACT

The Chinese Automotive industry was established in 1953 with the assistance of the former Soviet Union. China became the world's largest automobile consumer and producer in 2009. A direct consequence of the rapid economic development that led to such a dramatic surge in automobile production has been a significant level of urban development within Chinese cities. This has led to the promotion of urban motorisation, especially private motorisation. As a result Chinese cities have experienced a massive shift in their primary mode of transport, with the automobile becoming increasingly important as a means of personal mobility. However, automobiles do not fit into Chinese traditional urban fabrics. These consist of dense, mixed land use patterns, which are ideal for public transport, walking and cycling rather than automobiles. This incompatibility has resulted in severe traffic congestion and other traffic-related problems in many Chinese cities. Therefore, it is imperative to make a comprehensive analysis of motorisation in urban China to help mitigate automobile use and allow cities to adapt to a more sustainable future.

In order to respond to this need, the overarching question addressed by this PhD thesis is **Using the examples of Beijing and Shanghai, can Chinese urban motorisation become a more sustainable form of mobility?** This thesis by

Publication has answered the question through four refereed articles and one refereed book chapter. Paper 1 systematically analyses the Chinese automotive industry from 1956 until the present day, with focus on the prevailing institutional environments.

The unprecedented prosperity of Chinese automotive industry, which was stimulated by economic growth, urban growth and government guidance, has brought with it a significant level of urban motorisation in China. Paper 2 and 3 have utilised Beijing,

Shanghai, and Guangzhou as case studies to explore reportable urban motorization trends in more detail. The urban mobility in Chinese megacities of Beijing, Shanghai, and Guangzhou has transitioned from *Bicycle*, to *Automobile* and then to *Train* in terms of daily trips by automobiles. These Chinese cities are actually automobile- saturated, but not yet automobile-dependent because the automobile modal split accounted for only around 30%. In particular, the urban transport in Beijing and Shanghai has reached peak car use with the prosperous development of rail transport and its associated bus systems. They can no longer be classified as Non-Motorised Cities but the data suggests that they could instead be called “Emerging Transit Cities” (in contrast to the mature Transit Cities found in Europe and Japan), which are transit-oriented rather than automobile-dependent.

This phenomenon (peak car use) has occurred much sooner than could have been expected based on Beijing and Shanghai’s economic performance. Paper 4 has examined the relationship between urban transport and urban fabrics in Beijing and Shanghai by applying the Theory of Urban Fabrics. Technological advancement and administrative guidance from the Chinese national authorities (especially the national Five-Year Plans) have undoubtedly had a strong influence on the direction taken by urban transport in the short term but have been offset by induced traffic from growth in wealth. However, Chinese traditional walking, cycling and public transit urban fabrics have had a direct and fundamental influence on transport patterns now transforming to a less automobile-based transport system.

Paper 5 has suggested that Beijing, Shanghai, and Guangzhou stand at the forefront of urban transformation in China. The common patterns and processes of change in these three cities have far-reaching implications for other cities throughout China and

other emerging cities around the world particularly as they are all now needing to decouple their economic growth from greenhouse emissions.

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## STATEMENT OF CONTRIBUTION OF OTHERS

All of the written materials submitted as part of this PhD by Publication were conceived and coordinated by Yuan Gao. The majority of the calculation and writing for each publication was undertaken by Yuan Gao.

Signed detailed statements from each co-author relation to each publication are provided as a cover page of each publication.

Signed:



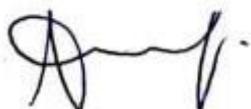
Yuan Gao, PhD Candidate



Professor Peter Newman, Supervisor



Professor Jeffery Kenworthy, Supervisor



Professor Dora Marinova, Supervisor

Date 14/10/2016

## **PUBLICATIONS INCLUDED AS PART OF THIS THESIS**

### **Paper 1 (Peer reviewed journal article):**

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### **Paper 2 (Peer reviewed journal article):**

**Gao, Yuan** Peter Newman and Philip Webster. 2015. "Transport Transition in Beijing: from bikes to cars to transit." *Sustainable Mobility*, 2 (1): 11-26.

### **Paper 3 (Peer reviewed book chapter):**

**Gao, Yuan** and Jeffrey Kenworthy. 2016. "Chapter 3: China." In *The Urban Transport Crisis in Emerging Economies*, eds Dorina Pojani and Dominic Stead, New York, NY: Springer (In Press)

### **Paper 4 (Peer reviewed journal paper):**

**Gao, Yuan** Peter Newman and Jeffrey Kenworthy. 2016. Are Beijing and Shanghai Reaching Peak Car? *Journal of Urban and Regional Research* (Under Review)

### **Paper 5 (Peer reviewed journal article):**

**Gao, Yuan** Jeffrey Kenworthy Peter Newman and Philip Webster. 2013. "Analysis of The Competitive Capacity of Six Midlands Provinces in China Towards Central Rise." *Transformacja*, 3 (4): 368-385.

## **LIST OF ADDITIONAL PUBLICATIONS EXCLUDED FROM THIS THESIS**

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## LIST OF ABBREVIATIONS

<b>AIP</b>	Automotive Industrial Policy
<b>BICP</b>	Beijing Municipal Institute of City Planning & Design
<b>BJMBS</b>	Beijing Municipal Bureau of Statistics
<b>BJMG</b>	Beijing Municipal Government
<b>BMEPB</b>	Beijing Municipal Environmental Protection Bureau
<b>BRT</b>	Bus Rapid Transit
<b>BTRC</b>	Beijing Transportation Research Centre
<b>CBD</b>	Central Business District
<b>EC</b>	European Community
<b>EIA</b>	Energy Information Administration
<b>FYP</b>	Five-Year Plan
<b>GDP</b>	Gross Domestic Product
<b>GHG</b>	Greenhouse Gas
<b>GNI</b>	Gross National Income
<b>GTPRI</b>	Guangzhou Transport Planning Research Institute

<b>HSR</b>	High Speed Rail
<b>ICTs</b>	Information and Communication Technologies
<b>IEA</b>	International Energy Agency
<b>IPCC</b>	Intergovernmental Panel on Climate Change
<b>MCs</b>	Motorcycles
<b>MDGs</b>	Millennium Development Goals
<b>MVs</b>	Motor Vehicles
<b>NBSC</b>	National Bureau of Statistics of the People's Republic of China
<b>NEVs</b>	New Energy Vehicles
<b>NMM</b>	Non-motorised Modes
<b>OECD</b>	Organization for Economic Co-operation and Development
<b>PM</b>	Particulate Matters
<b>RMT</b>	Rapid Mass Transit
<b>SAR</b>	Special Administrative Region
<b>SCCTPI</b>	Shanghai City Comprehensive Transportation Planning Institute

<b>SDGs</b>	Sustainable Development Goals
<b>SEI</b>	Strategic Emerging Industries
<b>SMBS</b>	Shanghai Municipal Bureau of Statistics
<b>SMPLRB</b>	Shanghai Municipal Planning and Land Resource Bureau
<b>TDM</b>	Transportation Demand Management
<b>TOD</b>	Transit Orientated Development
<b>UNCED</b>	United Nations Conference on Environment and Development
<b>UNEP</b>	United Nations Environment Programme
<b>UNFCCC</b>	United Nations Framework Convention on Climate Change
<b>UPT</b>	Urban Public Transport
<b>VKT</b>	Vehicle Kilometres Travelled
<b>WCED</b>	World Commission on Environment and Development
<b>WTO</b>	World Trade Organization

# CHAPTER 1: INTRODUCTION

## 1.1 Background

*Our Common Future* (also well known as the *Brundtland Report*) states that:

*“Sustainable development is the development that meets the needs of the present without compromising the ability of future generations to meet their needs”* (World Commission on Environment and Development (WCED) 1987, p. 41). Global joint efforts have been made to apply this principle within a city context, especially today when the global urban population occupies more than 54 per cent of the globe (United Nations Human Settlements Programme (UN-HABITAT) 2016) and is estimated to reach as high as 70 per cent by 2050 (Shen et al. 2011). As much as 80 per cent of global Gross Domestic Product (GDP) is produced from cities. Cities also account for as much as 70 per cent of global total energy consumption as well as 70 per cent of global total carbon dioxide emissions (UN-HABITAT 2011).

Sustainability for a city means the reduction of footprint (resource inputs and waste outputs) whilst there are improvements in liveability (social facility, health, individual and community well-being) (Newman and Kenworthy 1999).

The global urbanisation process has been further accelerated by emerging or developing countries, which are in a rapid course of urban development. Urban sustainability is therefore crucial to achieve global sustainable development targets within the environmental capacity of the planet whilst improving liveability. It is an unfortunate but unavoidable reality that rapid urban development is often at the expense of the environment and the cause of significant social problems at present (Breheny 1992; Williams, Jenks and Burton 2000). This is especially true within

developed cities and it is becoming an ever-increasing problem in developing countries that are experiencing massive urban growth (Burges 2000).

The city, as the largest system in which transportation activity is embedded, is facing escalating motorisation and mobility demands along with the demands of economic growth and resulting need for urban development. However, the spiralling effect between automobile use and automobile-induced urban problems has resulted in high levels of automobile dependence in the cities of the countries such as the United States, Australia and Canada, all of which have low-density urban settlement patterns with high footprints and incredible outcomes (Newman and Kenworthy 1999, 2015). A dependence on fossil fuels and the linked effects on climate change might be the two most pressing issues these cities face (Newman and Kenworthy 1991). Within cities the transport sector has become the greenhouse gas (GHG) emitter with the greatest rate of emission increase (Intergovernmental Panel on Climate Change (IPCC) 2014). As transport patterns shapes cities then they also increase their resource and environmental footprint. Thus, sustainable mobility is where transport patterns in a city are not increasing footprint but are decreasing it while still increasing liveability.

New China, which was established in 1949, has been on the course of rapid economic prosperity, especially since the *Reform and Open-Up* policy issued in 1978 and the country's entry into the World Trade Organization (WTO) in 2001 (Sheehan and Grewal 2008). It has become an economic powerhouse second only to the United States since 2010 (Barboza 2010). China has gradually drawn the world's attention as the global automobile giant, when it successfully overtook the United States as the largest automobile producer and consumer in 2009 (Gao, Kenworthy and Newman

2015). Since 2015, 56.1 per cent of the Chinese population reside in urban areas although there is still substantial variability in the levels of urbanisation across regions (National Bureau of Statistics of the People's Republic of China (NBSC) 2016a). China has experienced a rapid pace of urbanisation from 10.9 per cent in 1949, compared to Europe that has taken 150 years for the urbanisation ratio from 12 to 51 per cent (Clark 2013). Privately owned automobile use underwent a significant increase both across the whole nation and in the individual selected Chinese cities of Beijing, Shanghai, and Guangzhou since 2000 due to their economic growth and urban development.

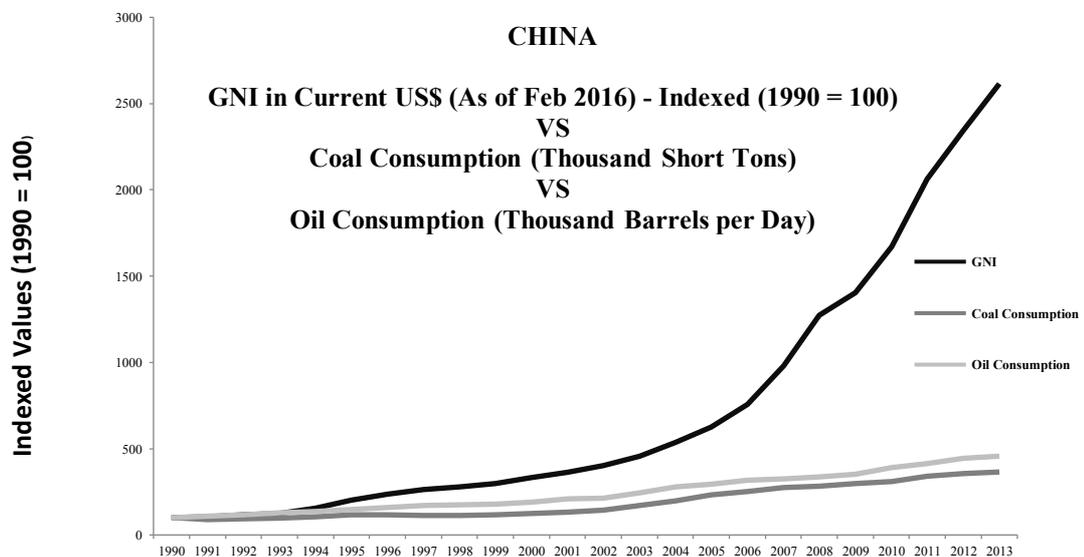
Automobiles replaced bicycles on the streets of China, which had been widely recognised as the “Kingdom of the Bicycle” since the mid-1980’s. During this period of transition, Chinese cities were subjected to several negative impacts as a direct result of the rapid growth in private motorisation. These included...

- Energy vulnerability;
- Atmospheric pollution;
- Loss of agricultural land to new city development; and
- Cultural Changes.

On top of the local impacts arising from the growth in automobile use, the global dimension should not be forgotten because these traffic-related environmental impacts are across national boundaries. China has since overhauled the United States as the largest energy consumer and hence the largest GHG emitter (Kennedy 2011). The road transport system in China is one of the largest and most rapidly growing oil consumers (He et al. 2005). The carbon dioxide emission generated from fossil fuel

consumption and cement production experienced a sharp increase since 2002 after a steady period during the whole 1990's (Sheehan et al. 2014), which matches the trajectory of the automotive industry and urban transport in selected Chinese megacities.

However, China's economic growth has gradually decoupled from fossil fuels (see Figure 1.1). This process of decoupling is a way of summarising the core sustainability issues in a nation as the continuing growth of GDP or GNI is a summary way of measuring liveability whereas GHG is a way of summarising footprint. The trend to reduce coal and oil use whilst increasing economic opportunities is the key issue that underlies this thesis. Sustainable mobility will need to be developed in all of the world and especially in China, the world's biggest emitter of GHG and the world's fastest growing large economy.



**Figure 1.1 China's Gross National Income (GNI) vs Coal and Oil Consumption**  
 Source: Compiled based on data provided by the NBSC (2016b), The World Bank (WB) (2016), and the U.S. Energy Information Administration (EIA) (2016)

The reduction in coal while increasing economic output is the focus of the analysis by Sheehan et al (2014). This thesis will enable some perspective on the Chinese

decoupling from oil through the mobility transition observed through the data on three major Chinese cities. The world is concerned and watching these trends in China so the thesis examines the Chinese urban transport transition, with a focus on automobile usage in terms of modal split of daily trips. The thesis sets out a remarkable turnaround in these trends that has yet to be recognised in any significant way. Compared to the modal split by automobiles in some American and Australian cities, which reached levels as high as 80 per cent (Newman and Kenworthy 2015), Beijing and Shanghai have plateaued and then peaked from around 2010 (peak car use), a phenomenon which has been recorded in some developed cities since around 2004 (Newman and Kenworthy 2011, 2015).

The reason for this dramatic shift in the trend to motor vehicles is analysed in terms of infrastructure investment (especially the Metro systems in each city) and land use patterns. Mounting quantitative evidence generated over the past decade highlights the significant shift in these Chinese cities' infrastructure and built environment in shaping urban transport. The fabric of Chinese cities is much denser and transit-oriented than the heavy car using cities of the world and hence the changes can be understood by using the "Theory of Urban Fabrics" (Newman and Kenworthy 2015; Newman, Kosonen and Kenworthy 2016). The fundamental importance of urban fabrics is also reflected in the following quote from the Guangzhou Transport Planning Research Institutes (GTPRI) Annual Report:

*"Land use patterns determine the size and features of urban transport. The fundamental solution to traffic-related problems is to connect the urban transport with urban land use,"* (2012, p. 3).

Urban transport must continuously adapt to changing economic, environmental and social conditions rather than maintaining a “steady state” or “fixed target” based on simple projections based on expected growth. The implications for future progress in alleviating and improving Chinese urban transport based on this research will be valuable for decision-makers, practitioners and researchers but most of all can send a hopeful signal to other emerging economies grappling with the growth of the automobile in their cities.

## 1.2. Research design and methodology

This section first describes the design adopted by this research to achieve the objectives (1.2.1.); the second section discusses the methodology used and how it was implemented (1.2.2.); finally, the last section discusses the ethical considerations of the research and its potential problems and limitations (1.2.3.).

### 1.2.1. Research design

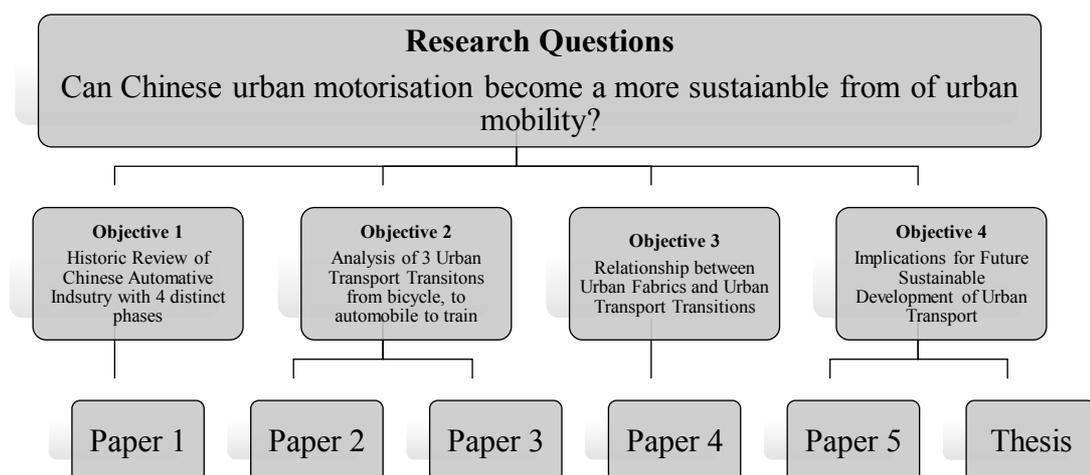


Figure 1.2 Schematic Diagram of the Research Structure

As shown in Figure 1.2, this research design has been crafted upon the premise of “Raising” and then “Answering” the central question: **Using the examples of Beijing and Shanghai, can Chinese urban motorisation become a more sustainable form of mobility?** In doing so it has achieved the following four key objectives...

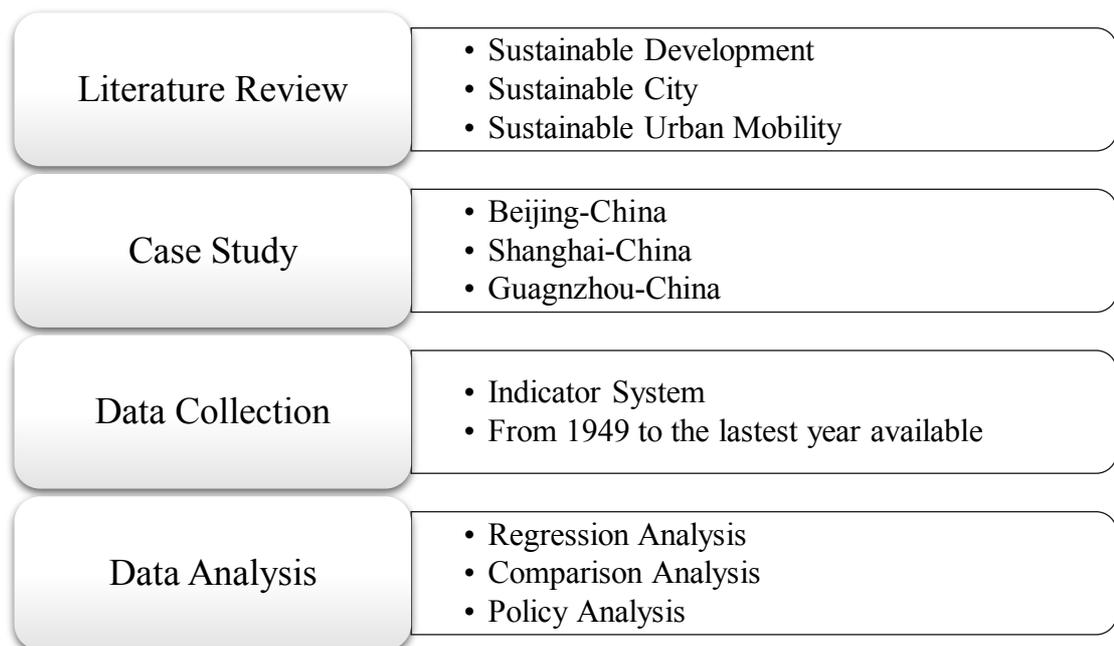
- *Objective one:* Provide a general historic overview of the Chinese automotive industry, which has facilitated urban motorisation, and determine the role that Chinese economic growth, urban development and administrative guidance has played in the development of the Chinese automotive industry;
- *Objective Two:* Collect urban transport and urban form data from 1949 to 2015 (or the latest year available) to help establish Chinese urban motorisation trends, with an emphasis on the shifts of travel patterns;
- *Objective Three:* Present a brief history of the relationship between Chinese urban fabric (in selected cities) and transport transitions moving from the bike to the private vehicles and then to the train; and
- *Objective Four:* Assess the implications for future sustainable urban mobility based on a comparison of urban transport and urban fabrics in Beijing and Shanghai. This will help establish lessons for other Chinese regions and other developing cities with a higher level of automobile growth to follow as part of their own automobile and greenhouse mitigation strategies.

This research constructs a thorough picture of urban transport transitions in Beijing, Shanghai, and Guangzhou from 1949 to 2015 (or the latest year available). It assesses the whole city trend, considering the total change over time and individual

driving patterns. It then reduces the geographic scope to the metropolitan areas and individual districts, paying close attention to individual behaviour and differences in land use characteristics. It then analyses the results and provides conclusions. The thesis has analysed these conclusions into a series of implications for Chinese sustainable urban transport to help answer the second part of the research question and also its implications for other emerging cities.

### 1.2.2. Research methodology

The research methodology adopted by this proposed thesis including its supporting publications is composed of literature review, case study, data collection, and data analysis (see Figure 1.3).



**Figure 1.3 Research Methodology Framework**

They are explained in detail below.

### 1.2.2.1. Case study

Case studies are widely recognised as a research method to provide historic, in-depth explanations of social science studies (Zainal 2007). They allow the data to be examined within a specific context (Yin 1984), like a small geographical area or specified pool of individual subjects. It also provides a practical solution when a big sample population is difficult to obtain. However, there are also some arguments against case studies as a reliable research method because of their inability to produce scientific generalisation especially in comparison with surveys or experimental research (Gromm, Hammersley and Foster 2000). The researcher is often stuck with limited applicable evidence, but its transferability can offer similarities between sampled and target cases (Lincoln and Guba 1990).

This thesis has initially conducted a longitudinal examination over the period from 1949 to 2015 (or the latest year available) to make a systematic and historic analysis of the urban transport transitions in Beijing. It then adopts multiple-case design in Shanghai and Guangzhou<sup>1</sup> for a generalised set of conclusions. All case studies for this research are conducted in a descriptive, explanatory and exploratory way. They describe the phenomenon of Chinese urban transport within the system in a narrative form. The thesis tries to generalise the conclusive results on the basis of the collected data using the Theory of Urban Fabrics that presents the relationship between urban form and urban transport (Newman and Kenworthy 2015). Further Chinese cities could be conducted in any future research, comparing the findings in this thesis with those from other Chinese cities. It will help develop a clear picture of how

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<sup>1</sup> As time series data becomes available future research on Guangzhou will be able to deliver the same level of analysis.

motorisation and sustainable mobility can be managed successfully in China. It can also be extended to other emerging cities using the same approach.

#### 1.2.2.2. Data collection

The thesis has conducted data collection to analyse the development trend and current status of the Chinese automotive industry, which has been completed and presented in Paper 1. It also examined urban transport transitions in Chinese selected megacities, which has been mostly shown in Paper 2 and Paper 3 and also been supplemented by “Extra Findings” in Chapter 3. The subjects of this research were urban mobility within three Chinese megacities Beijing, Shanghai, and Guangzhou. More importantly, comparisons have also been made between these three cities and global counterparts found in the “Global Cities Database”, which was developed by Professor Peter Newman and Professor Jeffrey Kenworthy and provided in a number of publications such as Kenworthy and Laube (1999) and Newman and Kenworthy (2015). The dataset has been developed with a comprehensive set of 42 urban variables to expose the development trends and current urban transport situation within each Chinese city.

The proposed indicators should contain components or processes to reflect the status of systems as well as provide feedbacks to various target groups for decision-making (Huang, Wong and Chen 1998). The variables used in the dataset cover transportation, land use, economic and environmental factors. Thus the data can largely be broken down into two distinct types of perspective: namely cross-sectional and time-series. There are always issues in collecting urban data in a comparative way and so the approach used by Kenworthy and Laube (1999) was followed carefully. For example:

- Urban density is fundamental in terms of how a place becomes dependent on motorisation as well as how quickly they hit congestion limits with cars and need to do something different to get out of the mess. Thus it is very important to collect urban data where the land use is actually developed not just a political boundary that includes lakes, agricultural land, and other undeveloped areas. The relevant data are mostly available from national and municipal Yearbooks, Census Reports, from international organisations or government departments and land use master plans.
- The urban transport data can be collected from transport-related reports or surveys released by the government at various levels, research organisations and annual statistics of commercial transport companies. However, related research institutes, government departments, and companies can restrict public access making retrieval difficult. This was resolved where possible with face-to-face requests in China.

Other issues encountered during the data collection phase included:

- Some data were initially gathered for other purposes by the department/organisation in question and the required information needed to be extracted in a form pertinent to the proposed research. This involved format/unit conversions and other data manipulation. For example, there is no vehicle-use data on a routine basis because China does not officially publish Vehicle Kilometers Travelled (VKT) data.
- The reliability of data often needed to be examined by comparing the same data item from different sources and deciding on the most accurate source for

the purposes of this research. As a result it is possible that some of the data used in this research, are derived estimates, which can potentially be misleading. As an example, the data on urban density in Shanghai's city centre omits the Built-up area of the Pudong New area, due to practical issues resulting in failure to collate the full range of data for that area. However, the data available is still very close to the full functional urban region and thus provided a good basis for collecting the aggregated parameters used in this study<sup>2</sup>.

### 1.2.2.3 Data analysis

This thesis has analysed sustainable urban mobility through the perspective of the Theory of Urban Fabrics based on the collected data within selected Chinese megacities and framed around answering the key research questions. It employs Regression Analysis and Comparison Analysis to analyse the data collected and then uses Policy Analysis for the implications:

- Regression analysis: is a statistical process for estimating the relationships between contributors to automobile ownership and use. Importantly, the research scrutinises historic trends of urban transport reflected in the selected Chinese cities. It then makes a comparison between Chinese cities and global cities, which are available in the "Global Cities Database". This is done in terms of the ranking of the Chinese cities among world cities and the degree

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<sup>2</sup> The author has also assisted in updating and complementing data for other cities included in the "Global Cities Database" like Taipei through measuring all the length of the highways and freeways based on the utilisation of the Google Earth software.

of changes that has occurred between 1949 and 2015 (or the latest year available).

- Comparison analysis: A more detailed multivariate analysis of the different case study Chinese cities was conducted using the parameter. More specifically, it assessed the economic performance, vehicle ownership and journey-to-work factors such as modal split within each city.
- Policy analysis: A key part of the analysis in this thesis, once all data were collected and presented, was the interpretation of the data and derivation of its policy implications and conclusions. Policy implications were drawn from what the data reveal directly, but also through interpretation of the data in relation to an in-depth review and explanation of many Chinese policies on many different levels. For example, the Chinese Five-Year Plans have very important influences on what happens in Chinese urban planning and transportation. As well, there are a raft of other policies at the national level regarding the Chinese automotive industry and other aspects of the Chinese economy, which have also been carefully integrated into the analysis and interpretation of data. Of course, there are the specific policies that are in force at a local level in the major Chinese cities (e.g. controls over car ownership), which also bear a relationship to the data. All these different policies and the timing of their introduction, have been taken into careful consideration in analysing and interpreting data, as well as in prescribing future policies or recommendations.

### *1.2.3. Ethics and limitations*

The research required the collection of a set of more than 130 data items. Although it is secondary data that has been collected, there is no pre-established specific collection of data available for analysing the interactions between urban transport and land use. Thus it was necessary to go to China and seek out the data from a range of local, provincial and national sources. These data could then be used to glean differences in urban transport and urban fabrics between the three cities especially the differences within the metropolitan areas.

The nature of the interactions with people with responsibility for data in China was to request assistance in gathering this wide variety of data, but only those items that were unpublished. No one individual was asked to supply all 42 data items. None of the questions are of a personal nature, nor do they impinge on any individual's privacy. Hence the research was considered to be a low risk and was given ethical clearance on this basis.

## **CHAPTER 2: LITERATURE REVIEW**

This literature review is a critical analysis of existing empirical and theoretical literature in the specific area of sustainable mobility as well as Chinese urban transport and land use. It is more than a simple summary and goes beyond being a descriptive annotated bibliography (Hart 1998). Much of the literature is contained within the published papers but a summary is provided here to form a holistic and systematic perspective of the interdisciplinary understandings that is an integral part of the proposed research and which help to guide the theory development (McCutcheon and Meredith 1993).

The thesis began by reviewing the current state of knowledge on motorisation in Chinese cities with the aim of dissecting the Chinese automotive industry; this was completed within Paper 1 (see Chapter 3). It produced a clearer picture as to the ways in which the Chinese automotive industry has grown from its inception in 1956 to the global giant it is today. The next four papers were based on theory related to the literature summarised below on sustainability and cities with a particular emphasis on the relationship between urban form and urban transport. The thesis cannot conduct a comprehensive literature review on the concept of sustainability but it can attempt to cover the “Sustainable City” and in particular it can review the relationship between urban transport and urban form as highlighted within the dual theories of “Sustainable Urban Mobility” and “Sustainable Urban Form”, otherwise known as “Theory of Urban Fabrics”. A theoretical understanding of these concepts and theories is necessary as they were to be applied to Chinese case studies, the results of which are then reported within this thesis.

## 2.1 Literature review on sustainable cities

### 2.1.1. Basic definitions of sustainability

Studies on sustainability can be tracked as far back as the 1800s (Hassan and Lee 2015) and have drawn global concern since 1987 when “*Our Common Future*” (also well known as *Brundtland Report*) was released. This document contained the first formalised definition of sustainable development (WCED 1987).

Sustainable development is an immensely complicated issue, which has various definitions and brandable terminologies (Pickett, Cadenasso and McGrath 2013).

Essentially, it is the ability to balance the three different dimensions of the economy, society and environment (Newman and Kenworthy 1999). Also of concern is the issue of intra-generational and inter-generational equity (Chan and Lee 2008).

There are however, some variations in meaning to be considered for example:

- Sustainable development is considered as a dynamic process to meet current and future generations’ needs (Berke and Manta 1999); and
- Sustainability is referred to as a stated goal or fixed outcome (Gladwin, Kennelly and Krause 1995).

However, both of these terms are widely used concurrently to highlight an overall global objective of drastically reducing the negative environmental impacts or “footprint” associated with mankind’s interaction with the natural world whilst continuing to deal with social and economic issues like reducing poverty. This is of great significance to China as the environmental gains cannot be achieved unless important economic growth and poverty reduction are also being achieved (Bringezu et al. 2014).

The development of sustainability as a globally recognised concept can be tracked through a number of influential documents released between the late 1980's and the present. The most important of these are indicated below:

- 1987: *Our Common Future* (aka *Brundtland Report*) was issued by United Nations World Commission on Environment and Development (WCED). It is widely accepted to have enabled conceptual understandings but there are no actionable mechanisms to assess the level of sustainable development or sustainability.
- 1992: *Agenda 21* was issued in the Earth Summit (1992 United Nations Conference on Environment and Development (UNCED)) in Rio de Janeiro. Accordingly, global action and research on sustainability shifted from theoretical frameworks to practice. But it was a non-binding, voluntary action plan which required each nation state and local government to implement the responsibilities and obligations.
- 1997: *Kyoto Protocol* was released by the United Nations Framework Convention on Climate Change (UNFCCC); the Protocol successfully specified emission reduction obligations for different countries to follow, with a focus on contributions first from industrialised developed countries. It put forward the notion of the “Carbon Market” providing a specific mechanism by which various countries could work towards decarbonising their economies and hence reduce their GHG emissions.
- 2007: *Bali Road Map* was issued during the 13th Conference of the Parties to the UN Framework Convention on Climate Change and the 3rd Meeting of the Parties to the *Kyoto Protocol*. It emphasised the importance of climate

change adaptation, at a level suitable for the mitigation of set emission targets. It also focuses on global cooperation for dealing with climate change including efforts to involve reluctant members of the international community such as the United States, which had refused to ratify the *Kyoto Protocol* despite being in the top tier of global polluters.

- 2009: *Copenhagen Summit* (aka United Nations Framework Convention on Climate Change) was held in 2009, with the aim of formulating further global agreement on climate change to replace the *Kyoto Protocol* beyond 2012 when its first period of implementation was due to end. Only general recommendations were adopted though the key notion of ensuring that no more than 2 °C increase in global temperature should be allowed.
- 2012: *UN High Level Panel Report on Global Sustainability* was entitled “*Resilient people, resilient planet: a future worth choosing*”. This document suggests that it is still difficult to put the concept of sustainable development into practice because it has not yet been incorporated within the economic policy debate, especially when the short-term reward is disproportionately obtained by policies, politics and institutions. However, it did outline the importance of decoupling economic growth from environmental footprint and suggest that this was now possible with new technology and new policies.
- 2015: *Paris Agreement* was issued at the 2015 Climate Change Conference in Paris, with aims to mitigate and adapt to GHG after the year of 2020. It is a legally binding agreement on climate change made by 195 different countries and it came into force in October 2016 when India adopted the goals in its national legislation and pushed the number of countries adopting the

Agreement over the minimum needed. China had previously adopted the Agreement in early September at the G20 meeting. The Agreement will be assessed every five years and will be tightened if the future global temperature may increase by over 2°C. Another productive outcome is the “bottom-up” negotiation mechanism, namely the intended nationally determined contribution that would be adopted to implement the agreement. Nations and their cities now need to work out how to achieve their targets and this thesis is based around how the reduction in oil-based emissions can be achieved in emerging, fast growth cities.

- 2015: *Sustainable Development Goals (SDGs)* were adopted by all nations to replace the *Millennium Development Goals (MDGs)*. This included for the first time a new approach to cities that they should be “inclusive, resilient, safe and sustainable”. Thus, the reduction in emissions suggested by the Paris Agreement also needs to be achieved whilst economic growth is channelled into solving the problems of development, i.e. there needs to be a substantial decoupling of economic growth and greenhouse emissions.

Sustainable development within the urban context has become the global focus especially considering the unsustainable nature of cities (Camagni, Capello and Nijkamp 1998; Dou, Li and Wang 2013) and problems that arise relating to urban sprawl and resource consumption. The city has therefore been recognised as a key contributor towards achieving global sustainability targets (Burnett 2007).

### *2.1.2. Sustainability and its application to cities*

The phrases “sustainable city”, “urban sustainability”, and “sustainable urban development” are often interchanged, even though there are some small differences

(Richardson 1994). Urban sustainability is stressed as a complex of conditions or a desirable state (Hassan and Lee 2015). Sustainable urban development refers to a process towards sustainability within the urban area (Maclaren 1996). Sustainable urbanisation is a broader term, with a focus on local and global sustainability (Roy 2009).

There is no consensus on a uniform definition of the “sustainable city” (Kolte et al. 2013) due to the economic, geographic, and demographic differences between cities (White and Lee 2009). Essentially, sustainability within existing cities as well as new urban developments refers to their ability to achieve economic and social progress whilst overcoming the barrier of environmental risk (Hassan and Lee 2015). Another approach suggests that it means citizens within the sustainable city are able to access all resources without compromising the ability of other citizens (Oktay 2012) or other regions (Rogers 1997) to do the same. Various other approaches enlarge on this idea that liveability needs to increase as a part of sustainability.

#### 2.1.2.1. Sustainability, liveability and sustainable city

The research on liveability has emerged over the past decades, with a focus on the impact of change on communities and residents (Tan, Nie and Baek 2016). Newman and Kenworthy (1999) suggest that it is only possible to define sustainability in cities by considering how cities can reduce their urban metabolism (resource consumption and waste outputs) whilst simultaneously increasing their liveability (health, equity, access to housing, transport and community). Liveability is thus an integral part of sustainability and is close to the notion of “well-being” (Namazi-Rad et al. 2016). It broadly refers to the quality of life for individuals and households within the built environment, where there needs to be a range of socio-economic conditions met

(Tan, Woo and Aw 2014). There is no consensus on its exact definition or indices to capture the liveability of a city but the new SDG on cities suggests some characteristics of sustainable cities (Kanuri et al. 2016).

#### 2.1.2.2. Types of sustainable city

There are several well-known types of city that represent a real effort at achieving a paradigm towards urban sustainability. This thesis has chosen some of the most well known for a more in-depth examination. These include the Ubiquitous Eco-city, the Zero-Carbon Eco-city and the Compact City:

- *Ubiquitous Eco-city*. In the Ubiquitous Eco-city the use of Information and Communication Technologies (ICTs) within the urban environment provides dwellers with access to any service without incurring any location or time limitations (Lee et al. 2008). Urban technologies such as the mobile phone can reduce trip needs whilst helping to meet the economic and social requirements of the sustainable city (Vinnitskaya 2012). However, ICTs will not satisfy all travel needs nor can it replace face-to-face communication thus it may not be a fully sustainable city.
- *Zero-Carbon Eco-city*. The term “Eco-city” was invented in 1987 (Register 1987) and this has been built on to provide the Zero Carbon Eco-city (Rauland and Newman 2015) which refers to a carbon-free city through the implementation of renewable energy and other new technologies. However, the high cost and uncertainty in relation to new technologies hinder the wider application of this urban form within a global cities context, and hence is probably just being applied to wealthy areas of a city where the technology

can be applied. Consequently, the Zero Carbon Eco-city is still far removed from being truly sustainable city.

- *Compact City*. The term “Compact City” was coined in 1973 (Dantzig and Saaty 1973) and popularised in the 1980s and 1990s to solve the problems arising from post-war urban planning. It aimed to reduce car trips through denser and mixed land use patterns (Dujardin, Marique and Teller 2014; Lau 2013; Newman and Kenworthy 1989). This was designed to achieve a more equal jobs-housing balance in a given urban area as well as reducing the need to travel for all urban purposes. Hong Kong is one of the most high density cities in the world (Newman and Kenworthy 1996). It adopted high-rise and high-density urban development as the solution to meet its demands for urban land in a very constrained site (Chau 1983). But there is some debate as to whether the compact living environment based on this kind of built form and urban planning has impaired the environmental and social outcomes or improved them (Chan, Tang and Wong 2002). If the planning system enforces little or no green space provision and high density development is allowed to proceed in an unrestricted way, then a concrete jungle is possible. However, this is not inevitable as evidenced by Hong Kong where over 60% of the land area is given to country parks and open space within easy access of the city. There are also countless European cities, where the provision of greenery around, on and in compact housing is very high (Newman and Kenworthy 1999; Beatley 2011).

Thus, these concepts of the sustainable city show that there is much debate and much more to demonstrate before a complete model of reducing environmental footprint

whilst improving liveability is enabled in our cities. However, there is enough conceptual agreement that the future of cities is unlikely to include more greenhouse emissions and less liveability, but is likely to include less greenhouse emissions and more liveability. This thesis sets out to see how this is happening in China.

### *2.1.3. Relationship between sustainable city and sustainable urban transport*

Approximately 70 per cent of the global population is projected to reside in cities by 2050 (UN-HABITAT 2016). Cities could not function and evolve without effective urban transport systems (Mumford 1961). Transport systems then give rise to different urban forms (Stover and Koepke 1988). The reciprocity between urban transport and urban form has been examined from both a theoretical and practical point of view in terms of urban planning, transport planning, geography, and economics (Giuliano 1989). The key variables of urban form include urban density (population density and employment density) and land-use mix (Frank and Pivo 1994).

Urban density is a highly significant factor when attempting to determine both fuel consumption and GHG produced by traffic (Banister, Watson and Wood 1997). If properly implemented, suitable levels of urban density can dramatically reduce trip length and increase the overall efficiency of public transit, making it a viable alternative to the private automobile. This is especially true when considering the requirements of planning concepts such as the Marchetti Travel Time Budget (aka Marchetti Constant – see Section 2.1.3.1 below). In tandem with land development patterns favouring the establishment and growth of efficient public transit corridors, the end result of suitably implemented urban density can be a potentially significant reduction in VKT.

The Theory of Urban Fabrics, which is developed by Newman and Kenworthy (2015) and Newman, Kosonen, and Kenworthy (2016), is an integrated combination of different kinds of land use patterns/urban forms and traffic priorities within a policy context.

#### 2.1.3.1. Urban fabrics are shaped by transport priorities.

The Marchetti Travel Time Budget refers to a maximum acceptable daily trip time (about 65 to 70 minutes) on average (Zahavi and Talvitie 1980; Marchetti 1994).

Otherwise passengers come to believe that the time spent travelling to and from their destination (often place of employment) is time wasted or less valued (Mokhtarian and Chen 2004). With the increase in average daily traffic speed due to improvements in transport technology, three specific urban fabric types have arisen (Newman and Kenworthy 2015):

- Walking Urban Fabric

Cities were traditionally organised into or developed around the walking urban fabric, which features compact and mixed-use urban settings that enable walking to be prioritised within a 3-4 km diameter across a city (walking speed is 3-4 kph). Some city centres, nodal centres along rail lines or historic precincts still retain the walking urban fabric, especially in European and Asian cities but also in all American and Australian central cities.

- Transit Urban Fabric

There are two types of transit urban fabric. These are the train-oriented transit city located in corridors across cities (around 20 km) and the tram-based

transit city based within the inner city (around 10 km) due to the average speed of these transit systems enabling the city to follow such options. The tram-based linear development and train-oriented corridor development both promote the development of the city along dedicated transport corridors and nodes. Chinese cities, which predominantly retain the transit urban fabric, have started prioritising the development of public transport since the inception and approval of the Chinese central government's Twelfth Five-Year Plan (FYP) (2011-2015). However, without fast trains and trams, like most developing cities, they mostly rely upon buses and encounter the dilemma of excessive traffic congestion upon the traffic-dominated streets. Hence, China and many other emerging cities have begun to shift their focus to metro systems within cities and high-speed rail (HSR) lines between cities as a means of ensuring successful urban transport development (Newman and Kenworthy 2015).

- Automobile Urban Fabric

While the advent of the private automobile satisfies the individual's demand for urban mobility in all directions without location constraints, its uptake in sufficient numbers can result in significant urban sprawl of 40 to 50km as the boundary of the city expands outwards. The use of the automobile also encroaches upon the old walking and transit city fabric of inner cities by requiring excessive space for roads, parking and other facilities favouring automobiles. This functional zoning creates a dispersed and single-use urban context with a real danger of favouring the automobile at the exclusion of most if not all other transport modes. In such a situation fixed-track transit

networks become infeasible due to severe space constraints and while they can be replaced by express buses as a supplementary option to automobiles, their inclusion then generates a host of urban problems including further worsening of traffic congestion, and additional pollution encroachment on pedestrian road space.

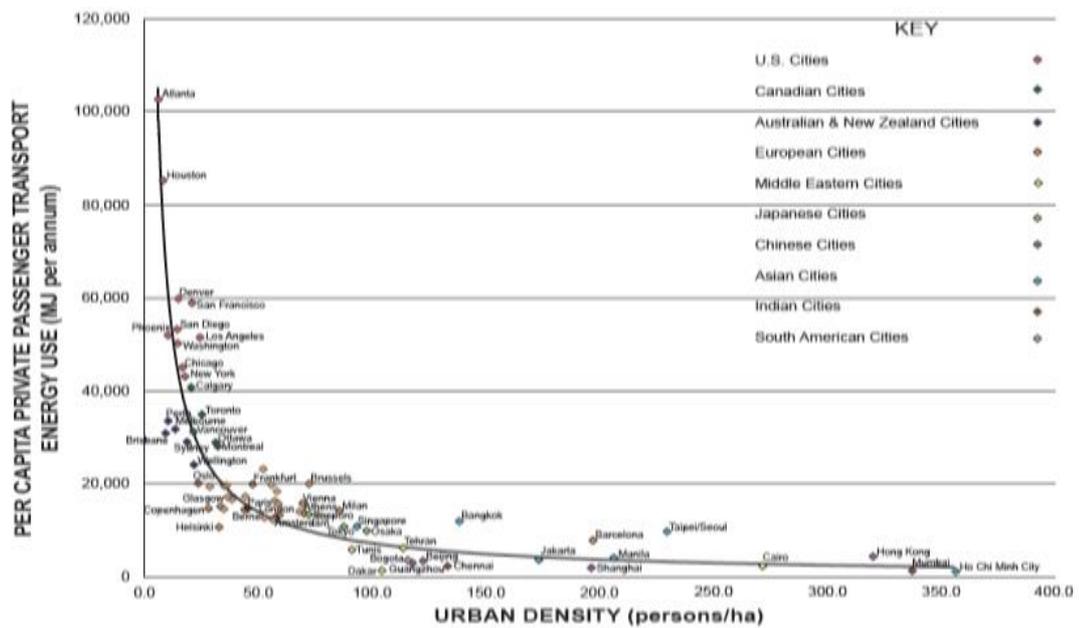
As the level of automobile dependence rises the problem of automobile dependence increases until cities are left with traffic speeds declining and the outer areas of cities becoming more and more dysfunctional as travel budgets become more and more beyond the Marchetti average. Newman and Kenworthy (2015) have shown that this may be a major reason why peak car use has happened in most developed cities and they suggest there are signs it could be beginning in emerging cities. This thesis therefore will be looking to see if Chinese cities may indeed be heading towards this phase as automobile dependence could perhaps reach its zenith before many other developing cities.

It is important to note that other transport modes (cycling, electric-bikes and para-transits), are also included as supplementary to the main transport mode(s) which generate each of the three urban fabrics discussed.

These three different types of urban fabrics are part of all cities and are overlapped in critical ways so it is possible for some to exist in effective symbiosis. Practically, the Central Business District (CBD) can be used as an excellent model of implementing all three types. Along with the CBD's major transit stations, a mixture of walking, transit and automobile city fabrics can be employed to ensure the best level of access possible.

### 2.1.3.2. Urban fabrics are of significance in determining transport patterns.

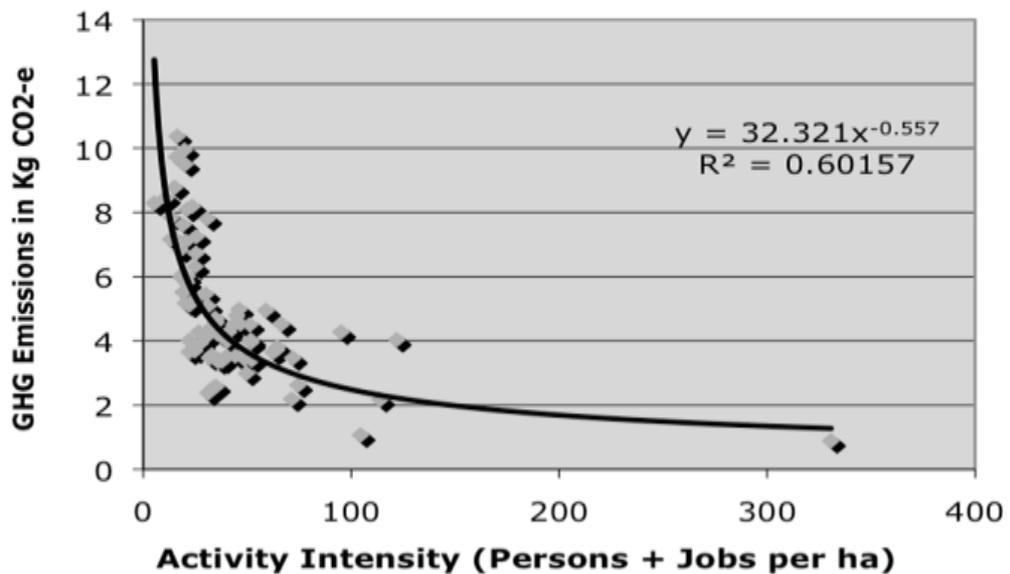
Land use within an urban environment affects the utilisation of the primary mode(s) of urban transport just as the transport modes link to the fabrics. Decades of studies by Newman and Kenworthy (1991, 1996, 2015) have revealed that urban density is exponentially related to car use because as walking and transit fabric increase then the need for a car is reduced in a multitude of ways. This is demonstrated in Newman and Kenworthy's graph from their "Global Cities Database" of urban density and transport fuel use (see Figure 2.1)



**Figure 2.1 The Rapid Decline in Car Use Per Capita with Increasing Urban Density Across Several Global Cities as Reflected Through Energy Use**  
Source: Compiled based on data provided by Kenworthy and Laube (1999) and Kenworthy, Laube, and Newman (2001)

This correlation also works within cities of different sizes and types; Figure 2.2 shows transport GHG and urban density in Sydney and Melbourne by local government area with the same exponential relationship.

### Activity Intensity and Daily Per Capita GHG Emissions in Sydney and Melbourne



**Figure 2.2 Activity Intensity and Daily Per Capita GHG Emissions in Sydney and Melbourne**  
 Source: Compiled based on data provided by Kenworthy and Laube (1999) and Kenworthy, Laube, and Newman (2001)

Specifically, with the lowering of urban density from the central CBD to the inner area, and the whole city to the outer area (fringe), private vehicle dependence becomes heavier and petrol usage/GHG increases. In this figure density is population plus jobs (activity intensity) as transport activity is obviously related to both.

Based on the Theory of Urban Fabrics and the impact of density on transport it is possible to see substantial transport literature suggesting that the way to reduce automobile dependence is through transit-oriented development (TOD). TOD is suggested to be an effective means of countering scattered urban development resulting from an overreliance on the automobile. The mass transit system is competitive with the automobile in terms of capacity and is much more suited to meeting the requirements of the Marchetti travel time budget by focusing on

development with dense and mixed land use patterns around train stations (Bernick and Cervero 1996; Cervero 1998).

## 2.2. Literature review on sustainable urban transport<sup>3</sup>

The notion of “sustainable transport” was suggested in 1996 by the (Organization for Economic Cooperation and Development (OECD) 1996) and is somewhat analogous to sustainable mobility. Transportation is a complex system with a porous nature connecting it to other human endeavours, so any changes to the transport system will invariably generate changes in other urban systems (Goldman and Gorham 2006).

There have been different ways to define sustainable transport as a concept (Jeon and Amekudzi 2005). However, Black (1996) has derived an explanation from the definition of sustainable development and suggests that sustainable transportation is transportation, which “*meets today’s transportation needs without compromising the ability of future generations to meet their transportation needs*”. Hence, a sustainable mobility system aims to retain transport-associated benefits, while reducing the negative impacts on the economy, society and environment (Köhler et al. 2009).

Newman and Kenworthy (1999) suggest that sustainable urban transport is whatever can be done to make cities more sustainable, i.e. less footprint and more liveability.

Thus sustainable urban transport must be implemented with both of the following two categories: policy pathways and policy targets (Goldman and Gorham 2006).

The former will need to enable better technology in vehicles, better modal splits, and

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<sup>3</sup> The existing literatures on sustainable transport range from passenger transportation to freight movement issues. This research focuses on passenger transportation.

better land use to reduce the need to travel. The latter vision emphasises the actual sustainable transport end points desired.

There are different types of directions and methods that can be utilised to alleviate traffic-related problems and to build up a sustainable transport system. However, technological improvements in vehicle transportation can largely be offset by further induced traffic (Newman and Kenworthy 1989, 1999). Urban growth management, which is strongly interdependent with transportation, is suggested as the fundamental way to improve this situation by reducing trip length and car use, which has been proved in developed cities (Newman and Kenworthy 1989).

Sustainable transport is also essential for the sustainable urban growth in megacities in developing countries (Zhao 2010). Significantly different from the low-density, heavily zoned cities in the United States, Australia, and Canada, Chinese cities have primarily evolved around walking, cycling and public transport. The urban development patterns, which have developed rapidly especially in the city fringe, still follow strong corridors of development. Therefore, it should be an interesting question to see the density trend data on these cities and see how they compare to other global cities as well as seeing what it all means for sustainable transport.

Sustainable urban design incorporates sustainability into urban development and especially urban redevelopment policies, with the aim to create sustainable community for the city's citizens whilst reducing the urban footprint (Oktay 2004). Transportation planning is critical to a more sustainable built environment (Chan and Lee 2008). This thesis will examine whether Chinese cities are achieving such goals and the policy environment that surrounds the transition they are going through.

## CHAPTER 3: RESULTS

This research is a direct response to national and international concerns regarding the surge in private motorisation across Chinese cities. It highlights what is needed to build up a sustainable transport system to counteract this surge. This research aims to reveal the policy implications of urban growth management for sustainable transportation in the Chinese megacities of Beijing, Shanghai, and Guangzhou (used as case studies). The findings presented can then be applied in other regions in China and other emerging cities in an effort to combat private motorisation and prevent automobile dependence.

This thesis by Publication consists of four peer reviewed journal papers<sup>4</sup> and one reviewed book chapter. This section will summarise each publication and extra findings and then show the extent to which each has contributed to answering the stated two-part research question. Finally, potential future research directions as a continuation of this thesis are presented.

### 3.1. Summary of publications

#### *3.1.1. Paper 1: Growth of a Giant: A Historical and Current Perspective on the Chinese Automobile Industry*

Paper 1 provided a synoptic overview of the Chinese automobile industry, classifying it into four distinct phases, which were characterised by the prevailing institutional environments, with a focus on the formulated and applied automobile industry policies:

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<sup>4</sup> Impact factor of Sustainable Mobility is 1.0381. The impact factors of the remaining 3 journals were unavailable.

- *Start-up Phase* from 1956 to 1978;
- *Growing Phase* from 1979 to 2000;
- *Prosperity Phase* from 2001 to 2010; and
- *Stationary Phase* from 2011 until the present day.

More specifically, the Chinese automotive industry has experienced a dramatic shift in focus into the 5<sup>th</sup> decade since its inception in 1956. At the time of its birth in 1956 the Chinese Automobile industry was originally designated to meet military and economic construction demands. It was initially referred to as the “Chinese Truck Industry” rather than the “Chinese Automotive Industry” up to 1978 when China transitioned from a state-controlled economy to a market-oriented one. The main mechanism of this transition was the *Reform and Open-up* policy (1978).

With the introduction of the Automotive Industrial Policy (AIP) in 1994 and the Tenth Five-Year Plan (FYP) (2001-2005), individuals and families were successfully encouraged to purchase passenger cars. The production focus was shifted from freight vehicles to passenger cars. The production and private ownership of automobiles sped up in 2001 when China joined to the global automobile market as the 143<sup>rd</sup> member of WTO. Besides policy interventions other factors affecting the demand for private motor vehicles included rising purchasing power and increasing commuting distances. This was a direct result of the implementation of mono-centric urban development and the urban development on the fringe of Chinese cities. These factors served to further stimulate the Chinese automotive industry allowing it to undergo further rapid growth and supersede the United States as the world’s largest automobile producer and consumer in 2009 (see Table 3.1).

**Table 3.1 Year and Duration of Automobile Production Exceeding Given Amount**

<b>Year</b>	<b>1992</b>	<b>2000</b>	<b>2002</b>	<b>2003</b>	<b>2004</b>	<b>2005<sup>5</sup></b>	<b>2006</b>	<b>2007</b>	<b>2008</b>	<b>2009</b>	<b>2010</b>
<b>Duration (Years)</b>	36	8	2	1	1	1	1	1	1	1	1
<b>Yield (10,000 Units)</b>	100	200	300	400	500	600	700	800	900	1400	1800

**Source: Compiled based on data provided by China Automotive Industry (CAI) (2011)**

Such a soaring amount of private automobiles is far beyond the capacity of traditional transit and walking urban fabrics in China and has led to severe and worsening automobile-induced quandaries. These included energy vulnerability, air pollution, climate change, loss of agricultural land to new city development, and large cultural changes, which acted as a significant counterbalance to any positive economic benefits from the industry's rapid growth.

Since 2011 the Chinese governments' industrial policies have gradually shifted from promoting "stimulation" towards achieving "sustainability" to counteract these increasingly negative consequences. Policy measures implemented have included Transportation Demand Management (TDM) to curb car ownership and usage, coupled with prioritising Urban Public Transport (UPT) and the regeneration of walking and cycling (especially electric) within China's urban environments. The Chinese automotive industry has now entered into a new "stationary phase," where

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<sup>5</sup> The actual auto production in 2005 was 5,707,688, which is less than the data shown in Table 3.1. It is rounded to 6 million in the paper for simplicity.

emphasis is being put on encouraging people to use public transit in favour of the private automobile. This paper also discusses several on-going incentives designed to encourage the growth of sustainable transport such as New Energy Vehicles (NEVs) which have become one of the nation's Strategic Emerging Industries (SEI) as highlighted in the nation's Twelfth Five-Year Plan (FYP) (2011-2015).

### *3.1.2. Paper 2: Transport Transitions in Beijing: from bikes to cars to transit*

The development trajectory of the Chinese automotive industry has also been similarly reflected by the urban transport transitions in Chinese cities, as demonstrated by a case study of Beijing. Paper 2 recognised three major transitions in terms of modal split for daily trips in Beijing, the *Pre-modern Phase* of the bicycle (1949-2001), the *Automobile Phase* (2002-2010) and the *Train Phase* (2011-).

Beijing was built around walking, cycling and other non-motorised transport modes with its dense traditional urban fabric, which features flat terrain and small alleys (*Hutong*). Walking and cycling enabled commuting distances within this traditional urban fabric. This in turn was facilitated by socialist welfare-oriented housing provision by state-owned departments (*Danwei*). Besides these state contributions, China was well known as the “Kingdom of the Bicycle” as reflected by mass bicycle production and a culture favouring the use of this mode of transport over all others throughout the mid-1980's.

From 2002 the private automobile became more affordable and available to the average Chinese citizen as a direct result of the prosperity enjoyed by the Chinese automotive industry, the country's growing economic capacity as well as cultural and political support. This was especially true when the Tenth Five-Year Plan (FYP)

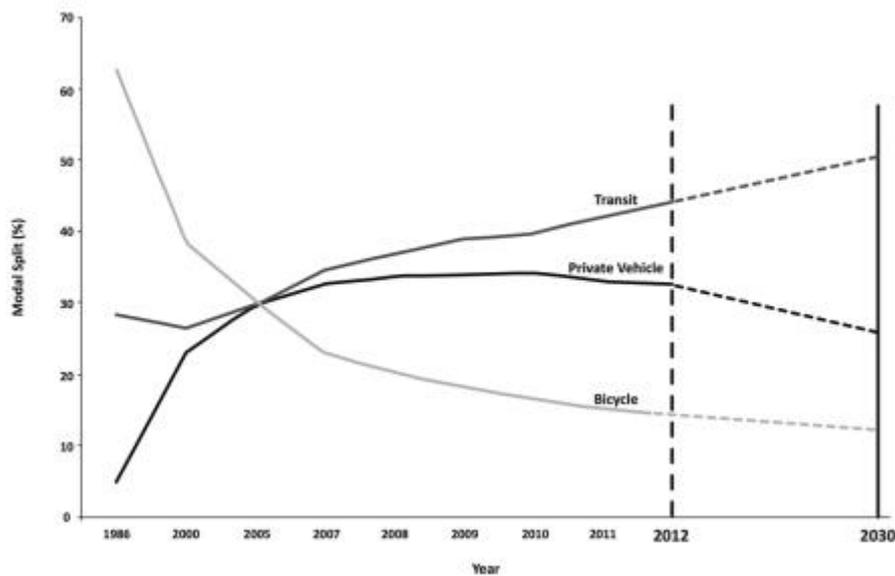
(2001-2005) was introduced. This policy encouraged Chinese families to purchase cars at the national level. Consequently, Beijing has had the nation's highest level of private vehicle ownership and its streets soon became filled with automobiles at the expense of bicycles. The automobile modal split by daily trips surged from 5 per cent in 1986 to 34.2 per cent in 2010.

Chinese traditional dense urbanism could not support such a large increase in the volume of automobile traffic. Even though private vehicle ownership is not as high as in other global cities, traffic congestion is even worse in Chinese urban environments due to their unsuitability for automobile use. Hence, automobile-based problems (particularly traffic congestion) rose to a point where automobile use became dysfunctional. From around 2011 prioritisation of the private automobile has been replaced by an emphasis on development of the Chinese metro and high speed rail (HSR) and the associated bus systems. Political intervention has played an important role in this transition from the automobile to the trains. They include:

- The demise of pro-car policies (2011);
- Limitations on car use (2008) and ownership (2010); and
- A sharp increase in rail infrastructure development (2008) as a priority over automobile infrastructure.

In 2010 the metro became the fastest growing public transport mode in Beijing, with its mode share expanding from 3.6 per cent in 2000 to 13.8 per cent in 2011. Bus is still the dominant mode of public transport but with a slowing increase in its modal split from 22.9 per cent to 28.2 per cent over the same period. The two modes are usually interconnected so parallel growth can be expected.

The paper identifies the driving factors determining these urban transport transitions as: government intervention, urban fabrics, and economic growth. Economic development affects automobile ownership more than actual usage (i.e. cars are seen as a status symbol of wealth and many people own automobiles, but catch public transit for most of their daily commutes). Administrative guidance, especially the national Five-Year Plans (FYP) set up by Chinese authorities has worked to curb unsustainable automobile numbers in the short term. However, the typical dense urbanism found in Chinese cities, which differs greatly from that found in the revival of most western cities, has been the critical factor in altering the dominant urban transport mode in China in the long run. In Beijing, for example, the urban development corridor is ideally suited to public transit as it is directly linked to the new transit fabric of the expanding Beijing metro. The city has also taken great pains to retain and regenerate its traditional walking and cycling fabrics as part of a larger commitment to the global environmental agenda. Beijing is projected to move towards the next transition (TOD) based on a continuation of recent trends, which is less automobile-dependent and more sustainable transport-oriented (see Figure 3.1).



**Figure 3.1 Future Projection of Beijing Modal Split<sup>6</sup> to 2030**

**Source: Compiled based on data provided by Beijing Transportation Research Centre (BJTRC) (2013) and Authors Own Projections.**

Beijing, the capital of China, could represent much of what has happened in China due to its political, economic and cultural significance. Paper 3 compares the direction and progress towards sustainable mobility taken by Beijing with that of two other Chinese megacities: Shanghai and Guangzhou.

### *3.1.3. Paper 3: China-The Urban Transport Crisis in Emerging Economies*

Paper 3 compared the urban mobility trends amongst the three most influential megacities in China: Beijing, Shanghai, and Guangzhou. As with Beijing, discussed in Paper 2, the urban transport in Shanghai and Guangzhou also experienced three different stages in terms of mode share of daily trips by different transport modes<sup>7</sup>:

*Bicycle-led urban mobility (1949-the mid-1990's), Private car-led urban mobility (2002-2010) and Rail transit-led urban mobility (2011-Present Day).*

<sup>6</sup> Modal split refers to how much of daily trips by residents has been done by each different type of transport mode. The projection is based on 'continuation of current trends' as explained in the publication. It is also supplemented by the additional data shown later including sharply decreasing growth rate of private vehicle ownership, passenger traffic and per capita VKT.

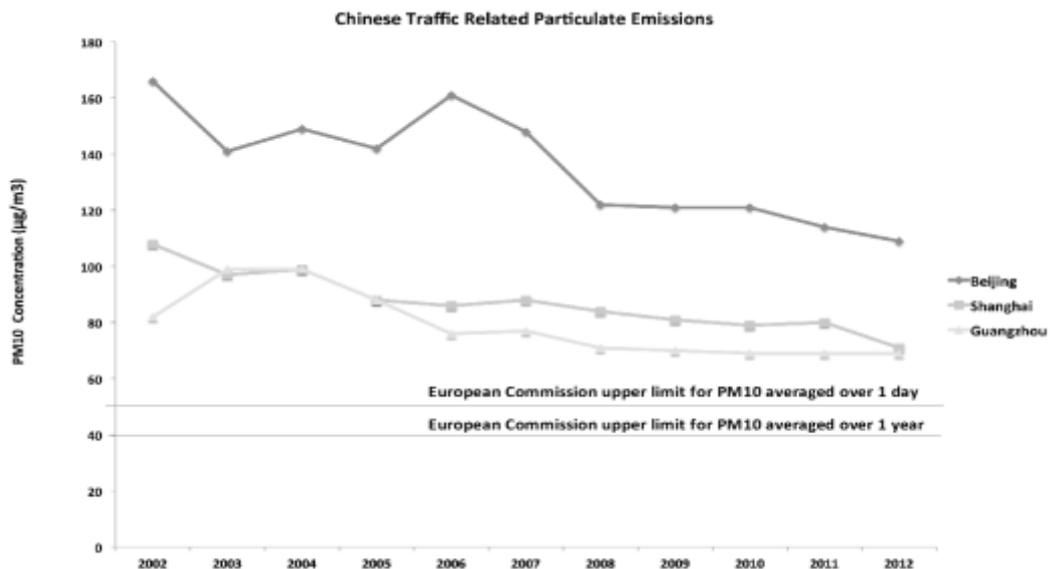
<sup>7</sup> The modal split of daily trips in these selected cities excludes walking for greater comparability with Beijing's data, where is not available.

The bicycle, which was officially imported into China in 1897 as a symbol of luxury status, has been the dominant transport mode in Chinese cities especially in the period leading up to the mid-1980's. Beijing and Shanghai had a similar level of bicycle use, higher than Guangzhou. Since the 1990's bicycle use spiralled further and further downward. The situation worsened even further in 2002 when priority was officially given to the automobile. It is interesting that cycling is still the dominant transport mode in Shanghai despite declining bicycle modal share. This retention of bicycle dominance despite such a steep fall can be attributed to the sharp increase in the use of E-bikes and E-scooters from 3 per cent in 1995 to 20.2 per cent in 2014.

Private vehicle ownership in these three selected Chinese megacities had been on the increase since 2002, in parallel with the national trend. Beijing is the biggest consumer of the automobile, followed by Guangzhou. Shanghai is significantly less automobile-oriented with a level of automobile use closer to the national average which includes all the rural areas and poorer areas in the west.

Most significantly the daily trips by private motorised modes peaked around 2010 before they then started to decrease. This fall in automobile use can be largely attributed to the resurgence of public transit. There has been significant growth in Rapid Mass Transit (RMT), which includes Bus Rapid Transit (BRT) and metro systems within cities and HSR lines between cities (replacing some automobile traffic within cities as people can link to the HSR by metro). This has been in a state of rapid growth especially since 2008 (Beijing Olympics) and 2010 (Shanghai World Expo). Beijing, Shanghai, and Guangzhou have pioneered the development of effective rail systems and this is now being copied in other Chinese cities as well as

in other emerging cities like in India. Each of the three Chinese cities is ranked near the top in terms of operational length and patronage across China for their metro systems that were built in around 10 to 15 years. Air pollution levels have fallen as a result, but still far exceed both the recommended European yearly and daily averages<sup>8</sup> of Particulate Matter (PM10) (see Figure 3.2).



**Figure 3.2 Traffic-related PM10 Emissions ( $\mu\text{g}/\text{m}^3$ ) (2002-2012)**  
**Source:** Compiled data provided by the BTRC (2013), the GTPRI (2012), the Shanghai Environment Protection Bureau (SEPB) (2013) and the European Commission (EC) (2015)

The third paper also sought to explore the urban mobility transitions experienced in the three Chinese megacities in terms of finance and governance. Political interventions including consecutive Five-Year Plans (FYP) function immediately as a direct response to the traffic-based pressures. The recommendations can be summarised:

- Chinese cities must resurrect their tradition of non-motorised transport, which functions as the solution to “First Kilometer” and “Last Kilometer”

<sup>8</sup> The annual average means the average amount within each year.

connection problems faced by public transport users. The emerging trend in response to this is a surge in E-bike and E-scooter use and the establishment of multiple Public Bike terminals;

- Chinese cities need to alleviate the environmental impacts of excessive private motorised travel demand through encouraging the development of NEVs technology and smartphone-supported car-sharing apps; and
- Chinese cities need preferential development of rapid mass transit (RMT), especially rail transport as an alternative to automobile infrastructure.

#### *3.1.4. Paper 4: Are Beijing and Shanghai Reaching Peak Car? Applying Urban Fabric Theory to Chinese Cities*

The level of “privately owned automobiles”<sup>9</sup> in China, while continuing to grow (despite registering a decline in the rate of growth), is far less than cities in developed countries and even some developing nations (NBSC 2016c; NationMaster Online Database (NMOD) 2016; Newman and Kenworthy 2015) The actual private automobile use in Beijing and Shanghai in terms of modal split both plateaued in 2010 before registering a decline, which has happened in some cities within developed countries, referred to as “peak car” (Newman and Kenworthy 2011). This has happened well before standard economic models based on income-related transport patterns have predicted. So, how can this phenomenon be explained as other Chinese cities and most other cities would want to know how they can become more sustainable in their transport systems?

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<sup>9</sup> Term “privately owned automobiles” include large, medium, small and mini-sized passenger cars.

Economic, political and cultural factors undoubtedly all contributed to the transport transition within these two Chinese megacities. However, the paper suggests that the differences between the land use patterns found within Chinese cities and other cities can explain the major part of the difference. Car use began to plateau as traffic speeds slowed in the dense urban fabric of Chinese streets and only when the metros began to increase their share was it possible to see the peak car phenomenon set in. Hence, Paper 4 sought to apply the Theory of Urban Fabrics to provide an answer to both the cause of the transport transition within each city as well as an explanation for the different land use patterns identified in each of these two cities based on their histories and cultural views of urban space.

Chinese traditional urban fabric feature walking city centres, with transit-oriented linear (corridor) formats of urban development built upon dense, mixed land use patterns. They are favourable of public transport systems as well as walking and cycling. Chinese cities also have been increasing in density. The causes are fourfold:

- Traditional low rise and high-density urban form and short blocks;
- Central square and linear forms of urban development;
- Traditional employment system during the Planned Economy until 1978; and
- Traditional acceptance of high-density living.

The density of city centres in both Beijing and Shanghai is as high as 250 person/ha, which is characteristic of the Walking City fabric. The density of the whole city while falling is still more than 50 person/ha, which is typical of European transit-oriented regions. The lowest urban density appears in the suburban areas of Beijing

(25 person/ha), which is still at the higher end of what is found as Automobile City fabric (see Table 3.2).

**Table 3.2 Comparisons of Urban Density by Different Districts between Beijing and Shanghai from 1980 to 2014**

Year	Central City <sup>10</sup>		Whole City		Suburb Area <sup>11</sup>	
	Beijing	Shanghai	Beijing	Shanghai	Beijing	Shanghai
1980	268.37					
1985	271.97					
1990	278.3					
1995	277.19					
1996		227.37		66.32		36.95
2000	273.32					
2004		214.02		57.87		
2005	222.1	226.44	47.61	74.07	24.61	49.62
2006	223.08	224.46	48.31	76.59	24.94	
2007	223.94	224.32	49.1	76.46	25.31	
2008	225.46	225.6	50.19	74.35	26.11	
2009	228.49	225.6	51.97		27.07	

<sup>10</sup> Central City in Beijing covers Dongcheng, Xicheng, Chongwen and Xuanwu. It covers 9 old districts in Puxi (Huangpu, Nanshi, Luwan, Xuhui, Changning, Jingan, Putuo, Zhabei Yangpu) in Shanghai.

<sup>11</sup> Suburb Area in Beijing covers the rest districts except central city and Chaoyang, Fengtai, Shijingshan and Haidian. It covers the rest districts except Central City and Pudong New Area in Shanghai.

<b>2010</b>	234.01	241.34	57		32.04	
<b>2011</b>	232.71	242.54	58.67		33.16	
<b>2012</b>	237.58	244.39	60.14		34.15	
<b>2013</b>	239.42	244.57	60.86	79.97	34.54	
<b>2014</b>	239.53	243.41		77.65		

**Source: Compiled based on data provided by the Shanghai Municipal Bureau of Statistics (SMBS) (2014, 2016), the Shanghai Municipal Planning and Land Resource Bureau (SMPLRB) (2007) and the Beijing Municipal Bureau of Statistics (BJMBS) (2016)**

The difference between Beijing and Shanghai is the higher urban density in some districts of Shanghai. Beijing has a higher level of actual car use than Shanghai, where the slow moving traffic<sup>12</sup> has played a significant role in daily trips. The regular bus system still dominates Beijing while its metro system has grown rapidly but in Shanghai it has been trumped by the metro system since 2014.

The problem facing Beijing, Shanghai, and other cities in developed countries, which are determined to rebuild their walking and cycling urban fabrics, is the super-dense city centre. These super dense areas have become unaffordable for regular residents. In contrast the newer suburban areas in Chinese cities are well supported by the rail transport system, but the mono-centric development style they favour still generates higher car use between the city centre and these newer suburban areas in outlying areas. (This is discussed further in an additional section below that was not part of Paper 4).

<sup>12</sup> It refers to the walking with speed between 4 and 7 km/h and Non-motorized transport modes (including bicycle and moped) with speed less than 20 km/h in the urban transport system.

China has entered an era of peak car use similar to that experienced by the cities of the world's developed nations. What makes China unique is that the changes have happened in such a way (in terms of pace and extent) that has never been seen before. The paper shows that China is in the course of economic growth and urban development, but it is unlikely to succumb to automobile dependence by building automobile city fabric as a better alternative of fast urban rail and transit oriented land use now exists. This looks likely as Chinese cities continue to develop away from automobile dependence through building more metros and light rail, revitalising traditional urban form, promoting national cultural views that do not worry about density, ensuring green economic growth along with sustained efforts on a national scale to preserve agriculture land, mitigate air quality problems and alleviate greenhouse gas emissions (GHG).

#### *3.1.5. Paper 5: Analysis of The Competitive Capacity of Six Midlands Provinces in China Towards "Central Rise"*

Paper 5 built up an index system to compare both provincial and urban competitiveness before and after the implementation of a national sustainable strategy (economic, social, environmental). It determined that urban transport, in particular the level of public transport, played a critical role in alleviating environmental vulnerability and improving overall competitiveness in the six midlands provinces. These are significant as they make up the six most densely populated neighbourhoods in China.

Economic growth and urban development in different regions of China are by no means equal. They are impacted by a range of different policies and strategies, each with unique benefits to the region(s) in questions (see Table 3.3).

**Table 3.3 Summaries of Privileged Policies to Different Regions in China**

<b>Issued Year</b>	<b>Strategy</b>	<b>Beneficiary</b>
1980s	Developing Costal Regions	South-eastern Costal Area
1999	West Region Development	Western Regions
2002	Revitalization of the Northeast Old Industrial Base	North-eastern Regions
2004	Central Rise	Central Regions

**Source: Compiled based on data provided by State Council (SC) (2000a, 2003, 2009a)**

Beijing, Shanghai, and Guangzhou, which have experienced prosperous economic growth and rampant motorisation prior to other regions of China, are projected to produce a paradigm shift away from automobile dependence based on the lessons they have learned (outlined in the other papers). It is important to integrate the development nationwide to promote other regions, which are in the trajectory of rapid urban development, learning from the more advanced regions of China and implementing as quickly as possible the policies of sustainable transport that have begun to be so successful in Beijing, Shanghai, and Guangzhou.

### 3.2. Extra research findings besides publications

#### 3.2.1. *Extra findings in Beijing*

##### 3.2.1.1 Urban expansion and traffic congestion along the urban fringe

Starting in 1949, Beijing copied the urban spatial layout used in Moscow. This featured mono-centric and concentric development. Although effective during the initial establishment of New China, this urban pattern has had limited success in terms of sustainable urban development. Within Beijing the central city is the hub of

public function and resource. For example, about 20 central/national ministries, 100 bureau-level authorities and more than 250 municipal departments have been established within Beijing's Second Ring Road alone. According to data released in 2013, approximately 84 per cent of all college students and associated teachers reside within Beijing's central city (Beijing Municipal Government (BJMG) 2015a). There are also several shopping malls and historic sites such as The Palace Museum. Beijing continues to expand outwards through the construction of highway loop roads. The Seventh Ring Road<sup>13</sup> (aka The Highways Around Capital Region) is currently under construction, while the Second Ring Road was completed in 1992 (BJMG 2015b). The disposition of established and planned ring roads is demonstrated in Figure 3.3 below.



**Figure 3.3 Map of Ring Roads in Beijing**  
**Source: Lo (2014)**

<sup>13</sup> Compared to other ring roads located within Beijing, the Seventh Ring Road is designed to transcend the boundaries of Beijing to link with some of its surrounding regions. It aims to transfer the through traffic, especially freight traffic from Beijing to its surrounding regions to alleviate traffic pressure and improve air quality. It also aims to promote the balanced development between Beijing and its surrounding regions, the city of Tianjin and the province of Hebei.

The permanent population beyond the Fourth Ring Road now accounts for 51 per cent of the municipal total of Beijing. Figure 3.4 shows the growth in population in different regions of Beijing from 1980 to 2014. From the 1980's the population of the central city has fallen first slowly and then speeding up in the 1990's from 2.337 million (1980) to 2.213 million (2014). Within the same period there has been a sharp increase in the population of the suburbs from 6.52 million (1980) to 19.303 million (2014). However, in terms of total population, the two most populous districts of Chongwen and Xuanwu have been on a continuous downwards trajectory. This was only halted when they were merged with the districts of Dongcheng and Xicheng, respectively.

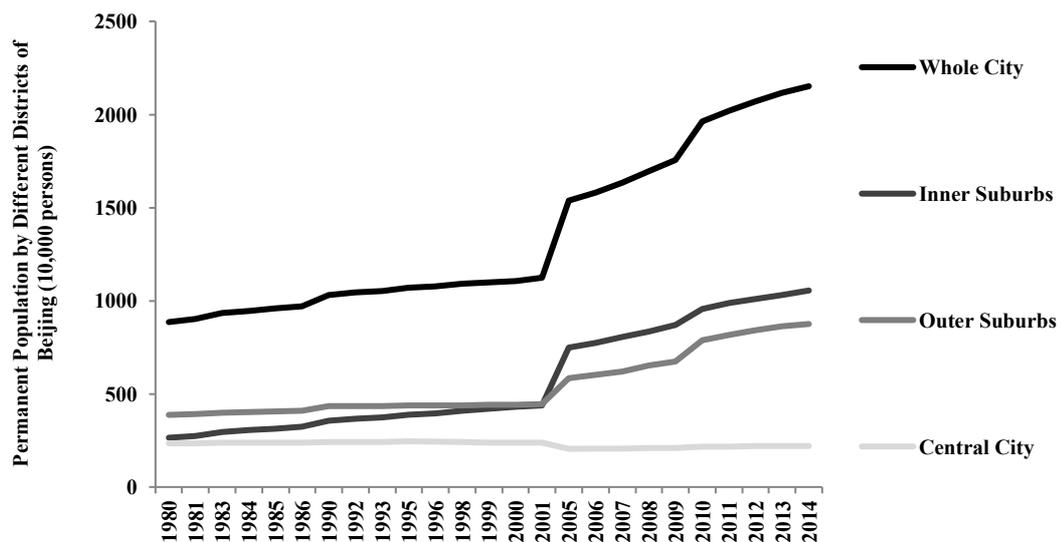


Figure 3.4 Permanent Population Trends by Different Districts of Beijing from 1980 to 2014<sup>14</sup> (10,000 persons)

Source: Compiled based on data provided by Beijing Municipal Bureau of Statistics (BJMBS) (2016)

There are some reasons, which help to explain these shifts in Beijing's population demographic away from the central city and into the outlying suburbs:

<sup>14</sup> The breaks in data are due to the unavailability of data.

- The massive population growth has been far beyond the environmental capacity of the central city to accommodate it. The increased severity of traffic problems such as congestion along with soaring living costs has served to push residents away from the central city and into the suburbs in the search for better living conditions;
- Development of Beijing's famous metro system promotes a significant extension to the city's activity radius while at the same time reducing commuting costs. Hence, the separation of jobs and housing is more affordable and the time required to commute is lessened relative to the congested roads;
- With improvements to the transit system, more sectors of the city not related to the specific functions of the nation's capital have been relocated away from the city centre. This has been accompanied by industrial structural changes (e.g. creation of industrial parks) and significant relocation of these new establishments to other cities; and
- As the number of immigrant workers continues to increase, there is a greater preference for living within the more affordable suburbs as opposed to the higher prices found within the central city.

The impact of traffic is significant to the functioning of any city. Within large Chinese cities such as Beijing and Shanghai peak times often overload the system completely. In Beijing for example, 2012 data reveals that morning peak (07:00-09:00am) traffic speed during workdays falls as low as 26km/h (BTRC 2013). This often results in travel times that are firmly opposed to the maximum 1hr proposed by

the Marchetti Travel Time Budget. This is a situation which worsens the further that Beijing's urban fringe expands out from its centre, unless effective transit infrastructure (e.g. metro and HSR) can be built to cater for the added distances between work and home involved. This has obviously happened as has been shown in Paper 4 but will need to continue to provide more options if the trend to car use decline is to be facilitated. This could involve light rail and autonomous vehicles servicing the last mile and first mile of the fast rail system.

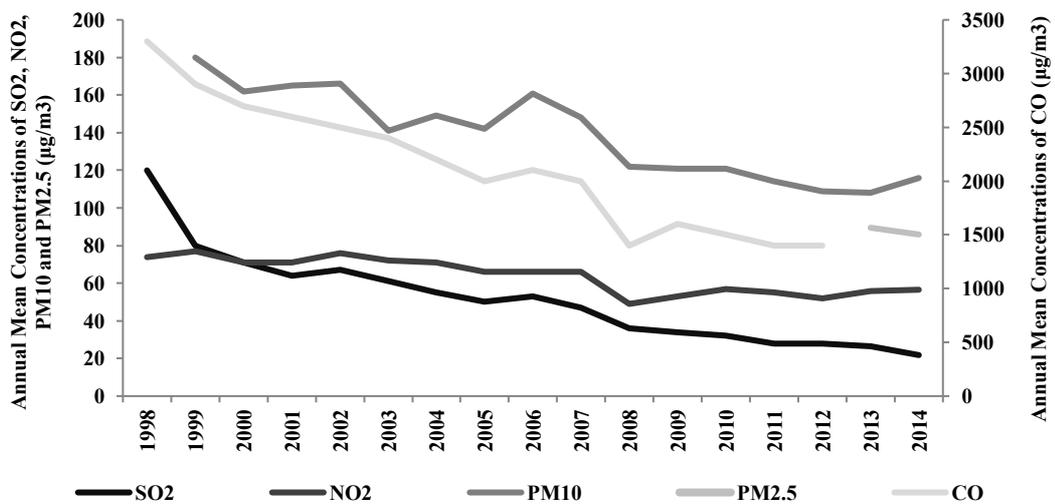
### 3.2.1.2 Air quality

As a large volume of cars has been introduced into Chinese cities within a relatively short time, China has become susceptible to a significant degradation of its air quality. The question to ask is whether or not the deteriorating situation (e.g. increases in PM2.5 concentrations and other atmospheric pollutants) is underestimated or overhyped by the public media. Since 2008 the significant fall in Chinese urban air quality has received international attention. The catalyst was the US Embassy in Beijing, which initiated air quality monitoring that year, releasing hourly PM2.5<sup>15</sup> concentration figures for the world to scrutinise. The first notable efforts to control this degradation in air quality occurred that same year when Beijing played host to the Olympic Games. Besides the significant relocation of industry to other cities, Beijing implemented several road-rationing initiatives (see Paper 2) designed to combat the overuse of automobiles within the city.

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<sup>15</sup> In response the State Council added the PM2.5 monitoring and harnessing to the new Ambient Air Quality Standards issued in 2012, although it has adopted the loosest Interim Target (IT-1) level of the World Health Organization (WHO).

The result of these initiatives was a general improvement to Beijing's air quality resulting in remarkable falls in the concentration of several airborne pollutants and particulates. These included Sulphur Dioxide (SO<sub>2</sub>), Nitrogen Dioxide (NO<sub>2</sub>), Particulate Matter<sup>16</sup> (PM<sub>2.5</sub> and PM<sub>10</sub>) and Carbon Monoxide (CO) (notwithstanding some notable and well-publicised extreme air pollution events over recent years) as demonstrated in Figure 3.5 below.



**Figure 3.5 Annual Mean Concentrations of Major Atmospheric Pollutants (SO<sub>2</sub>, NO<sub>2</sub>, PM<sub>10</sub>, PM<sub>2.5</sub> and CO) (µg/m<sup>3</sup>) in Beijing from 1998 to 2014**  
 Source: Compiled based on data provided by Beijing Municipal Environment Protection Bureau (BJMEPB)<sup>17</sup> (2014a)

Looking at Figure 3.5 more closely it is clear that SO<sub>2</sub> emissions have been on a continuous downward trend and have been replaced by relative increases in NO<sub>2</sub>, PM<sub>2.5</sub>, and PM<sub>10</sub> concentrations, which are all commonly associated with automobiles. It is also worth noting that the level of PM 2.5 (micrograms per cubic meter) in Beijing is 8.59 times above the recommended World Health

<sup>16</sup> More importantly, the data released by US Embassy also shows that there is a big decline in PM<sub>2.5</sub> in 2015 (82.5) compared to 2010 (104.2) and 2014 (97.7).

<sup>17</sup> The local government has published data of annual mean concentration of SO<sub>2</sub>, NO<sub>2</sub>, PM<sub>10</sub> and CO even though the data of PM<sub>2.5</sub> is not officially available until 2013. These are relatively reliable because they are officially published by government on a continuous yearly basis compared to other organisations.

Organization/WHO maximum (World Health Organization Europe (WHO/E) 2006).

These revelations support the arguments made throughout this thesis and accompanying papers that the rapid rate of motorisation, as experienced in Chinese cities such as Beijing, has played a growing role in human-made atmospheric pollution within the city, rather than industrial pollution (removal of industry from city). Compared to a 28-36 per cent regional transmission level of pollutants into Beijing, the local urban pollution within the city limits was on its own responsible for 64-72 per cent of the total PM<sub>2.5</sub> concentration experienced within the city boundaries between 2012 and 2013. Out of this staggering level at least 31 per cent could be directly attributed to the emissions generated by private automobiles moving throughout the city's streets and freeways (BJMEPB 2014a).

The principal cause behind this change to the source of Beijing's air quality degradation is the reduction of industrial emissions. There have been seven urban master plans introduced in Beijing throughout the years of 1953, 1957, 1958, 1973, 1982, 1992, and 2004 (Beijing Municipal Institute of City Planning & Design (BICP) 2013). The first four plans, which were formulated and implemented before the *Reform and Open-up Policy* (implemented in 1978), defined the urban function of Beijing as the national centre of politics, economy and culture with a focus on industry and science (BICP 2013). However, it was not possible to meet all of these requirements due to resource and land restrictions. From the 1982 master plan onwards Beijing was redesignated as being solely a political and cultural centre with economic initiatives transferred to other cities such as Shanghai. As a consequence factories were instructed to move their operations out of the city to neighbouring regions from 1984 onwards, in an attempt to upgrade the quality of Beijing's urban

environment. Beijing's City Master Plan (2004-2020) clearly states Beijing's urban planning goals as becoming a "national capital", "international city", "cultural centre" and most importantly from a sustainable planning perspective a "liveable city".

### 3.2.1.3. Extra data on 'peak car' hypothesis for Beijing.

Beijing's peak car is evident in the thesis papers through the data on modal split. This section expands on the findings using new material now available based on actual VKT which is normally used to explain VKT in other cities. The peak car hypothesis is further verified by the data below on the declining growth rate of ownership in private vehicles, declining per capita VKT and declining growth rate in total VKT:

- *Declining growth rate in vehicle ownership.*

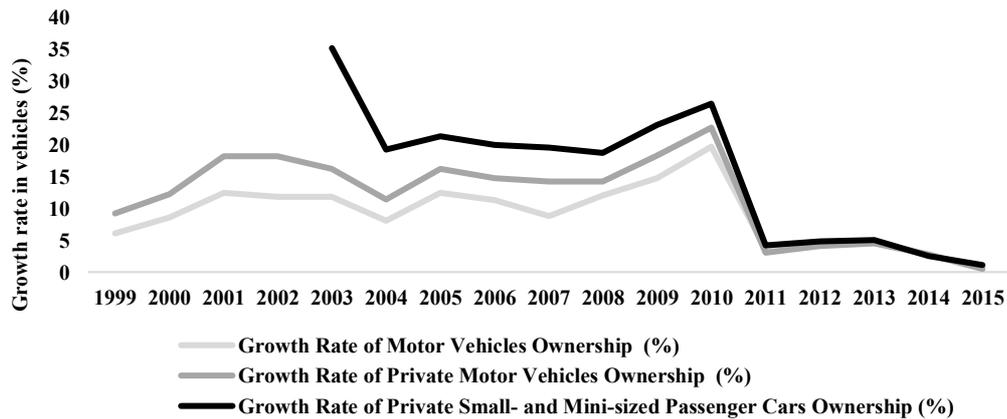
Figure 3.6 suggests that the ownership of motor vehicles<sup>18</sup>, private motor vehicles and private small- and mini-sized passenger cars<sup>19</sup> in Beijing began to increase around the 2000's, albeit at a fluctuating growth rate. However, these growth rates sharply decreased in 2011 largely as a result of the implementation of the Transportation Demand Management (TDM) plans at both a national and municipal government level that have been discussed before. The quotas have been further tightened from 240,000 (2011) to 150,000 (2014), aiming to limit total vehicle ownership to less than 6 million by 2017 (within a metropolitan area estimated to

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<sup>18</sup> Motor vehicles include automobiles, motorcycles and other types of motor vehicles. Automobiles include coaches, passenger cars, trucks and other types of automobiles. Other types of motor vehicles include special vehicles, tramcars, trailers and agricultural vehicles and tractors etc.

<sup>19</sup> Passenger cars include large-, medium-, small- and mini-sized passenger cars.

have a population of more than 20 million, so about 300 cars per 1000 persons) (Beijing Municipal Government (BMG), 2013). The ownership of private cars, which in the past has driven car motor vehicle ownership data as reflected by Figure 3.6, showed sharply slowing growth (down to 4.8%) in 2011 from its high point of 35% in 2004.

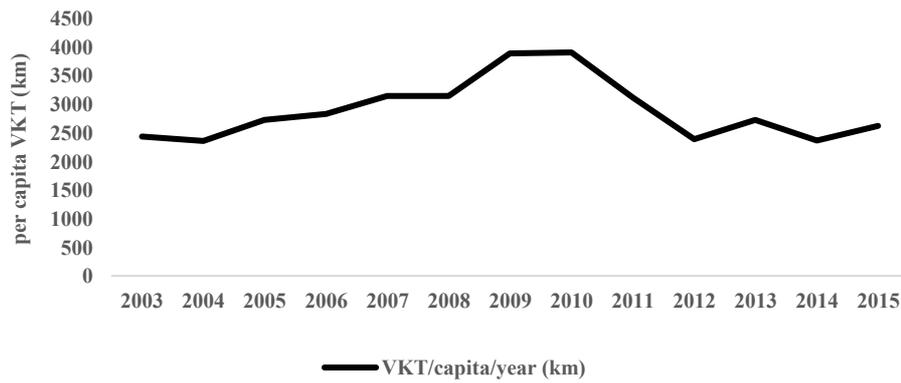


**Figure 3.6 Comparisons of growth rate of ownership between motor vehicles, private vehicles and cars in Beijing from 1999 to 2015**

Source: Compiled from data provided by the (BJTRC, 2002-2015; 2016).

- *Declining growth rate of per capita VKT*

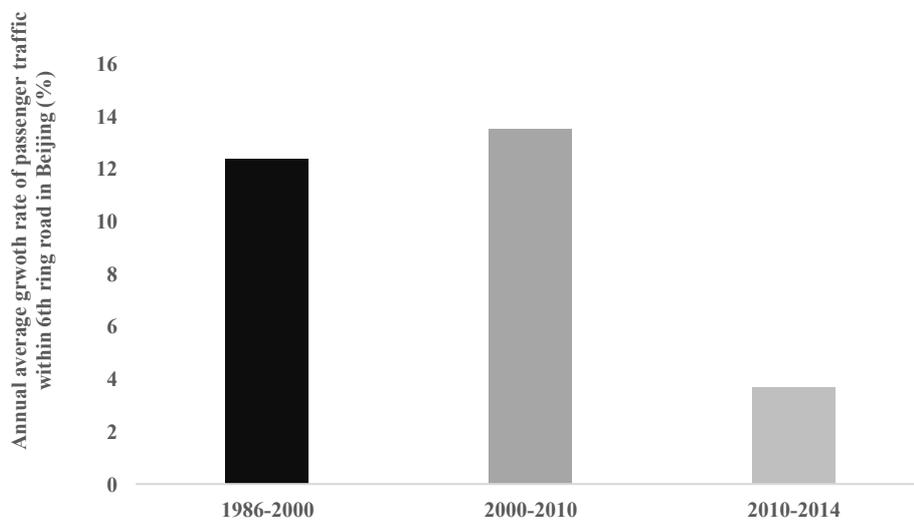
The per capita VKT, which reflects the actual use of private vehicles, started to decline around 2009-2010 in Beijing (Figure 3.7), in a similar trajectory to the trend of modal split by private vehicles. Beijing has therefore entered the peak car phase as explained by Newman and Kenworthy (2015) which is observable in most developed cities. This is a major and significant global trend as it shows that emerging cities are able to achieve such change well below the expected transition based just on levels of wealth. The peak car phenomenon has occurred, as discussed in the thesis, during the rapid growth phase of urban rail transit-led urban mobility.



**Figure 3.7 Growth and decline of private vehicle VKT per capita in Beijing from 2003 to 2015**  
 Source: Compiled from data provided by the (BJTRC, 2002-2015; 2016).

- *Declining growth rate of passenger traffic*

Peak car should be observable in traffic levels as the pressure of car use growth eases. The growing trend of passenger traffic in Beijing has declined substantially around 2010 (see Figure 3.8). This is consistent with the peak car data above.



**Figure 3.8 Annual average growth rate of passenger traffic<sup>20</sup> within 6th ring road<sup>21</sup> of Beijing from 1986 to 2014**  
 Source: Li et al, 2016

<sup>20</sup> 10,000 trips\*km

<sup>21</sup> Permanent population within 6<sup>th</sup> ring road of Beijing accounts for 75.9% in 2014 (Beijing Municipal Statistical Bureau, 2015).

There is considerable discussion on the factors that lie behind the generation of passenger VKT per capita in cities. Urban fabric is a dominant contributor to travel choice in cities (Newman and Kenworthy, 2015) as outlined below.

#### 3.2.1.4. Urban fabrics of Beijing

Beijing has served as the nation's capital for six dynasties and beyond with the establishment of New China in 1949. Its old urban pattern was formed during the Qing and Ming Dynasties (1406-1924) and still functions today, with the Forbidden City at its heart. The other important buildings, which were the symbols of imperial power during the Feudal Age, were symmetrically distributed around the central axis. Until today, the traffic corridors in Beijing, such as its metro system and highway loop roads, are still following the old grid street pattern, as clearly seen in the Beijing metro plan and its rectangular configuration (see figure 3.9)



**Figure 3.9 Map of Beijing Subway System Showing its Essentially Rectangular Configuration and Linear Corridors (Left) and Map of Shanghai Subway System Showing its Polygon Configuration as well as Linear Corridors (Right) (updated to 2015)**  
Source: Beijing Subway Operation Company Ltd (BSOC) (2013) and Shanghai Municipal Transportation Commission (SMTC) (2015)

### 3.2.2. Extra findings in Shanghai

#### 3.2.2.1 Urban makeup of Shanghai

According to the Shanghai Statistical Yearbook (SMBS 2016) from an administrative perspective the entire city of Shanghai consists of 16 districts and 1 county. The makeup and management of these districts is explained further in Tables 3.4 and 3.5 below.

**Table 3.4 Changes of Administrative Districts in Shanghai**

Year	Event	Authority
2000	The revocation of Huangpu and Nanshi has been approved and the new area of Huangpu consists of the original Huangpu and Nanshi.	State Council
2009	Nanhui was incorporated into Pudong New Area.	State Council
2011	The new Huangpu District will consist of the original Luwan and Huangpu.	State Council

Source: Compiled based on data provided by the SC (2000b, 2009b, 2011)

**Table 3.5 Statistical Division based on Administrative Division in 2014**

Statistical Division	Administrative Divisions in 2014
Old Districts in Puxi	Zhabei, Hongkou, Huangpu, Jingan, Changning, Xuhui, Putuo and Yangpu
Pudong New Area	Pudong New Area
City Centre	Old Districts in Puxi and Pudong New Area
Suburbs	Baoshan, Jiading, Minhang, Jinshan, Songjiang, Qingpu, Fengxain and Chongming
Whole City	City Centre and Suburbs

Source: Compiled based on data provided by (SMBS 2016)SMBS, 2015

As shown in Figure 3.9 the shape of the Shanghai metro networking is different from Beijing and features a polygon configuration. This is partly due to the fact that Shanghai is the commercial hub of China rather than the political centre as in Beijing. The landscape also differs as Shanghai has been built along both banks of the Huangpu River.

#### 3.2.2.2. Urban fabric and urban transport within Shanghai

The urban density of districts within the city centre (Huangpu, Jingan and Luwan) of Shanghai, which have the highest density of residential development from their historical development, decreased markedly from 1996 to 2013 while it has been increasing in the Central City and the Whole City. This is partly due to the redevelopment of the old city and the massive development in suburban areas. The city centre has been redesigned for administrative, commercial, and cultural purposes. Manufacturing-type enterprises have been gradually relocated into industrial parks or hi-tech parks on the fringes of the urban area. Hence, the geographical distribution of existing residents and immigrant workers from neighbouring regions has been from city centre to suburbs due to the unaffordable living cost. The traditional mono-centric urban form and rapid urban development has resulted in an increase in traffic between the city centre and other parts of the whole city. However, the urban fabric has not become as automobile dependent as one might expect at any stage. This can largely be attributed to the massive development of a high-capacity public transport system (see Section 3.2.2.3.) as well as continuing high density urban form rather than American/Australian low density suburbs. This kind of dense urban development in the old centre is based on European style urban fabric that is not high rise as it was built of stone; however the

new urban fabric is based on high rise in all parts of the city right out to the city fringe. These dense, high rise-based areas lend themselves to easy access by fast quality rail services. See photographs 1 & 2 below:



**Photo 1** Low-rise, dense and linear urban form of Shanghai representing the historic urban fabric.

Source: Photo provided by the Shanghai Urban Planning and Design Research Institute (SUPDRI) (2015a)

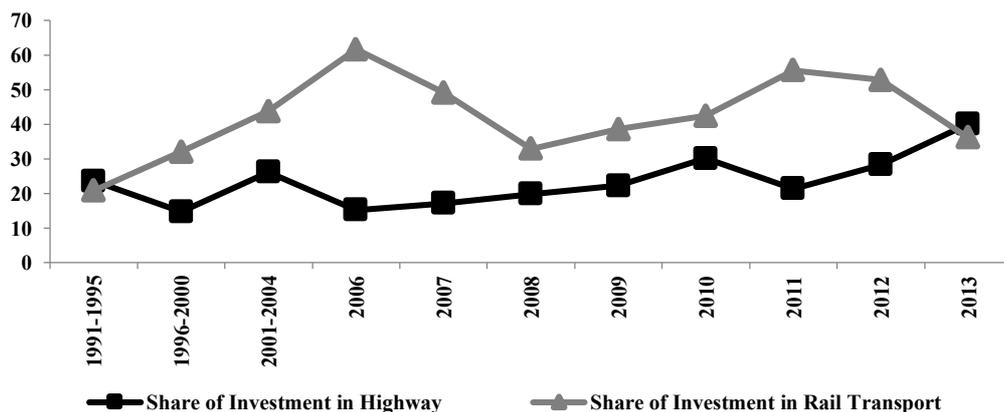


**Photo 2** High-rise areas of Shanghai representing the new urban fabric (2015)

Source: Photo provided by the SUPDRI (2015b)

3.2.2.3. Transformation in urban transport modes in Shanghai and its application for urban fabric and traffic management

Shanghai has conducted five traffic surveys at the municipal level in the years of 1986, 1995, 2004, 2009 (the actual execution time was from 2009 to 2010), and 2015. From 1997 onwards it has also undertaken small sample traffic surveys on an annual basis. These have been designed to maintain and update urban transport data. From this data it has been possible to extrapolate data on Shanghai’s public transit system (see Figure 3.10 - 3.13). The significance of each in relation to typical urban fabric and traffic management within Shanghai is discussed below.



**Figure 3.10 Share of Investment in Highway and Rail Transport in Shanghai (%)**  
 Source: Compiled based on data provided by the Shanghai City Comprehensive Transport Planning Institute (SCCTPI) (1997, 2016)

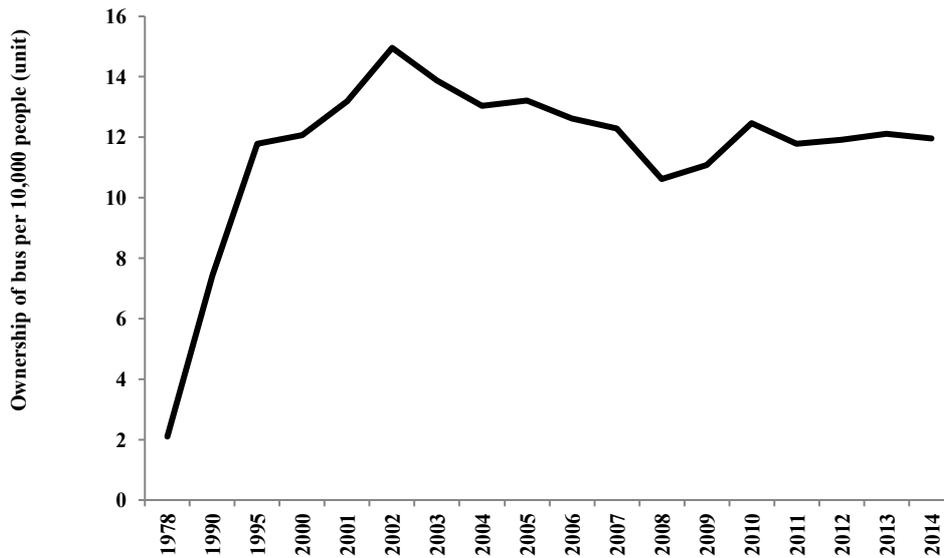
As Figure 3.10 shows, investment in rail infrastructure has been much higher on average than highway investment throughout Shanghai, when the first metro line initiated operation in 1994. The only exceptions being either end of the dataset where investment in highway infrastructure has only been slightly higher. All other recorded years show that much more funding has been given to rail in favor of highway, explaining why Shanghai enjoys one of the most comprehensive and

advanced rail systems in the country today. Besides a world leading metro system, the development trend of the other public transport modes has been summarised as below:

- Regular Bus

Trams and trolley buses have played important roles in public transport systems in the downtown of Shanghai in 1930's. The tram and trolley bus were initiated in Shanghai in 1908 and 1914, respectively. Regular bus does not service the main streets, but functions as the supplementary service in the suburbs. The first bus route was launched in 1922 in Shanghai.

As shown in Figure 3.11, the ownership of operational bus per 1,0000 people has increased sharply from the end of 1970's to the 1990's before peaking in 2002. This has occurred as a result of the merging of Shanghai's various bus companies along with economic evolution from a planned economy to a market economy. In addition, the bus fleet has been gradually upgraded to be equipped with air-conditioning, which has improved their comfort and made them more appealing as an alternative mode of transport to the automobile. Thirdly, the layout of bus lines has been extended and built within the new suburbs. It has improved the capacity of urban transit to connect the city centre and suburbs. It also pushes the redevelopment of the city centre by integrating with the metro system.



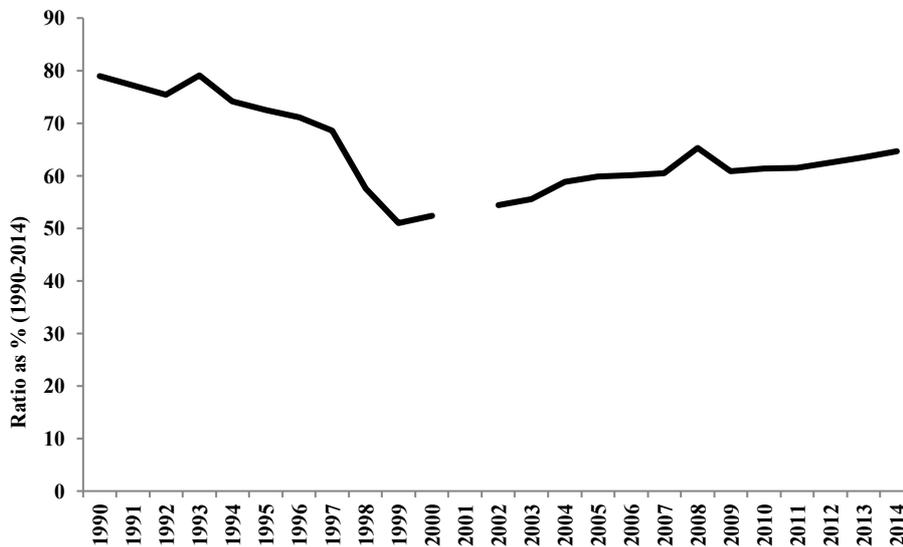
**Figure 3.11 Ownership of operational bus<sup>22</sup> per 10,000 people from 1978 to 2014 in Shanghai (unit)**  
**Source: Compiled based on data provided by SMBS (2016)**

- Taxi

Taxi provides another level of public transport service supplementary to the bus. Shanghai's taxi service has experienced rapid growth since the 1990's as a direct result of the city's strong economic growth. In 1996 alone taxis consisted of between 40-50 per cent of Shanghai's total road traffic. However, the passenger volume and the ratio of VKT by service both decreased even when the number of taxis on the road and total VKT increased. Many reasons can account for this situation, but the main one to consider is the rapid growth of private vehicles (cars and motorcycles). From 1996 until the 2000's this situation worsened with more and more private vehicles introduced onto the roads and highways. However, since the implementation of traffic management strategies in the mid-2000's, improvements to traffic congestion have partly occurred as a direct result of taxi's once again becoming

<sup>22</sup> It means all the buses in operation.

prime contenders for road space with private vehicles. One of the strategies used to ensure this resurgence has been a significant reduction to the flag-fall rates employed by the taxi companies (Figure 3.12).



**Figure 3.12 Ratio of vehicle kilometres of service by Taxi to total VKT by taxi in Shanghai from 1990 to 2014 (%)**

Source: Compiled based on data provided by the SMBS (2016) and the and the SCCTPI (1997, 2016)

- Car-sharing Programs

The introduction of App-based car sharing and other emerging technologies and social trends have also affected urban transport patterns with greater preference for public transit over the automobile including Didi Chuxing<sup>23</sup>. This has merged with Chinese Uber in 2016 to offer a competitive alternative mode of transit. As a result the total app-based passengers in China have dramatically increased from 13 million in 2012 to 211 million in 2014. This car-sharing program is significant as it reduces

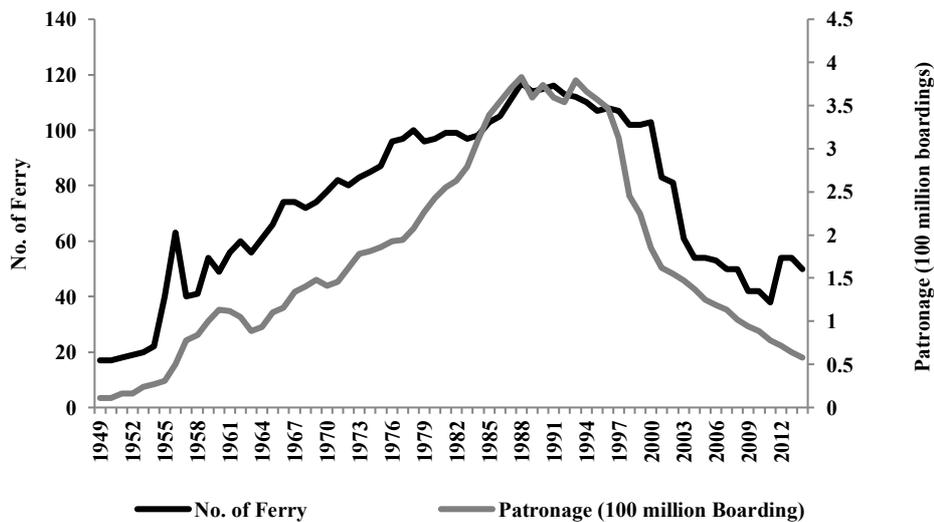
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<sup>23</sup> It is a Chinese online network company after the merger of Didi Dache and Kuaidi Dache. It sends customer request for vehicle and taxi service to Didi drivers, who use their own personal cars, through Didi phone apps.

the possibilities of single-occupant vehicles and hence the associated environmental cost including traffic congestion, fuel consumption and GHG emissions.

- Ferry

The official operated ferry was initiated in 1911 and became the dominant water transport mode. Previously there was dramatic growth in both ferry numbers and patronage since the establishment of New China in 1949, before a peak was reached in the mid-1990's. However, the massive level of bridge and tunnel construction designed to link Pudong and Puxi in Shanghai has had a detrimental impact on ferry services and as a result patronage numbers have fallen further (see Figure 3.13). The bridge, tunnel and metro transport have dominated the cross-river traffic in 2015 while the use of ferry continues declining.



**Figure 3.13 Number of Ferry (unit) and Annual Patronage by Ferry (100 million boardings)**  
 Source: Compiled based on data provided by the SMBS (2014)

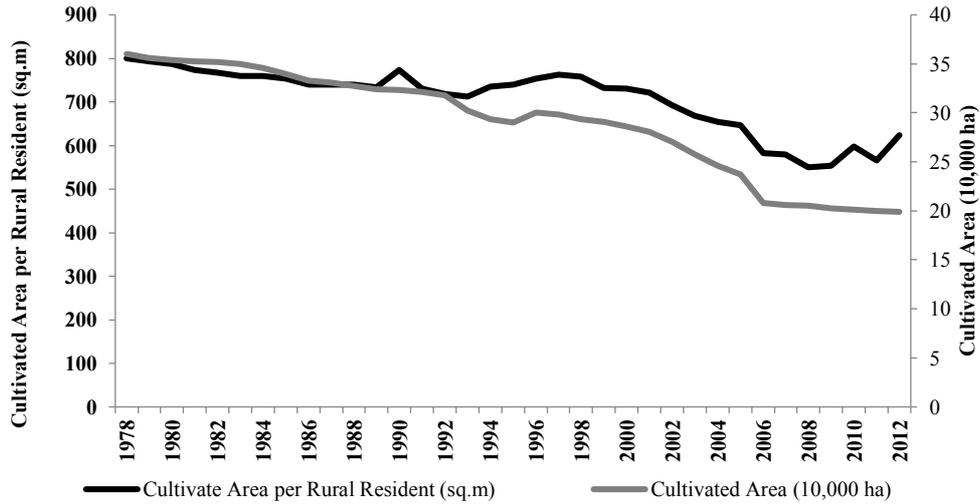
#### 3.2.2.4. Environmental impacts from urban transport in Shanghai

- Traffic Congestion

The road area in Shanghai's central city has increased by 25 per cent from 2004 to 2009. Despite this the much more aggressive growth in both automobile numbers and traffic flow has far offset any induced benefits from the addition of this new road based infrastructure. For example, registered automobile number in Shanghai doubled and traffic flow increased by 55 per cent during the same period. The arterial traffic speed during the peak hour within the inner-ring of the central city was as slow as 16km/h (morning peak) and 15km/h (evening peak) in 2009, decreasing by 9 and 3 per cent compared to 2004 level.

- Cultivated area

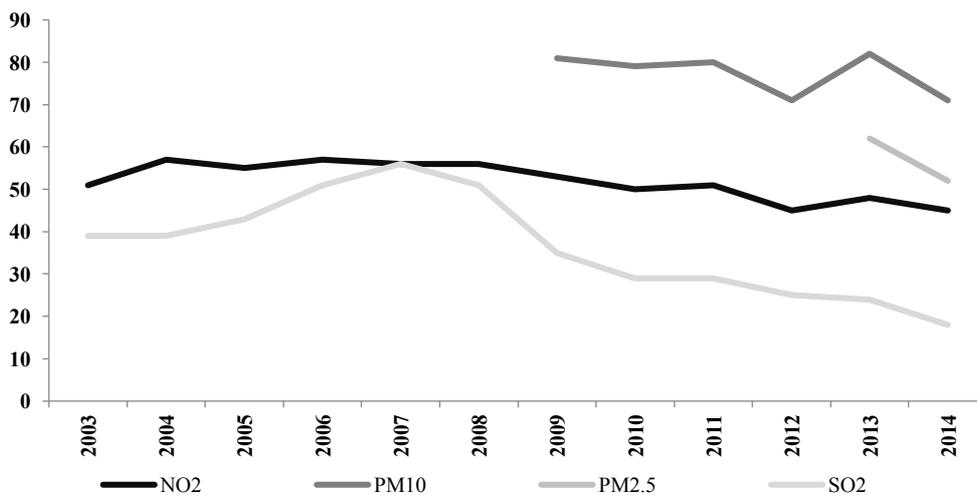
Cultivated area is essential for the food security and sustainable development of the nation especially for the megacities of the world's largest developing and densely populated country (Yang and Li 2000). Due to the massive demand on urban development such as the need to accommodate China's soaring urban population and urban expansion, cultivated land has been encroached upon for urban functions (Xu, Chan and Yung 2014)). Specific needs of the automobiles such as additional road construction and parking facilities have been catered for at the expense of food production. Fortunately this situation has been improving since the mid-2000's. The per capita cultivated land in the rural area has started to recover increasing from around 2011 onwards, partly due to the massive development of urban metro systems in preference to freeway and other road construction.



**Figure 3.14 Gradually Reduced Cultivated Area in Shanghai (10,000ha) (1978-2012)**  
 Source: Compiled based on data provided by the SMBS (2014)

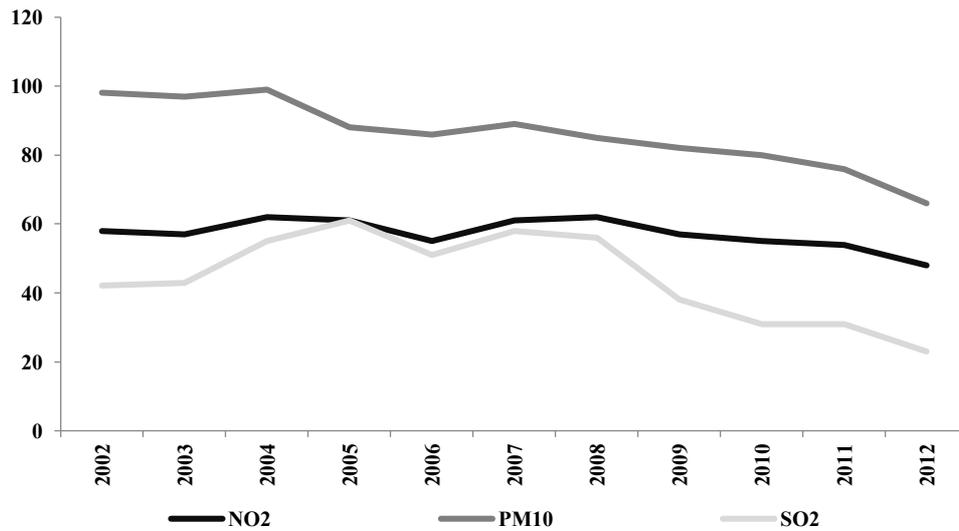
- Air Pollution

According to Figure 3.14 and 3.15, the level of air pollution in both the whole and central city of Shanghai has improved from around the mid-2000's. Of particular interest is the finding that the concentrations of SO<sub>2</sub> and NO<sub>2</sub> has been lower than that of PM<sub>10</sub> and PM<sub>2.5</sub>, which indicates that the industrial pollution has been replaced by traffic-related pollution as the primary source of the city's air quality problems.



**Figure 3.15 Air Pollution within the Whole City of Shanghai (µg/m<sup>3</sup>)**  
 Source: Compiled based on data provided by the SCCTPI (1997, 2016)

The central city of Shanghai has higher level of PM10 than in the whole city, which could be explained by the higher level of automobile use. But it entered into a downward trajectory around 2004. The rate of decrease has also sped up since 2011 indicating that the period of peak car within Shanghai has been reached (see Figure 3.16).

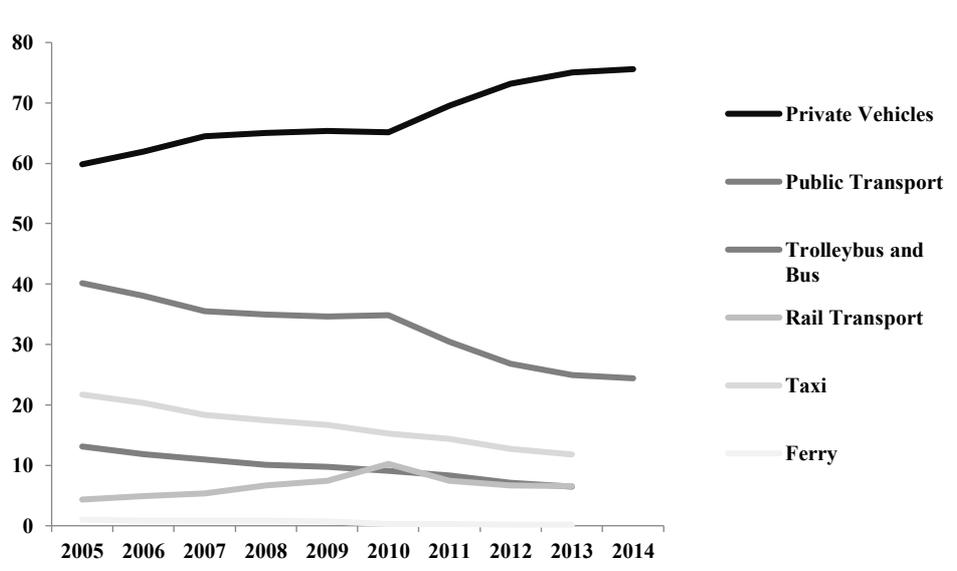


**Figure 3.16 Air Pollution within the Central City of Shanghai ( $\mu\text{g}/\text{m}^3$ )**  
Source: Compiled based on data provided by the SCCTPI (1997, 2016)

- Energy Consumption

The significant development to Shanghai’s public transport system, especially its metro system, has promoted the remarkable decrease in energy consumption.

Accordingly, the share of energy consumption by private vehicles has increased since around 2010 (see Figure 3.17)



**Figure 3.17 Share of Energy Use by Different Transport Modes within the Whole City of Shanghai (%)**

Source: Compiled based on data provided by the SCCTPI (1997, 2016)

## **CHAPTER 4: CONCLUSIONS AND FUTURE**

### **RESEARCH**

#### 4.1 Conclusions from this thesis

This thesis began with the question “Using the examples of Beijing and Shanghai, can Chinese urban motorisation become a more sustainable form of mobility?” The answer has been presented in five papers and a set of supplementary materials in this exegesis. It suggests that a positive affirmation can be offered. It means that Chinese megacities, Beijing and Shanghai are not automobile dependent cities and will not succumb to automobile dependent cities despite the dramatic growth in private vehicle ownership and pressing automobile-related problems. This conclusion is drawn on the basis of declining modal split of daily trips by automobiles. It has also been supplemented by declining per capita VKT and declining growth rate of passenger traffic, which shows a decline around 2010 in Beijing. This is significant to all Chinese cities as well as all emerging cities as the transition has begun and is happening very quickly. It does not mean there is a common form across China. The common patterns and processes of change in Beijing and Shanghai are suggested to function as examples for other Chinese cities which have been gone the automobile route but are trying to turn this around now for more sustainable transport and the others which are still going fastest on the automobile route.

Automobile usage has been built into the economy and social life in the whole of China, which has become the powerhouse in the global automobile market.

However, the massive traffic is colliding with Chinese traditionally dense urban fabric, which results in traffic-related problems. Hence, this research has focused on

the historic trend and current status of urban transport within Chinese cities utilising three megacities as case studies. It has explored the driving factors for urban transport transitions and implications for their future sustainable transport through data aggregated on a decadal timescale. It suggests that Chinese megacities like Beijing and Shanghai have reached peak car use from around 2010 and can build up sustainable urban transport based on their traditional urban fabrics which favour walking, cycling and public transit over the automobile.

The thesis has presented a series of publications that have in combination:

- Analyzed the emergence and then dominance of the Chinese automotive industry, a situation which has led to unsustainable levels of private motorisation;
- The types and subsequent causes of Chinese urban transport transitions within three case study Chinese megacities; and
- The relationship of each transport transition to Chinese urban fabrics as both a cause and then later a potential solution to achieving more sustainable levels of private automobile use in these and all other Chinese cities.

It serves as a background document to help support and facilitate ongoing discussion for all emerging cities, especially about how oil can be reduced as part of a climate change strategy in relation to automobile use within cities. It is the baseline to which future research can be undertaken in the area of Chinese traffic management, sustainable transport transitions, and the development of suitable supporting urban fabrics. Hence, further research is recommended based on the preliminary findings of this thesis.

## 4.2 Proposal for future research

*How to make a continuum of motorisation from the least motorised to the most motorised with some cities along different development types and pathways across the whole of China?*

As of 2015 China has over 600 cities. Paper 2 and Paper 3 choose three Chinese megacities as case studies and were able to identify similar urban transport transitions from bikes to automobiles to trains along with corresponding growth and decline in Chinese private urban motorisation, changing urban development and economic growth patterns. These three cities are the most representative cities in China in terms of their political, economic and cultural influences; however, further research is needed to affirm whether or not China has truly stepped into the era of peak car use in the other smaller cities and less developed parts of the country.

This proposed further study will aim to seek a perspective across a broader national spectrum of cities. It will be complemented by a selection of case studies across the three distinctly different types of Chinese cities whereas this first study has focussed solely on megacities. The common factor will be a recognition that each case city despite its classification, is on an undesirable route of automobile dependence, but efforts will be made to show how this might be turned around in favour of a transition towards a more sustainable transport format. It will use the preliminary work that has come out of this thesis showing how three major Chinese cities have begun to show the transition to sustainable mobility. It could potentially provide a way of looking at different development paths and potential futures for Chinese cities and perhaps show a range of options suitable to a diverse set of cities within the sea

of literally hundreds of Chinese cities. It will adapt and apply the comparative methodology within the context of a developing city. The significance of this is that the transport systems and issues a developing city face are very different from those experienced by developed cities; however the differences between developed and developing cities can now be seen to be much more similar than was once considered possible due to a remarkable transition to a more sustainable mobility in the three big Chinese cities examined in this thesis.

Once this research has developed a model for all emerging cities in China it could be applied to other parts of the world as it is likely that most urban models will be comparable to these in China. In that way, a more global perspective on the transition to sustainable mobility can be made available to a world now looking for such solutions.

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**Gao, Yuan (PhD Candidate) (60% Contribution)**

*Preparation and completion of the manuscript, establishment of theoretical framework, data collection, preparation of figures and tables, policy analysis.*



*Yuan Gao, PhD Candidate*

**Kenworthy, Jeffrey (Co-supervisor) (20% Contribution)**

*Supervising, revising and editing the manuscript.*



*Professor Jeffrey Kenworthy, Co-supervisor*

**Newman, Peter (Principle Supervisor) (20% Contribution)**

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*Professor Peter Newman, Principle Supervisor*

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PROFESSOR JOHN WHITELEGG  
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UNIVERSITY OF YORK,  
YORK,  
YO10 SYW, U.K

PAUL TRANTER  
SCHOOL OF PHYSICAL ENVIRONMENTAL &  
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WORLD TRANSPORT POLICY AND PRACTICE,  
41 CHURCH ST,  
CHURCH STRETTON,  
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SY6 6DQ  
TELEPHONE +44 (0)1694 722365  
E-MAIL:

[john.whitelegg@sei-international.org](mailto:john.whitelegg@sei-international.org)

WEB:

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## **Growth of a Giant: A Historical and Current Perspective on the Chinese Automobile Industry**

*Yuan Gao, Jeffrey Kenworthy and Peter Newman*

### **1. Introduction and Context of Chinese Motorisation**

Development patterns at national and international levels not only depend on relations between society and economy within and across regions, but also on the ecosystem capacity of other regions (Folke et al., 1998). As a result, the majority of developed cities around the world have gained useful social, economic and especially, environmental returns from their recent mitigation of vehicle overuse (Puentes and Tomer, 2009; Newman and Kenworthy, 2011). However, cities in most emerging economies are undergoing rapid motorization such that it is imperative to explore the current status and negative impacts of this growing motorization in these countries. China is particularly important in this regard since it is now widely acknowledged as the world's largest car market and is the focus of most major car manufacturers, selling products from basic cars up to luxury models. In 2010 China overtook Japan as the second largest economy behind the United States. Cities in developed countries have stepped into an era of declining car use, which some are terming "peak car use" (Newman and Kenworthy, 2011). The Chinese cities, on the contrary, are in a stage of flourishing development with a prosperous automobile industry supporting it. Undoubtedly, social and economic benefits from increasing motorization cannot be ignored. Nonetheless, this comes at the cost of scarce natural resources, serious environmental impacts and large cultural changes expressed partly in the way that urban public spaces are being turned over to roads and parking and the old walking fabrics previously reliant on pedestrian and bike traffic are often transformed into congested, noisy and polluted places (Mao and Chen, 2009).

Based on Petty-Clark's Law and Kuznets Theory<sup>1</sup>, China has experienced an upgrade of its industrial structure along with

<sup>1</sup> They refer to the transformation of industrial structure from labor-intensive to capital-intensive and finally to technology-intensive with the process of economic development.

an advanced economy. The automotive industry partly pushed forward the process. The mounting desire for motor vehicles is deemed as a vital driving force for boosting domestic demand and energizing economic growth. The contribution of the auto sector to GDP in China is reported to have risen from 0.97% (1999) to 2.29% (2009). Furthermore, global automobile focus has shifted eastwards to China. The International Organization of Motor Vehicle Manufacturers (or Organisation Internationale des Constructeurs d'Automobiles/OICA) reported that U.S. auto sales experienced a precipitous tumble to 13.49 million vehicles or an 18% decline in 2008, the worst performance since 1992, strongly affected by the 2008 Global Financial Crisis (GFC). Chinese auto sales rocketed in 2009 by 46% and China overtook the U.S. as the major car consumer worldwide (notwithstanding this was at a time when global auto sales were at a depressed level).

Nevertheless, current levels of private motorized transport worldwide are unsustainable. The International Energy Agency (IEA) in 2010 recognised that the production of conventional crude oil had peaked in 2006 and that from here on only expensive and vulnerable oil sources remained (World Energy Outlook 2010). About 14% of all oil is consumed by road transportation (World Development Indicators 2012). The 2011 CO<sub>2</sub> emissions by transport around the world accounted for 22% of the total. Road transportation, as the fastest-growing sector, contributed 52% of that in 1990, but some 75% in 2011 (CO<sub>2</sub> Emissions From Fuel Combustion Highlights 2013). The other pertinent costs from road transportation include noise pollution, infrastructure costs, congestion costs, and costs from community severance and destruction of the public realm of cities (Newman and Kenworthy, 1999). Transport in general, and urban transport in particular, is broadly recognized as the major contributor to energy vulnerability, climate change and these issues grow daily in significance on the world stage.

China, whose proportion of global energy consumption has risen to 18.5% in 2009 (Global Energy Statistical Yearbook 2013), has overhauled the U.S.A as the largest energy consumer (Kennedy, 2011). The dramatic growth of motor vehicles is one of the most rapidly rising drivers of Chi-

na's increasing oil demand, accounting for roughly 32% in the national context in 2002 (He et al., 2005). In regard to globally serious environmental deterioration, China achieved a worrying status in 2006. Its fossil fuel CO<sub>2</sub> emissions were 24% worse than the United States level and China became the world's largest emitter of CO<sub>2</sub> (Yan and Crookes, 2009), stoking the increasingly severe global warming problem (Photo 1). The road transport-related CO<sub>2</sub> emissions in China were 280.47 Mt, accounting for 57.5% of the transport-related CO<sub>2</sub> emissions and 4.6% of the total CO<sub>2</sub> emissions in China (Reducing Transport Greenhouse Gas Emissions Trends and Data 2010).



**Photo 1:** China's rapid increase in private motorised transport is fuelling increased CO<sub>2</sub> emissions

*Source: Yuan Gao*

This paper begins with an overview of the Chinese auto-industry from its trial establishment, tortuous development, tremendous prosperity to sound planning. It then retrospectively discusses the driving factors that resulted in the prosperous development and unparalleled influence of the Chinese automobile industry. It examines economic growth, rising disposable income, high savings rates, population explosion, urban sprawl, shifting land use practices and traditional culture, with a focus on the formulated and applied industry policies from the Chinese government. With industrial policies shifting towards managing transportation demand and improving urban public transport (UPT), it also discusses several on-going incentives including New Energy Vehicles (NEVs) and rail transport. In light of the expanding clout of this industrial giant worldwide, appropriate development of the Chinese

automobile industry will be an important focus for sustainable development that can stimulate economic growth as well as social and environmental well-being both nationally and internationally.

## **2. History of the Automobile Industry in China**

The "Preparatory Group of the Auto-Industry" under the Ministry of Heavy Industry was set up in 1950 shortly after the People's Republic of China (PRC) was established in 1949 (Liu, 2000). The Chinese automobile industry, which was originally designated to meet military and transportation need, was more oriented to freight vehicles. The Automotive Industrial Policy (AIP) enacted in 1994 and the Tenth Five-Year Plan (FYP) (2001-2005) successively encouraged individuals and families to purchase passenger vehicles. Passenger vehicles, which reflect higher technologies and more profitability, have therefore gradually been developed. Faced with integration into the global automobile community through entry into the World Trade Organization (WTO) in 2001, the Chinese auto industry strategically shifted its development focus from expanding its production scale to enhancing its industrial structure. After these early developments, which helped pave the way for the Chinese automobile industry, the next step was the "Plan on Automobile Industry Restructuring and Revitalization" (2009). This report stated that the auto-industry would play a crucial role in Chinese economic growth and social development.

The automobile industry in China, which has now marched into its 5th decade, went from a situation where not a single vehicle had been produced before 1956, to one where in the space of just over 50 years, it has grown to be the largest auto producer and consumer on a global scale since 2009 (Ferrazzi and Goldstein, 2011). What makes the achievement even more extraordinary is that for much of this 50-year period China was a centrally planned, communist economy, not functioning with the capitalist principles that gave birth to the world's other major auto manufacturing countries, such as Japan, the USA and Germany. It is therefore important to understand some of the detailed history behind this astonishing achievement. The following sections divide the development

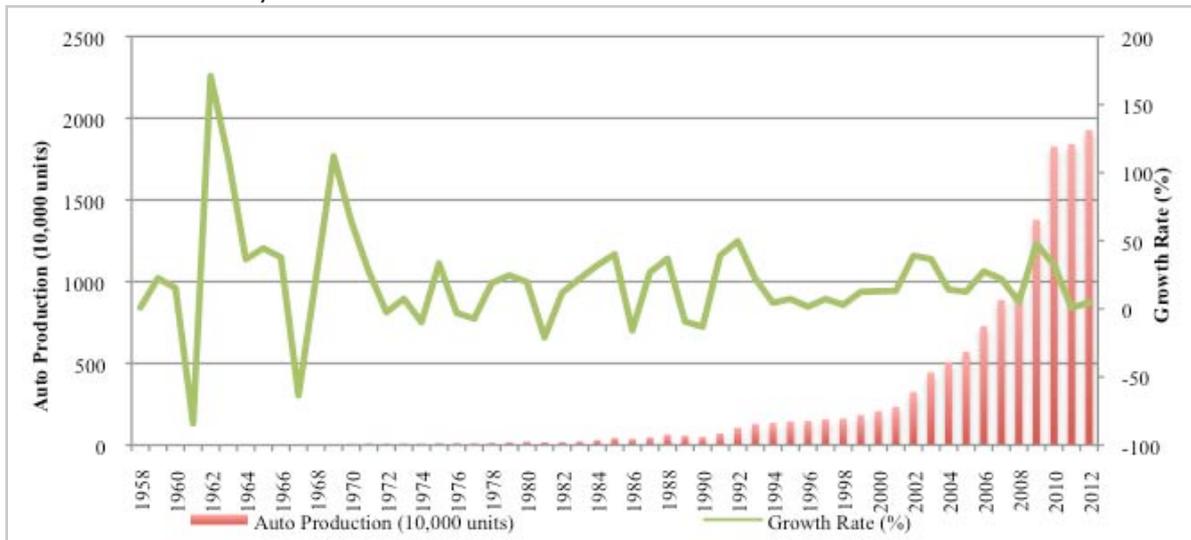
of the Chinese auto industry into four distinct phases:

- Start-up Phase from 1956 to 1978;
- Growing Phase from 1979 to 2000;
- Prosperity Phase from 2001 to 2010;
- and
- Stationary Phase from 2011 until the present day.

### 2.1 Start-up Phase (1956-1978)

In an attempt to transform China from an agricultural country to an industrial power, (the so called "New China"), the "Common Program of the Chinese People's Political Consultative Conference" (1949) stipulated that nationally concentrated efforts

From then on, at least until China's 1978 "Reform and Opening-up Policy," the country groped forward with a dramatically fluctuating growth trend in its vehicle production rate (see Figure 1). Even after 1978, growth rates were very variable, but not of the same order as the "roller coaster" levels that characterised the period between 1958 and 1978. The 1955, 1956 and 1957 data are also available but are even more intensely volatile as would be expected with the small numbers being compared. For example, the auto production of 1955 (61 Units) is 2611 times less than the 1956 level (1,654 units). Hence, these three earliest years are omitted from the time-series dataset.



**Figure 1:** 1958-2012 Auto Production (10,000 Units) and Growth Rate (%) in China  
*Source: Compiled based on China Automotive Industry Yearbook and National Data (National Bureau of Statistics of China)*

should focus preferentially on revitalization and development of heavy industry. The automobile industry was accordingly included in China's first Five-Year Plan (1953-1957) under Mao Tse-tung and throughout all China's national planning since then, right up until the latest Five-Year Plan (2011-2015), China's twelfth such plan since the communist revolution. The First Automobile Works (FAW), which was established in 1953, within the framework of a technology collaboration program between China and the former Soviet Union, was geared towards heavy vehicles production for defence demand (Gan, 2003). The Chinese auto-industry formally broke ground in 1956 when the first group of heavy-duty trucks rolled off the production line (Zhou and Nie, 2007).

In the time of the Cold War when China was antagonistic towards the U.S., the full acceptance of Soviet-style technology undoubtedly sped up the process of industrialization. But it also caused the Chinese auto-industry to become isolated from real economic conditions, and it built up institutional obstacles to self-developed products (Holweg, et al., 2009). Thus, the kind of administrative management and economic frameworks in which Chinese vehicle production operated thwarted innovation. Vehicle production in China was run by the government rather than through the market economy and it mainly served to develop the mechanized means of freight transport to satisfy economic construction. The central government held a monopoly on automobile supply in China. Vehicles

manufactured from the FAW accumulated up to 150,000 units until 1965, representing 88.2 per cent of the national total (Hu, 2002). Auto-enterprises were deficient in intrinsic motivation under the mandatory plan in strict compliance with China's Planned Economy and therefore lacked the necessary innovation processes for a progressive, modernising auto industry.

In spite of this general situation, some national strategies emerged that, although being recognized as going against the 'law' of Chinese development, nevertheless somewhat helped to facilitate the Chinese automotive industry. Mao's Great Leap Forward (1958-1960) is an example. It aimed to emulate and surpass the United Kingdom in the field of major industrial products output within 15 years. Consequently, more than one hundred minor local automotive factories were quickly formed and the entire vehicle production in 1958 almost doubled the 1957 level (China Automotive Industry Yearbook 2002). The resulting proliferation promoted four more automobile production sites built in the cities of Nanjing, Shanghai, Beijing and Jinan. Similarly, the Cultural Revolution (1966-1976) caused nationwide upheaval but improved the localization of the automotive industry with the decentralization of central government power. The Second Auto Works (SAW), established in 1969, has been recognised as becoming basically technologically independent in auto-manufacturing (Sit and Liu, 2000). Its location and products also reflected Chinese conditions. Since the Sino-Soviet split in 1960, China felt threatened by both the U.S. and the former Soviet Union. The SAW was therefore placed in a mountainous region and mainly supplied military crossover vehicles and trucks designed to help prepare China against a possible foreign attack (Harwit, 1995).

The Chinese auto-industry, which started out with imported international technology and national financial support, featured weak autonomy and rigid administration practices under a centrally planned economy. Under no circumstances can private auto-enterprises enter into the automobile market, or existing ones retreat from the auto market, when a national government erects such strong industrial barriers. Such practices generate inefficiencies and uncompetitive production systems. The

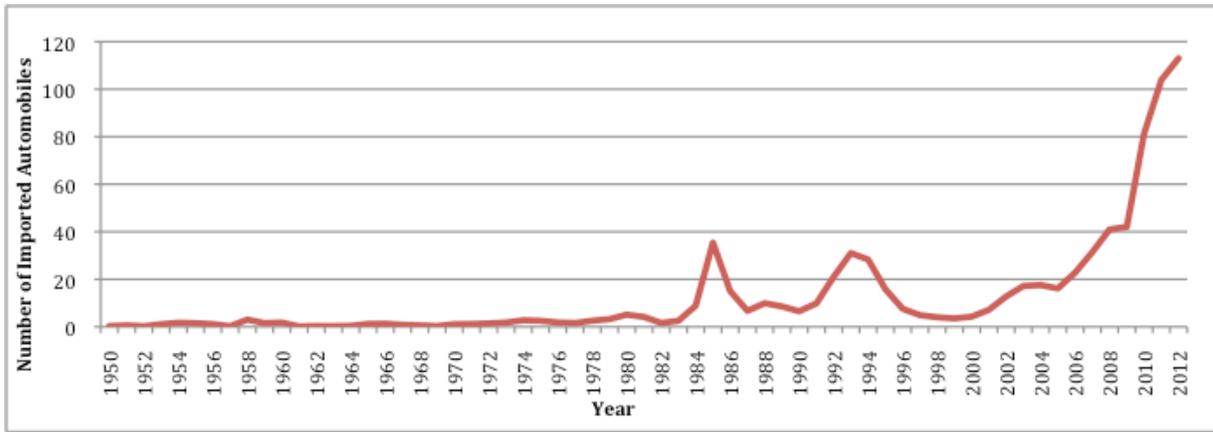
cumulative output of automobiles in China in the 22 years from 1955 until 1977 was 1,252,527, about equivalent to the monthly production in 2009 (China Automotive Industry Yearbook 2010).

## 2.2 Growing Phase (1979-2000)

The 1978 institutional reform from a state-controlled economy to a market-oriented one had a remarkable influence on everyday aspects of social, economic and cultural life (Qian, 2000). As far as the automobile sector was concerned, the commercialisation of motor vehicles was not initiated until 1983 when the government relinquished a 10 per cent share of self-marketing to auto-manufacturers themselves (Zhang, 2004). As explained earlier, the automotive industry in China in its formative years was regarded as a producer of freight vehicles and this generated a shortage of light vehicles. With respect to the passenger car that was trial-produced by the FAW in 1958, it remained in a state of slow development until 1978. In that year its production reached a low of 2,640 units, accounting for just 1.7 per cent of China's entire automotive products. It was at this time actually the "Chinese Truck Industry" rather than the "Chinese Automobile Industry".

A large transformation occurred in China in 1984 when the purchase of private vehicles was explicitly acknowledged as legal at the national policy level (Provisions on Individual or Corporate Farmers Purchase Motor Vehicles, Vessels and Tractors for Transportation Business). The Chinese government then adopted an even more positive stance towards ownership of private vehicles in the AIP (1994) and entrenched the concept of "Encouraging Passenger Cars into Family" into the Tenth Five-Year Plan in 2001. The demand for automobiles in China, which had been dominated by government cars, subsequently transformed to private ownership of vehicles, which was even forbidden before 1979 (Liu, 2008).

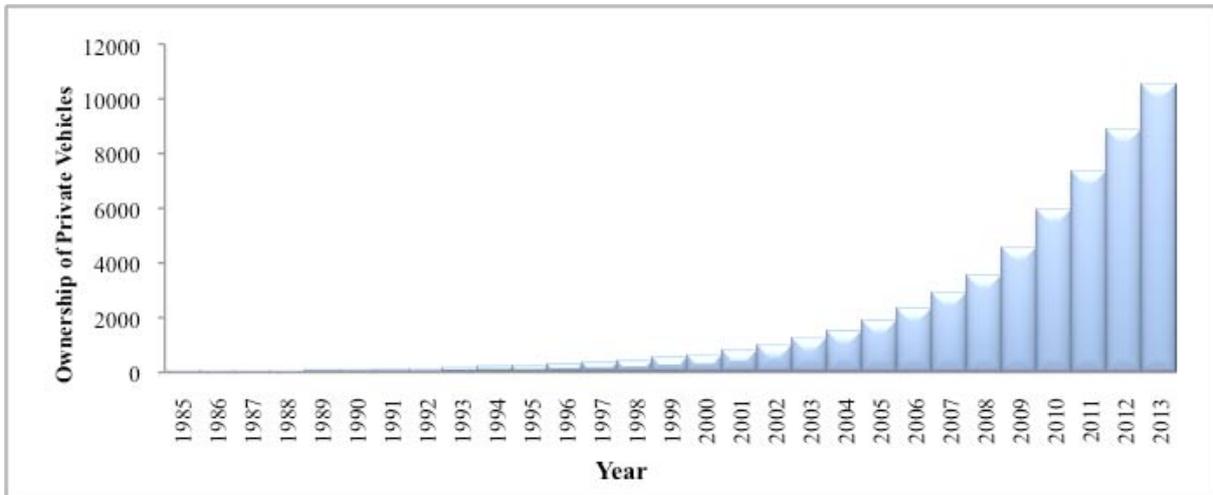
Consequently, the surging imbalance between a rapidly inflated demand for automobiles and limited domestic production triggered an import binge (see Figure 2). Imported-automobiles poured into China, both legally and illegally. The amount of imported automobiles from 1978 to 2012



**Figure 2:** Number of Imported Automobiles in China (1950-2012) (10,000 Units)  
*Source: Compiled based on China Automotive Industry Yearbook (2010) and China Association of Automobile Manufacturers/CAAM*

occupied up to 93 per cent of China’s gross imports of all types of vehicles. The share of foreign imports of automobiles to the domestic market hit a peak of 44.5% in 1985 (Ministry of Commerce/MOC, 2009). For the purpose of mitigating the exacerbated drain on China’s foreign exchange, the central government resolved to tighten macro-regulatory conditions and cultivate its own national car-industry instead. More specifically, starting in 1985, high tariffs were levied on car-imports in order to protect the infant Chinese car industry. Such

mobile production up to 15% per annum from 1992 to 2002, which was ten times more than the global level (CAAM, 2002). The proportion of light-, mid-sized- and heavy-vehicles was adjusted to 78.5%, 17.8% and 3.7%, respectively in 1998. The amount of imported cars accordingly reduced throughout the 1990s and bottomed out in 1998 (18,016 Units), whereas the ownership of private vehicles rose from 284,900 Units in 1985 to 4,236,500 Units in 1998, an almost 14 times increase in just 13 years (see Figure 3).



**Figure 3:** Ownership of Private Vehicles (10,000 Units) from 1985 to 2013  
*Source: Compiled based on National Data (National Bureau of Statistics of China)*

tariffs reached up to 220 per cent in 1992 according to Notice on Cancelling Import Adjustment Tax (China Customs General Administration/CCGA, 1992). On the other hand, Sino-foreign joint ventures under the “Market for Technology Strategy” that was approved in 1984, promoted the integration of the Chinese auto-industry into the world. Promulgation of incentives boosted the average growth rate of Chinese auto-

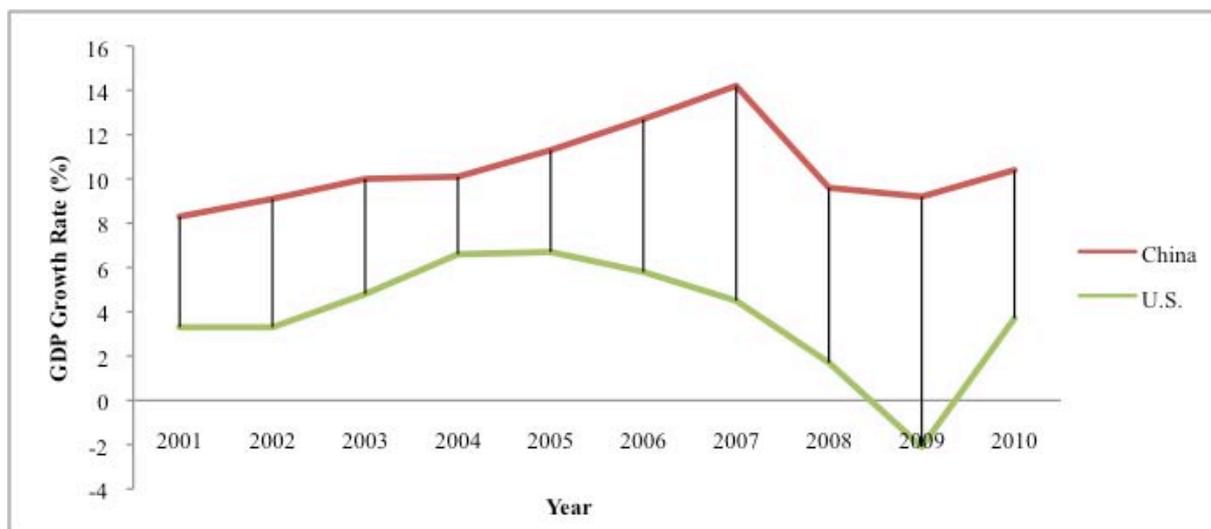
### 2.3 Prosperity Phase (2001-2010)

Following from the previous period, China came under the gaze of the WTO and China itself also recognized the value of being admitted to the WTO. As a result an agreement was struck between China and the WTO, that the import tariff on an assembled car would in 2001 be reduced to 80 per cent where the size of the engine

is less than or equal to three-litres, or 110 per cent where the size of the engine is bigger than three-litres and to 25 per cent by July 1, 2006 (Tianjin Economic-Technological Development Area Automotive Industry Development Research Report). These significantly decreased tariffs, as well as deregulation of non-tariff barriers (such as easing restrictions on car-import permits), made China's entry into the WTO in 2001 the major new thrust in the development of the Chinese car industry.

In the meantime, in the face of the accelerated pace of globalization, China made significant economic progress from 2001 onwards. Its real per-capita Gross Domestic Products (GDP) stayed on an annual 8 per cent high-growth trajectory, whilst the American economy went into a downturn (see Figure 4). Personal income, which is recognized as the principal economic stimulus to vehicle ownership (Dargay et al., 2007), remained for the most part in double-digit<sup>2</sup> annual growth, along with national economic development during the same period.

to over 10 million in 2010 (Shenzhen Statistical Yearbook 2013). The National Urban System Planning (2010-2020) (Draft) selected Shenzhen, which was basically a fishing village, as the central city of southern China since 2010. This unprecedented demographic leap forward on such a huge scale in China has caused people to gradually move away from the central cities to suburban areas to avoid daunting housing prices and other serious urban problems. However, the central districts of Chinese cities have continued to serve as the sites for the main political, economic and recreational functions, due to the deficiency of ancillary facilities in peripheral regions (Song, 2013). The resulting commuting times rise rapidly with such mono-centric urban forms and expanding urban sprawl, albeit at considerably higher densities than in other sprawling cities such as Atlanta, Houston or Sydney (Newman and Kenworthy, 1999). This phenomenon, together with an element of the car being a symbol of social status, meant that the ownership of private vehicles in China ac-



**Figure 4:** Trend of GDP Growth Rate between China and USA (2001-2010)  
*Source: Compiled based on World Bank and Bureau of Economics Analysis (BEA)*

Furthermore, Chinese urbanization has been experiencing a continuous increase from 39.1% in 2002, up to 51.3% in 2011, with an average annual growth rate of 1.35% (China National Human Development Report 2013). This means that nearly 188 million rural dwellers have relocated to urban areas in China over that 9-year period. Shenzhen is a clear example, growing from 314,100 residents in 1979

celerated dramatically in the 2000s (Gan, 2003).

The rising purchasing power and increasing distances of daily commuting trips have generated huge demand for motorised travel, especially individual motorised transport. Cars owned by private individuals are reported to outweigh those by public authorities, accounting for 74.4 per cent of the Chinese market in the year 2006 (Statistical Bulletin on National Eco-

<sup>2</sup> Personal income growth was actually 8.8% in 2009.

nomics and Social Development in 2006). By 2010, ownership of private vehicles had reached 59.39 million, with a 25 per cent annual growth rate, 7.7 times more than the 2001 level in China (see Figure 3). China officially entered into the era of rapid motorization, driven by surging private vehicle ownership. It took thirty-six years from 1956 to 1992 for China to achieve its first million in auto production. The pace since Chinese accession to the WTO has accelerated to exceed millions of automobiles each year since 2003 (see Table 1).

in force since 1978 to introduce foreign investment and technology. In practice, however, China has become essentially one big assembly plant for the global giant carmakers. The AIP (1994) has prohibited imported technology through the Semi-Knocked Down (SKD) or Completely Knocked Down (CKD) approach to car manufacture, to protect the import substitution rate. But all requirements relating to the legal and institutionalised protection of China’s car industry should be cancelled, as required by the WTO. External factors, including government intervention are

Year	1992	2000	2002	2003	2004	2005*	2006	2007	2008	2009	2010
Duration (years)	36	8	2	1	1	1	1	1	1	1	1
Yield (10,000 units)	100	200	300	400	500	600	700	800	900	1400	1800

**Table 1:** Year and Duration of Automobile Production Exceeding Given Amount

Source: Compiled based on China Automotive Industry Yearbook (2011)

\* The actual auto production in 2005 was 5,707,688, which is less than the data shown in Table 1. It is rounded to 6 million in the paper for simplicity.

Both the opportunities and challenges that the Chinese auto-industry has faced are extraordinary since its entry into the WTO. China’s CR3 of “Big Three” auto-manufacturing bases<sup>3</sup> produced 75% of the country’s cars in 2002, which reveals the high industrial concentration in a few sites, dictated by administrative intervention. The urgency for China is to transform from ‘reactive protection’ characterised by government interference towards ‘proactive protection’ featuring global competitive advantages. According to WTO commitments, tariff protection and non-tariff barriers to cars should be gradually phased out within a five-year transitional period to buffer the stress from market liberalization. Fostering self-developed capacity and optimizing industrial structure are the long-run solutions for the future of the Chinese automotive industry.

still overemphasised in China compared to pure market mechanisms or the management of the enterprise itself. This has stifled the innovation ability of Chinese car manufacturing enterprises (MOC, 2004). To better confront the realities of the global environment with respect to cars, featuring a well-developed competition system and powerful multinational automakers, China adopted the integration of imported technology with independent innovation to avoid “Technology Hollowing-out” and to establish its national brand.

In light of China’s out-dated manufacturing system and incomplete component enterprises, the “Bring in” strategy has been

The Swedish auto company Volvo was ranked 232 of “The World’s 500 Most Influential Brands”, compiled by the World Brand Lab in 2006 based on its advantageous Share of Market, Brand Loyalty and Global Leadership. However, in the GFC of 2008 its auto sales fell by 18.3% to 374,297 Units worldwide compared to 2007. In 2010 the Chinese-owned Geely Automobile Holding company saw the opportunity for a takeover and made an agreement with the Ford Motor Company on acquisition of 100% stakes in Volvo and related assets, especially its intellectual property regarding technology. The Volvo Car Group subsequently announced its 2013 global sales increased by 1.4%, with a 46% surge in China (Volvo Car Group,

<sup>3</sup> The state council officially sanctioned the FAW, SAW and Shanghai-VW as China’s three major car-manufacturing bases in 1987. One year later, three small car assemblers in Beijing, Tianjin and Guangzhou were approved. It is the well-known “Big Three and Small Three” strategy. The SAW has been officially renamed as Dongfeng Motor Corporation in 1992.

Global Newsroom). Geely also transformed its operation from lower level cars towards more upscale models by way of Volvo's technology combined with Chinese market conditions.

The production capacity utilization of Chinese car manufacturing businesses was 72.5% in 2005. This means that there is potentially a structural overcapacity problem if things remain on a business-as-usual basis (National Development and Reform Concession/NDRC, 2006). The Tenth Five-Year Plan (2001-2005) enacted in 2001 accordingly suggested improving and updating product structure. The Automobile Industry Development Policy (2004), which listed Structural Adjustment as one chapter and the special policy called Notice on Opinions of Automobile Industry Structural Adjustment approved in 2006, both stressed the urgency of the above situation. The Plan on Automobile Industry Restructuring and Revitalization (2009) implied an acceleration of China's industrial restructuring in proper response to the 2008 GFC. Rightly or wrongly, depending on the perspective one takes, China has thus become the ray of hope for the global car market.

#### 2.4 Stationary Phase (2011 until Present Day)

In 2014 the global automobile industry stepped into its 128th year since the first automobile was introduced in 1886 (Ruiz, 1985). China surpassed the U.S. as the giant of global automobile production and consumption in 2009 and has been the major contributor to global automobile industry growth since then (Market Analysis Report: China's Automotive Industry), even though it came into being seven decades later.

After the extraordinary growth rates of auto production and auto sales in 2009 (48.3%; 45.5% respectively) and 2010 (32.4%; 32.4% respectively), the Chinese auto-industry uncommonly underperformed in 2011 (0.8%; 2.45%) (OICA, 2009-2011). This has ushered in a new 'stationary phase' of Chinese automobile industry development, partly affected by the implemented policies including Transportation Demand Management (TDM) and prioritising public transport development. This change has in turn been brought about by crippling levels of congestion in

many Chinese cities, dangerous levels of air pollution, growing traffic fatalities and injuries and other serious impacts from the introduction of such huge numbers of motor vehicles into Chinese cities in such a short space of time (Pucher et al., 2007). Photo 2 shows how the public spaces of Chinese cities are being taken over by motor vehicles.



**Photo 2:** Colonisation of footpaths by motorcycles in Shanghai

Source: Yuan Gao

However, before this period, The Chinese government formulated three pro-auto policies aiming to rebound from the 2008 GFC comprising "Purchases Duty Preferential" (Notice on Reduction in Vehicle Purchase Duty for 1.6-liter or less Passenger Cars, 2009), "Bring Auto into Countryside" (Plan on Automobile Industry Restructuring and Revitalization, 2009) and "Car-Scrapping" (Implemented Measures on Car-Scrapping, 2009) These are summarised in Table 2. The Purchase Duty Preferential, which stimulated sales of cars of 1.6 litres or less by 71% in 2009, was very influential in boosting the total auto sales in China (CAAM, 2010). However, these preferential policies and subsidy plans for auto purchases were required to terminate from 2011(MOF, 2011a, b, c). China began to free up in order to build a more resource-saving and environment-friendly society as per the Twelfth Five-Year Plan (2011-2015), in which the New Energy Vehicle<sup>4</sup> (NEV) is listed as one of the nation's strategic emerging industries (SEI).

<sup>4</sup> It consists of HEV (Hybrid Electric Vehicles), BEV (Battery Electric Vehicles, including Solar-Powered Autos), Fuel Cell Electric Vehicles (FCEV), Hydrogen-Powered Vehicles and other New-Energy vehicles defined by the New-Energy Vehicles Manufacturing Enterprises and Products Access Management Rules from 2009.

Policy	Content	Extension
Purchase Duty Preferential	The duty will be temporarily levied at the half-reduced rate of 5% on passenger cars with engines of 1.6-liter or less purchased from January 20 to December 31, 2009.	In the end of 2009, the State Council approved its extension to December 31, 2010. The newly formulated purchase duty was increased to 7.5%.
Bringing Auto into Countryside	A financial subsidy amounting to five billion RMB will be granted to farmers who replace three-wheeled vehicles or low-speed trucks with light-duty trucks or 1.3-liter or less mini-cars from March 1 to December 31, 2009.	It was extended to the end of 2010.
Car-Scrapping	The subsidy will be offered to upgrade old or yellow-label vehicles in advance. This includes gasoline or diesel vehicles failing to meet the National Emission Standard. The compensation value varied from 3,000 to 6,000 RMB and functioned from June 1, 2009 until May 31, 2010.	Its validity was extended to December 31, 2010.

**Table 2:** Three Auto-Encouragement Policies Designed to Overcome the 2008 GFC

In contrast to this short-term response to the GFC, deeper issues have taken over and have set China into a new phase of restrictions on private vehicles, in order to reduce some of the major problems afflicting Chinese cities due to large numbers of vehicles (Photos 3 and 4). Strategies restricting purchase and use of private vehicles are now emerging in the megacities of China. For instance, the Beijing municipal government initiated the rationing of road space since the 2008 Olympics. Car



use in Beijing was curtailed according to the number on the license plates. Another example is limiting the quota of new car registrations in Beijing in an attempt to curb unsustainable levels of automobile ownership (Song, 2013). This has since been further tightened by 37.5% to only 150,000 new car registrations per year since 2014 (in a metropolitan population which will be approximately 22 million people by that time) (Notice on the Work Plan of Beijing Motor Vehicle Emission Pol-



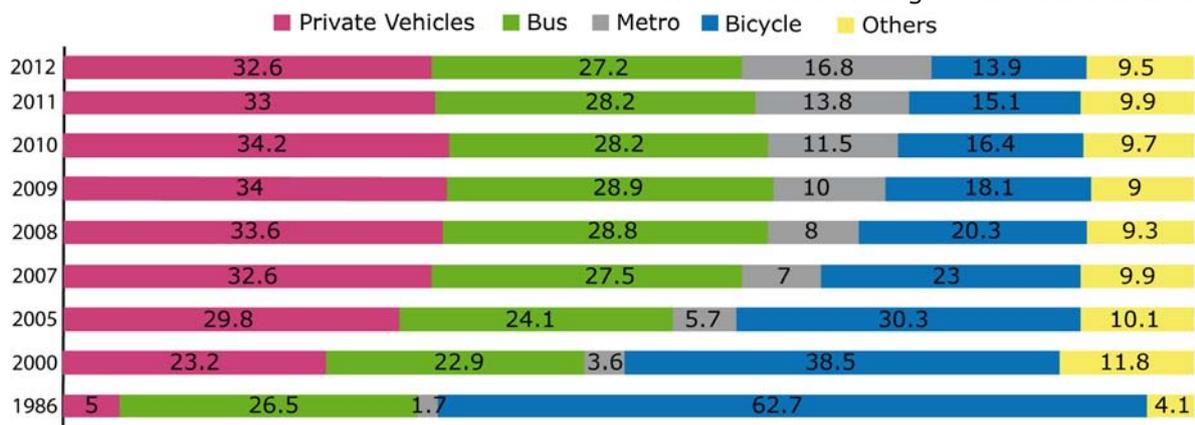
**Photos 3 and 4:** The dense urban fabric of Chinese cities is increasingly filling with cars, which is leading to programmes to limit car ownership in cities.

Source: Yuan Gao

lution Control 2013-2017). Up until the end of March 2014, Beijing, Shanghai, Guiyang, Guangzhou, Shijiazhuang, Tianjin and Guangzhou had already joined in similar efforts to restrain car ownership. There are two distinctive systems for new car registration around China: (1) an unpaid lottery system and (2) a paid bidding system. For instance, Beijing distributes the new car registration quota for free to the applicants through a lottery system. Conversely, Shanghai has adopted the Singapore-style Certificate of Entitlement

a 32.3% compound annual growth rate (2012-2013 China Urban Rail Transport Development Report). By the end of 2013, there were 87 urban rail lines in service among nineteen Chinese cities, with a total network length of 2,539 km (2013 Statistical Length of Chinese Operating Urban Rail Transport).

Rail transport is of critical importance in shifting trips away from cars and motorcycles. As shown in the modal splits for Beijing in Figure 5, the 465 km (2013) Beijing metro network length has had a dramatic



**Figure 5:** Travel Modes of Beijing Residents' Daily Trips (%) (Excluding Walking) (1986-2012)

Source: Compiled based on 2013 Beijing Transport Development Annual Report

for new car purchase, which means bidding at an auction for the right to buy a new car. Chen and Zhao (2012) and Zhao et al (2014) have analysed the respective merits of both these schemes.

Additionally, transport investment priority has now been transferred towards developing Urban Public Transport (UPT) at the national strategy level, especially Rapid Mass Transit (RMT) through the Twelfth Five-Year Plan. RMT, which includes Subway/Metro and Bus Rapid Transit (BRT) within cities, as well as inter-city High-Speed Rail (HSR), is now undergoing massive growth (Newman et al, 2013). The case of Chinese urban rail transport is illustrative of this new priority. The "metro" as a mode of transport first appeared in 1969 in Beijing, 106 years after the London Underground/Tube was first constructed in London (Strickfaden and Devlieger, 2011). Although developing urban rail transport was primarily embraced in the Tenth Five-Year Plan in China (2001-2005), Chinese investment in urban rail transport mushroomed from RMB 12 billion (2001) to RMB 260 billion (2012), with

effect on public transport modes. Beijing's subway is nationally the second longest, eclipsed only by Shanghai (577 km). The trips by metro in Beijing surged from 1.7% (1986) to 16.8% (2012). On the negative side there was a decimation of bicycle trips from 63% in 1986 to 13.9% in 2012. This was due primarily to a political move away from bikes as being "backwards" and the concomitant destruction of bicycle facilities in the city to make way for cars (Photo 5). It also became increasingly dif-



**Photo 5:** Cars parked in bike lane in Beijing  
Source: Yuan Gao

difficult to travel by bike due to the long trip lengths for many needs as the city spread (Yang et al, 2014). Finally, conditions for buses were not ideal either in Beijing, as reflected in the slow-growth of regular bus transit (RBT), which increased only from 26.5% to 27.2% during the same period.

### 3. Conclusions

China, as the largest rapidly developing country, accommodates 19 per cent of the global population (China Population Census, 2010) and contributes 9.4 per cent of global GDP (World Bank, 2010). It has become the object of widespread interest around the world. Its automotive industry has been facing a dilemma of risk and possibility throughout the institutional reforms of the decades since the end of the Second World War, including the New China Foundation in 1949, the Reform and Opening-up Policy in 1978, Entry into the WTO in 2002 and the New Era starting from 2011. This paper has documented China's automotive development history from a "Truck Industry" to a national pillar industry, from the global automobile giant of only a few years ago (a status which it still largely retains), to the current period of restricting car ownership in many cities and prioritising public transport within China's urban environments, especially through rapid development of rail transport.

The Chinese automotive industry, which mainly served military and economic construction needs due to strained international relations and a distinct command economy at the beginning of New China, overweighted its automotive production towards freight vehicles. The constantly changing national policies and excessive technology dependence resulted in an unproductive and uncompetitive automobile production system.

The 1978 open-door economic policy, which pushed towards the devolution to local economies, raised production motivation but intensified regional rivalry. Furthermore, permitting and encouraging the ownership of private vehicles along with enhancement of individual purchasing power, shifted the industrial emphasis specifically towards the manufacture of cars. The contradiction between ever-growing automobile demand and incompatibly low domestic automobile supply drove the thirst for auto imports in China, which

peaked in 1985. The Chinese auto industry attempted to achieve production-sales balance and then profitability through increasing its industrial concentration and importing foreign technology.

Being the 143rd member of the WTO has promoted the Chinese auto industry from an outlier towards a major contributor to the global automobile market. In contradistinction to mature automobile countries such as the USA, China's advantage in the car industry is having a huge base of new first time car buyers, rather than just updating requirements for cars. However, it has also suffered from the lack of internationally influential automobile products. Establishing and growing its car industry in a relatively protectionist environment, the Chinese auto industry has needed to upgrade its industrial structure and to develop self-owned intellectual products. On the downside, the car industry in China, especially in the dense and space-constrained Chinese cities, has generated very significant impacts in local communities (congestion, air pollution, increased traffic fatalities and degraded public environments to name a few impacts). Nationally and globally, the sheer size of the Chinese automotive industry brings many resource, environmental and other problems which reduce its positive economic aspects. This must be taken into account in any further efforts that China makes to become an automobile powerhouse of the world.

There is now evidence that China is beginning to see these bigger problems and is responding accordingly. An awareness is developing that it is not possible, wise nor even economically sensible to turn Chinese cities into automobile dependent cities. It is now possible to see the beginnings of a new focus on public transport and the regeneration of walking and cycling as important modes of urban transport. If continued, this will allow a diversity of modes, including cars and motorcycles, to co-exist better in Chinese cities. This does not spell any kind of "end" to automobiles in China, but rather it heralds a new realisation that Chinese cities will be better functioning, more environmentally attractive and better off economically to encourage a healthy balance of modes, in a similar way that many economically, environmentally and socially successful cities in Europe

have done (e.g. Copenhagen and Zurich). Chinese cities have more than enough capacity to head in such directions, and in a relatively short space of time, especially since they still have comparatively dense urban development patterns that support public transport, walking and cycling (Photos 6 and 7).



**Photo 6:** Bicycle parking outside a Beijing metro station  
*Source: Yuan Gao*



**Photo 7:** Chinese cities will increasingly look to extending good quality, green walking environments  
*Source: Yuan Gao*

Starting around 2011, we have now seen China quite aggressively pursuing TDM policies and vigorously advocating prioritising UPT. There has thus been a momentous shift in the Chinese automobile industry policy from 'stimulation to sustainability'. The Beijing Declaration (Wang, 1996) suggested that the primary objective of transportation systems is to realise the movement of freight and passengers rather than the movement of vehicles. Despite the significant achievements of the Chinese auto industry for the national economy, the liveability and sustainabil-

ity of Chinese cities cannot be realised if urban mobility is primarily oriented to private motorised travel modes (cars and motorcycles). An integrated and diverse urban transport system in China is now designated to satisfy the daily trip demand and mitigate environmental and social vulnerability.

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### **Author details:**

#### **Corresponding Author:**

Yuan Gao  
The CUSP Institute (Curtin University Sustainability Policy Institute)  
Curtin University of Technology  
Building 209, Level 1  
GPO Box U1987, Perth  
Western Australia, 6845  
AUSTRALIA

Email:  
[gaoyuan8416@hotmail.com](mailto:gaoyuan8416@hotmail.com)

Phone:  
+61 (0) 450 616 665

Jeffrey Kenworthy  
Curtin University Sustainability Policy Institute  
Curtin University,  
Perth,  
Western Australia

Peter Newman  
Curtin University Sustainability Policy Institute  
Curtin University,  
Perth,  
Western Australia

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### Statement of Contributions of Authorship

**Gao, Yuan** (PhD Candidate) (60% Contribution)

*Preparation and completion of the manuscript, establishment of theoretical framework, data collection, preparation of figures and tables, policy analysis.*



*Yuan Gao, PhD Candidate*

**Newman, Peter** (Principle Supervisor) (30% Contribution)

*Supervising, revising and editing the manuscript.*



*Professor Peter Newman, Principle Supervisor*

**Webster, Philip** (Research Assistant) (10% Contribution)

*Revising and editing the manuscript.*



*Philip Webster, Research Assistant*

**The attached Paper is an exact copy of the journal paper cited above**

# Transport Transitions in Beijing

## From Bikes to Automobiles to Trains

Yuan Gao, Peter Newman and Philip Webster  
*Curtin University Sustainability Policy (CUSP) Institute, Western Australia*

Beijing is one of China's most significant cities and thus its transport transitions represent much of what is happening across all of China. This paper recognises three major transitions. The pre modern phase of the bicycle dominated Beijing from 1949 to 2001. With considerable economic development and a well-established automotive industry, Beijing experienced the Automobile phase from 2002 to 2010. This phase began to replace bicycles on Beijing's streets and led to major traffic congestion, air pollution and accidents. A third Train phase emerged in 2011 with the dramatic expansion of the Beijing Metro and associated bus systems as well as a formulated transportation demand management programme. Its growth now appears to be gradually transcending automobile use growth and is more appropriate for Beijing's dense urban fabric and desire to reduce its automobile carbon footprint.

- Transport transitions
- Beijing
- Urban fabrics
- Economic growth
- Administrative guidance
- Transport demand management

**Yuan Gao** is currently undertaking her PhD study at Curtin University Sustainability Policy (CUSP) Institute in Western Australia. The topic of her research is sustainable Chinese urban transport. She was a recipient of the Intergovernmental Panel on Climate Change (IPCC) Scholarship granted by the prestigious Prince Albert II of Monaco Foundation in 2014 and 2015.



✉ Faculty of Humanities, Curtin University Sustainability Policy (CUSP) Institute, Building 209, 133 Kent Street, Curtin University Bentley Campus, Perth 6163, Australia

💻 [gaoyuan8416@hotmail.com](mailto:gaoyuan8416@hotmail.com)

**Peter Newman** is the John Curtin Distinguished Professor of Sustainability at Curtin University. He has written 17 books on sustainable cities and sustainable transport. He was the Lead Author for Transport on the IPCC for its 5th Assessment Report. He was awarded the Order of Australia for his services to urban design and sustainable transport.



✉ Faculty of Humanities, Curtin University Sustainability Policy (CUSP) Institute, Building 209, 133 Kent Street, Curtin University Bentley Campus, Perth 6163, Australia

💻 [p.newman@curtin.edu.au](mailto:p.newman@curtin.edu.au)

**Philip Webster** works as a Research Assistant for the Curtin University Sustainability Policy (CUSP) Institute. He specialises in academic research and referencing working for Professor Peter Newman.



✉ Faculty of Humanities, Curtin University Sustainability Policy (CUSP) Institute, Building 209, 133 Kent Street, Curtin University Bentley Campus, Perth 6163, Australia

💻 [phil.webster@curtin.edu.au](mailto:phil.webster@curtin.edu.au)

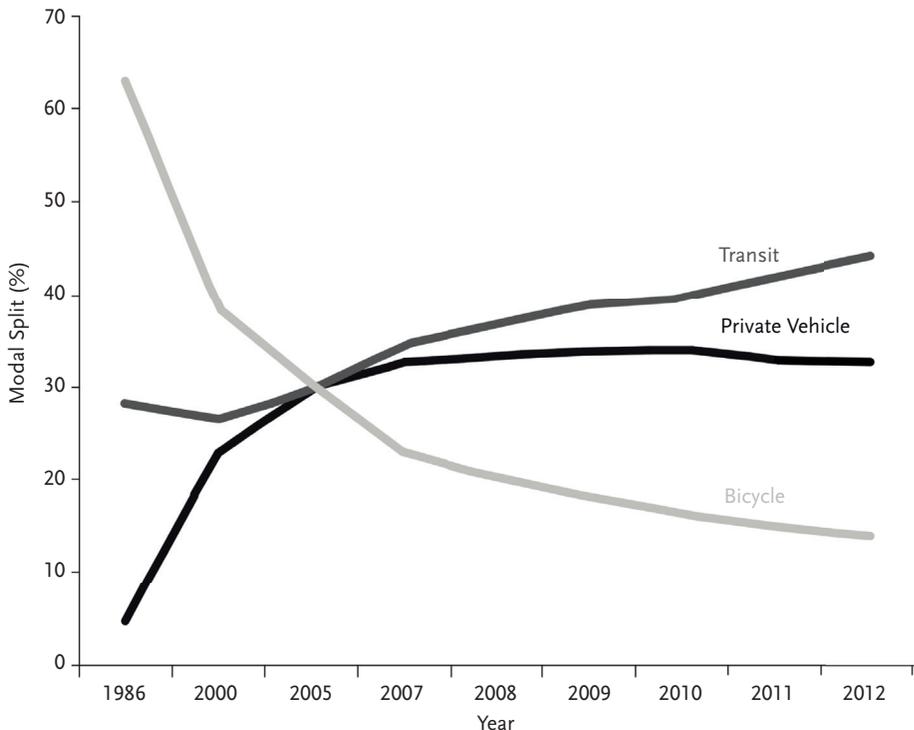
CHINA'S CAPITAL CITY, BEIJING, WHICH functions as the national centre of politics, culture and foreign relations, has risen and fallen with China's economic power and strength. In 2010, China surpassed Japan in terms of nominal gross domestic product (GDP) as the second-largest economy only behind the USA (Barboza, 2010). Beijing has grown in parallel with this economic development and achieved the status of being one of the world's largest cities. The gross regional product (GRP) per capita in Beijing has increased 1,324 times between 1949 and 2012 and is approximately 1.27 times higher than the Chinese average level (Beijing Municipal Bureau of Statistics, 2010). Urban economic growth is usually reflected in the transport systems of any city (Newman and Kenworthy, 1999, 2015). Beijing's transport transitions will be outlined here to show how they reflect the economic agenda of China and its capital city as well as other factors such as the history and politics of the city.

## Overview of transport transitions

The data on modal split in Beijing (see Fig. 1) shows the three transitions we will discuss in this paper:

**Figure 1** Modal split of Beijing from 1986 to 2012 (excluding walking)

Source: Compiled based on data provided by Beijing Transportation Research Centre (BTRC) (2013)



- ▶ **Phase 1.** The bicycle, the dominant mode from early days until 2001
- ▶ **Phase 2.** The automobile, the symbol of a modern economy that took over Beijing streets from 2002 to 2010
- ▶ **Phase 3.** The train, the modern metro that represents the sustainable transport mode of the future and its growth that started in earnest from 2011

The simplest way to understand these transitions is to see how the speed of the modes enabled their rise and fall. Bicycling was faster than walking with its average speed around 15 kph compared to 3–4 kph for walking (Newman and Kenworthy, 1999, 2015). But once cars became available and reasonably affordable, they certainly replaced bikes as their average speed is around 25 kph in most Asian cities (Newman and Kenworthy, 1999, 2015). However, dense Asian cities can slow down very quickly when their streets fill. For example, Bangkok's average traffic speed fell to 13 kph with buses at 9 kph before trains at 35 kph were able to take people at a higher speed. It is our contention that a similar process has occurred in Beijing.

These transitions will be examined in detail to determine their driving forces and to see what the next transition is likely to be in Beijing.

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## Phase 1: the bicycle (1949–2001)

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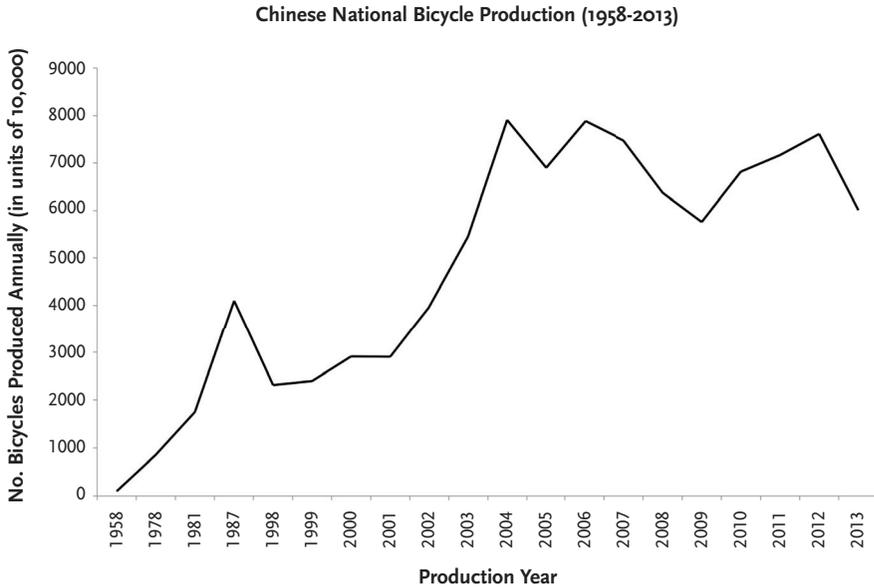
The ancient city of Beijing developed like all cities around walking and cycling (Newman and Kenworthy, 1999). The dense urban fabric featuring flat terrain and Hutong (small alleys) grew around the ability to walk and cycle to most urban destinations. The traditional employment system (so-called *dan wei* in Chinese) provided a nearby house as a portion of work-related welfare and thus resulted in walkable and cycling-enabled commuting distances (Zhao *et al.*, 2011). Bicycles were officially imported into China in 1897 as luxury items (Esfehani, 2003), and then foreign-operated bicycle factories were transformed into state-owned plants with the New China established in 1949. The 'Flying Pigeon', which was the first fully nationalised brand of Chinese bicycle, was transformed from one bicycle factory built by the Japanese in 1936. From the 1970s, the bicycle was included as one of the traditional marriage symbols 'Three Rounds and Sound'.<sup>1</sup> The bicycle became more available for transport with mass production (see Fig. 2). Bicycle use was also built into the economy and social life in all Chinese cities. China became well known as the 'Kingdom of the Bicycle' in the 1980s.

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<sup>1</sup> 'Three Rounds' means bicycle, watch and sewing machine. The 'Sound' refers to the radio.

**Figure 2** Nationwide bicycle production in China (10,000 units) 1958–2013

Source: Compiled based on national data provided by National Bureau of Statistics of China (NBSC) (2014a)



The bicycle fitted into Beijing's walkable urban fabric with ease, enabling the dense, narrow streets to be extended further out. By 1997 there were 9.24 million bicycles for 12.5 million residents in Beijing (Yang *et al.*, 2012). However the end of bicycle transport domination was in sight. Beijing's bicycle mode split in 1986 was 62.7% (probably the highest in any city in the last 50 years) but by 2000 it was down to 38.5% and by 2012 it had dropped to 13.9% (see Fig. 1). The dramatic transition was due to the automobile.

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## Phase 2: the automobile (2002–2010)

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The automobile began to be adopted in China from the early 1990s. Gao *et al.* (2014) suggest that there are four phases in the development of the Chinese automobile industry but the biggest boost came in 2002. The Chinese economy was opened up to the global community in 2001 when China joined the World Trade Organization (WTO), and the Tenth Five-Year Plan (FYP)<sup>2</sup> (2001–2005) encouraged families to purchase private cars. They immediately began developing a world competitive automobile production industry. By 2009 China had

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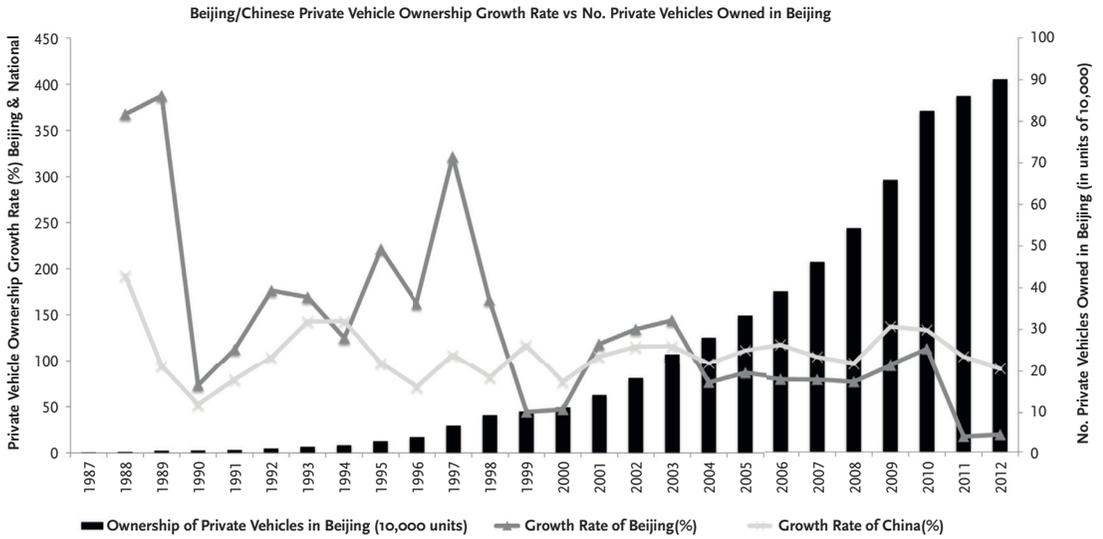
<sup>2</sup> It refers to a package of incentives to national economy and social development. It has transformed from 'plan' to 'planning' since 2006 according to further transformation of the Chinese macro economy from state-controlled towards market-oriented.

exceeded the USA as the world’s largest automobile producer and consumer (Ferrazzi and Goldstein, 2011).

As economic growth accelerated, so did Chinese private automobile ownership (see Fig. 3). From 7.7 million automobiles being privately owned by Chinese in 2001, the number rose to 88.4 million in 2012. This implies an annual growth rate of 24.8%.

**Figure 3** Ownership of private vehicles (10,000 units) and growth rate (%)

Source: Compiled based on national data provided by NBSC (2014b)



On an individual city basis Beijing has the highest private vehicle ownership per 1000 people in China with 240 as compared to its nearest rivals of Guangzhou (159) and Shanghai (89) in 2012 (GZTPRI, 2012). Beijing’s modal share for automobiles dramatically replaced the bicycle in the first decade of the 21st century. Automobiles had just 5% mode share in 1986 (when bikes were at 62.7%) but quickly rose to 34.2% by 2010 while bikes dropped to 16.4%. Supporting this massive modal shift in Beijing was a large increase in road infrastructure investment from US\$2.86 billion in 2001 to US\$7.59 billion in 2010 (an annual increase of 11.34%). Beijing expressways also experienced a surge in total length during the period (2001–2010) from 335 km to 903 km (representing a growth rate per annum of 11.65%). Finally the number of parking spaces in central Beijing was expanded to 109,000 in 2005, 2.32 times more than was available in 2000 (BTRC, 2001, 2011). These substantial changes in Beijing (and other major Chinese cities) resulted in what is probably one of the most striking social changes in urban history as more and more people left their bikes at home and began travelling by private automobiles.

Economic capacity and Chinese automobile availability were no doubt major factors in this transition but cultural and political encouragement were also influencing factors (see section on ‘Underlying processes’ below). Private and foreign joint enterprises have gradually replaced the state-owned ones as part of the development of the market economy since 1978 with the ‘Reform and Open-up’

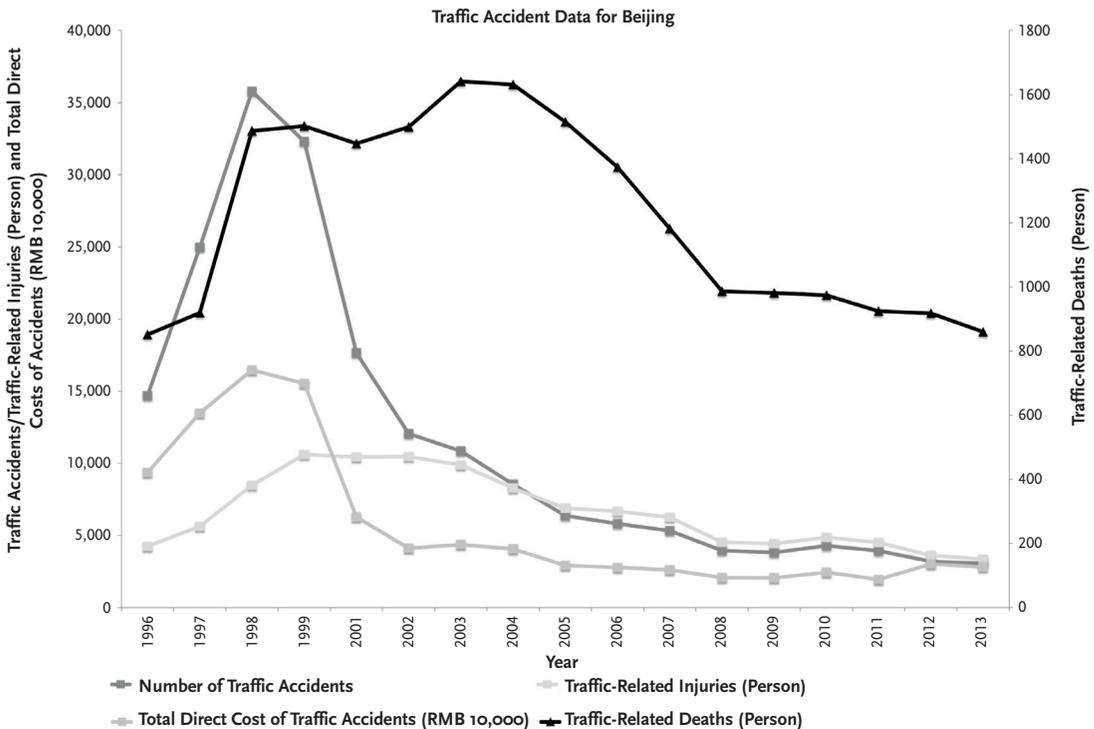
policy. One of the consequences of the demise of the socialist welfare-oriented housing provision was the collapse of the dan wei system. Hence, the commuting distance accordingly increased, which stimulated the demand for automobiles.

The success of the automobile however was short lived. The automobile did not fit into the dense urban fabric of cities like Beijing. The growth of the automobile hit the wall of traffic congestion and other impacts. The Beijing data show that the automobile modal split has risen, plateaued and then fallen. It has been replaced by metro growth (and its associated other elements of public transport such as integrated buses).

Why did such a rapid transition from bike to car run into such a wall? Most Western cities especially in America and Australia have automobile mode shares of over 80% (Newman and Kenworthy, 1999). There are very obvious reasons why the automobile, the symbol of Western modernism, has not been as dominant in Beijing’s transport transition, as in most other cities. The traffic congestion rose very noticeably (see below) to the point where automobile use became far less functional and freeing than advertising would suggest. Average traffic speed was a healthy 45 kph in 1994 but 9 years later it was reduced to 12 kph (Peng, 2004). Associated traffic accidents were very high though this began to improve through better controls and regulations after a few years (see Fig. 4).

**Figure 4** Traffic accidents in Beijing from 1996 to 2013

Source: Compiled based on national data provided by NBSC (2013) and BTRC (2001)



Another problem was that air pollution, as a direct result of private automobile proliferation, grew into a major health issue. Within Chinese cities such

as Beijing, primary automobile emissions such as nitrogen oxides (NO<sub>x</sub>) and particulate matter (PM) began to supersede primary industry emissions such as sulphur dioxide (SO<sub>2</sub>) as the greatest source of urban pollution (Hao and Wang, 2005). The annual average concentration of PM<sub>2.5</sub> in Beijing deteriorated to 89.5 ug/m<sup>3</sup> in 2013, 2.56 times worse than the national standard (Beijing Municipal Environmental Protection Bureau/BMEPB, 2013) and 8.95 times inferior to World Health Organization (WHO) guidelines (2005). The contribution of vehicles to the PM<sub>2.5</sub> was calculated as high as 31% in Beijing (BMEPB, 2014).

This required action, as it was a negative reflection on the nation's capital. In addition the strengthening global agenda to make major commitments to cut fossil fuel consumption ensured that doing nothing to curtail automobile growth was no longer a viable option.

In reality, the sheer functionality of Beijing was never greatly assisted by the automobile. After millennia of developing a culture around dense living with narrow streets that are suited to pedestrians and cyclists, the automobile just did not fit. Beijing literally hit the wall of its urban fabric. A similar process has begun in most developed cities where motor vehicles can no longer fit into the fabric of the city. This global phenomenon of 'peak car', is based on the value of economic productivity associated with dense urbanism in old cities, which is increasingly being recognised for its benefits in overcoming automobile dependence (Newman and Kenworthy, 2011, 2015). Beijing is possibly one of the first emerging cities to begin demonstrating that a better, more sustainable transport system is needed for economic productivity as well as environmental and social/health goals, as shown below.

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### Phase 3: the train (2011–)

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Growth in private automobile ownership and massive expansions in automobile production capacity have labelled China as the new 'Giant' of the automobile industry since 2009 (Gao *et al.*, 2014). A similar transport transition also emerged around 2008—a significant increase in rail infrastructure development within major Chinese cities such as Beijing (see Table 1). The transition then developed from 2011 affected by a package of transportation demand management in Beijing, including the termination of national pro-car policies designed to overcome the 2008 global financial crisis, incentives to train use through new infrastructure and restrictions on private car ownership and use. A large part of the reason behind this was the negative impacts associated with massive automobile proliferation within Chinese urban centres that were traditionally built around walking, cycling and other non-motorised modes of transport, while being poorly suited to large volumes of automobile traffic. The average speed of traffic in central Beijing decreased from 45 kph in 1994 to 12 kph in 2003, which is as low as any other congested city in the world despite much lower automobile ownership levels (Peng, 2004). More recent data is less certain though Guilford (2014) suggests that in 2014–5 the average speed

remains fairly unchanged from 2003 speeds. The Beijing Government does not believe that average traffic speeds will exceed 15 kph in 2015 (Beijing International, 2015). Such speeds greatly reduce the allure of the private automobile and encourage urban transport planners to look for alternative solutions.

This negative reaction to the automobile began to be seen officially with controls on vehicle overuse that built on interventions for the 2008 Olympic Games hosted by Beijing through road space rationing from 1 July to 20 September 2008 (BTMB, 2008). In December 2010 the government announced their further effort to cap total private vehicle ownership (BMCT, 2010). Unlike the Singapore-style paid auction system implemented in Shanghai, Beijing adopted the unpaid lottery to distribute new licence plates to public applicants. The quotas on new car registration have been further tightened from 240,000 in 2011 to 150,000 in 2014, which aims to cap total vehicle ownership at less than 6 million by 2017 (Beijing Municipal Government 2013). By 2011 the private ownership growth rate in Beijing had dropped to 4.25% compared to 23.37% in the rest of China (after being 25.27% in Beijing in 2010; see Fig. 3).

However, the biggest impact on automobile use growth has been the dramatic increase in the use of the Beijing Metro. Beijing's municipal government initially put forward its subway construction plans in 1953 for military defence on the basis of technological assistance from the former Soviet Union and East Germany (Gao, n.d.). The first line of Chinese urban rail transport in Beijing did not trial run until 1969 due to the Sino-Soviet split in 1960 and the Great Chinese Famine of 1959–1961 (Strickfaden and Devlieger, 2011). However, the 2008 Olympics led to the rapid building of the Beijing Metro system (see Table 1). Its success has bred continued growth. It grew from 2 lines, 54 km of track and around 400 million passengers a year in 2001 to 22 lines, 527 km of track and around 3,387 million passengers a year in 2014 (around 9 million passengers a day). This makes it one of the most successful rail systems in the world and certainly one of the fastest growing (Newman *et al.*, 2013). The mode share of metro increased from 3.6% to 13.8% between 2000 and 2011 while the bus share grew slowly from 22.9% to 28.2% over the same period. Thus we have chosen 2010 as the key date for the transformation of Beijing to a third priority in its transport system.

**Table 1** Development of Beijing Subway (2001–2014)

Source: Compiled based on data provided by BTRC (2013), CRT (2014) and Beijing Infrastructure Investment Company LTD (2014)

Year	Number of operational lines	Operational length (km)	Annual patronage (100 million)
2001	2	54	4.42
2002	3	75	4.82
2003	4	114	4.72
2004	4	114	6.07
2005	4	114	6.8

*Continued*

2006	4	114	7.03
2007	5	142	6.55
2008	8	200	12.2
2009	9	228	14.2
2010	14	336	18.46
2011	15	372	21.93
2012	16	442	24.6
2013	18	465	32.05
2014	22	527	33.87

Economic growth has continued in Beijing during the 21st century but now the city is directing this (in transport terms), into trains rather than automobiles. Throughout the past 20 years of urban growth in China and in Beijing the cities have continued to build densely in the same way that most other Asian nations have built. The 10–20 storey high buildings of Beijing may have gone further out than the ancient walking city has grown, but the corridors of development were ideally formed as transit urban fabric that would easily absorb an electric rail system with fast connections across the city. Thus the historic Beijing urban fabric could be retained and enabled to grow without the kind of automobile-based problems of the previous automobile transition phase. The metro was thus an enabler of sustainable transport and sustainable urban development (Newman and Kenworthy, 1999, 2015).

## Underlying processes guiding the transitions

Three processes are suggested to be critical to the three transport transitions in Beijing (and probably all Chinese cities):

- ▶ Administrative guidance
- ▶ Urban fabric
- ▶ Economic development

### Administrative guidance

China has drawn up Five-Year Plans to guide its cities and regions towards further economic and social development. In Table 2 the past seven Five-Year Plans are summarised in terms of their core transport outcomes. Each of the transitions from bike to automobile and from automobile to train, have been deliberately planned. Chinese automotive industry is still regarded as a significant sector; however, there is an explicit move towards the development of new energy vehicles (NEVs) and prioritising public transport, especially the metro.

**Table 2** Evolution of China's consecutive FYPs on private vehicles and public transport

*Source:* Compiled based on data provided by People's Congress of People's Republic of China (1981, 1986, 1991, 1996, 2001, 2006, 2011)

Sixth FYP (1981–1985)	The first FYP since 1978 was themed as adjustment of the existing freight vehicle production
Seventh FYP (1986–1990)	It was proposed that the auto sector should be regarded as a pillar industry of the national economy to meet transportation demand
Eighth FYP (1991–1995)	The role of the auto sector in the national economy was determined to be more than satisfying the transportation industry The development priority was shifted from freight vehicles to passenger automobiles
Ninth FYP (1996–2000)	It was determined that the auto industry, which performs as an engine of economic growth, needs to achieve mass production Furthermore it was made clear that a self-owned technology system for the automobile industry that has been running under joint venture should be built for gaining access to the WTO
Tenth FYP (2001–2005)	It officially proposed the concept 'Encouraging Passenger Cars into Family' It aimed to energetically foster public transport including rail transit in megacities at the same time It proposed a sustainable development strategy and other measures to alleviate global climate change but without detail on how
Eleventh FYP (2006–2010)	'Prioritising Transportation industry' was listed as an economic priority The development of energy-saving and environmentally friendly vehicles was encouraged as a means to control GHG emissions. Strengthening vehicle fuel economy standards was seen as another key priority aimed to assist with the development of a circular economy Rail transport was identified as a key priority in both Chinese qualified megacities and significant urban agglomerations
Twelfth FYP (2011–2015)	NEVs were identified, as one of China's strategic emerging industries (SEI) Specific sections of the plan such as those entitled 'Establishing Integrated Transportation Systems (ITS)', and 'Prioritising Public Transport', serve to stress the importance of further development of public transport including rail The Chapter 'Actively Respond to Global Climate Change' suggests that traffic-related GHG emissions should be controlled

## Urban fabric

There is an inherent logic to shifting to automobiles if only an economic consideration is provided but every city has its own combination of walking city fabric, transit city fabric and automobile city fabric (Newman and Kenworthy, 2015). Beijing and other Chinese cities use mostly walking and transit fabric and are thus always going to struggle fitting in automobiles. As discussed above the new transit fabric of the metro is enabling the traditional dense corridors of Beijing to be better served than by the congested traffic of the second transport transition.

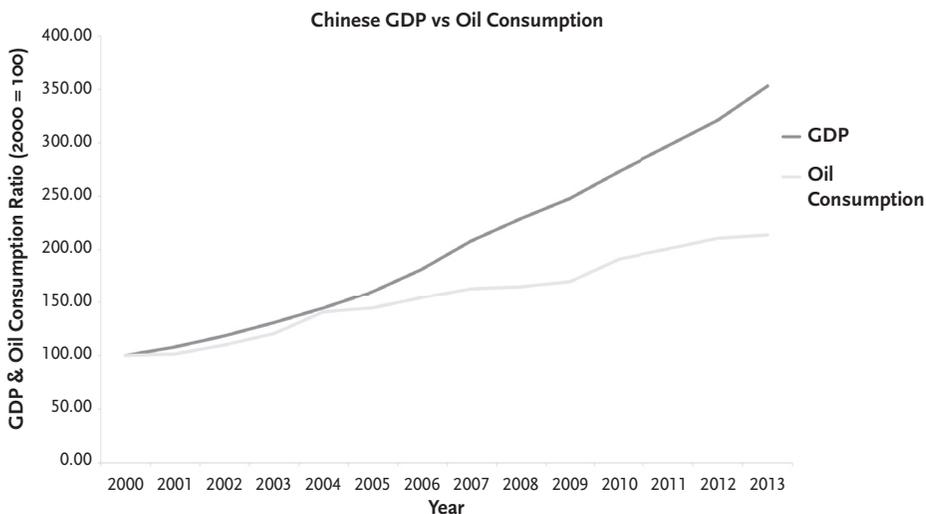
## Economic development

National economic growth increasingly depends on urban economic growth (Glaeser, 2011; Florida, 2010). In Phase 1 the bicycle-based city needed modernising, but by the end of Phase 2 it was clear that economic growth in Beijing could not work without a more green or sustainable transport foundation. In recent times this transition is being called the ‘Green Economy’, or ‘Green Growth’, (UNEP, 2011; OECD, 2011). The result is that GDP is becoming decoupled from fossil fuels (UNEP, 2011; Newman and Kenworthy, 2015).

In Figure 5 it is clear that China is decoupling its GDP from oil consumption. At least part of the reason behind this is the rapid growth of electric trains like that in Beijing’s Metro, which is now able to out-compete car use because average traffic speeds are low (Peng, 2004; Guilford, 2014; Beijing International, 2015).

**Figure 5** China GDP vs. oil consumption

Source: Compiled based on data provided by NBSC (2013)

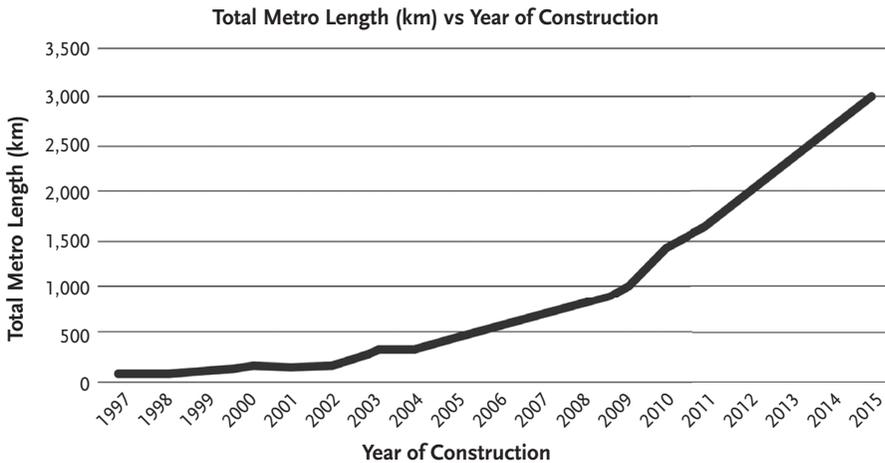


There were in fact 95 metros being built or operating in Chinese cities by the end of 2014 (see Fig. 6) and each step in the growth of patronage means that less oil is driving the economy.

As well as urban electric public transport growth there has also been dramatic growth in high-speed electric rail between Chinese cities (over 11,132 km was in operation by September 2014) (International Union of Railways/UIC). Oil will also be reduced by the development of electric private vehicles and on Chinese streets there are now over 250 million electric vehicles (mostly E-bikes and E-Scooters) (Newman, 2014). The growth of these electric scooters and bikes depends on the travel distances being reasonably short; over half of the daily trips by Beijing residents were within 5 km in 2012 (BTRC, 2013).

**Figure 6** Total expected length of metro construction by end of 2015

Source: Compiled based on data provided by Lohry *et al.* (2014)




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## The next transition phase?

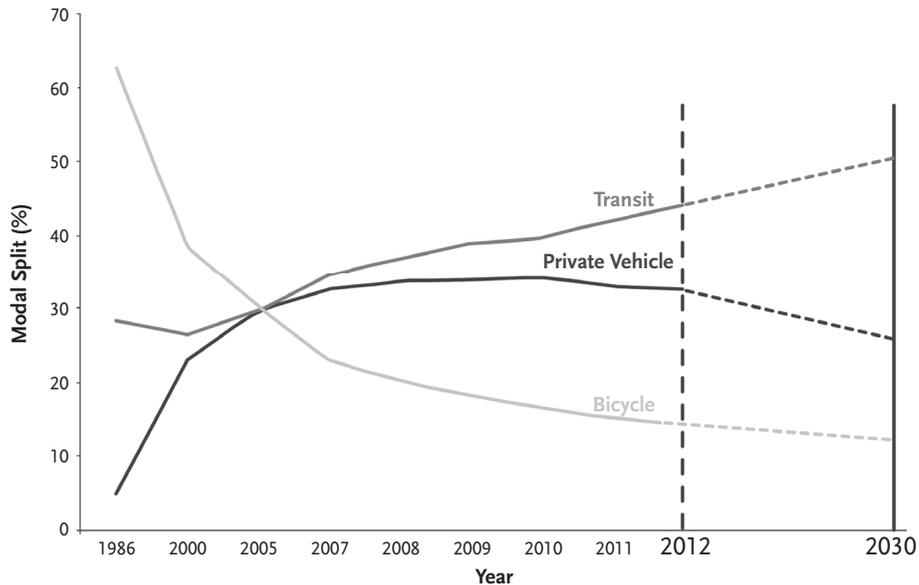
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Based on the evidence presented and the analysis provided there is likely to be a continuing growth of Phase 3—the train. The fundamental urban fabric of Chinese cities like Beijing, the political culture and the economic growth context, all suggest more focus on non-automobile-based economic development.

Electric bikes and electric trains are likely to be the basis of future sustainable transport trends in China, especially as the world begins to compete around the rapidity of their transition away from carbon intensive activity. Figure 7 shows the potential projection to 2030 in Beijing based on a continuation of recent trends.

**Figure 7** Future projection of Beijing modal split to 2030

Source: Compiled based on data provided by BTRC (2013) and authors' own projections



Perhaps a more dramatic direction change will be the need to better manage the traffic that is left with a greater emphasis on walkable urban design characteristics (Gehl, 2010). The six most walkable cities in the US have 38% higher GDP than the rest (Leinberger and Lynch, 2014). Such focus is likely to mean even more careful treatment of the Chinese urban fabric to ensure that sustainable mobility and economic growth can be achieved together.

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## Conclusions

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The three transition phases of Beijing based on bikes, automobiles and trains, are related to the economic and political drivers in the city but these are expressed in the fundamental urban fabric of the traditional dense urbanism of Chinese history and culture. The next phase is therefore likely to see these factors continue to create less automobile-dependent and more sustainable transport-oriented cities, especially in Beijing.

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**Gao, Yuan** (PhD Candidate) (70% Contribution)

*Preparation and completion of the manuscript, establishment of theoretical framework, data collection, preparation of figures and tables, policy analysis.*



*Yuan Gao, PhD Candidate*

**Kenworthy, Jeffrey** (Co-supervisor) (30% Contribution)

*Supervising, revising and editing the manuscript.*



*Professor Jeffrey Kenworthy, Co-supervisor*

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*Editors*

Dorina Pojani  
School of Earth and Environmental  
Sciences  
The University of Queensland  
Brisbane, Australia

Dominic Stead  
Faculty of Architecture and the Built  
Environment  
Delft University of Technology  
Delft, The Netherlands

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# Preface

This book was conceived and written to provide a contemporary view of critical urban transport issues, policies, and initiatives in 12 countries with emerging economies, each at somewhat different stages of development. With dedicated chapters on Brazil, China, Colombia, India, Indonesia, Iran, Mexico, Nigeria, Russia, South Africa, Turkey, and Vietnam, the book contains detailed, comparable information about the current urban transport situation in the major cities in these countries. Written by specialists in the field, the book draws on a wide range of information sources to provide up-to-date accounts of each of these countries. By assembling this information in one volume, it provides a valuable source for academics as well as policy-makers with an interest in the current and emerging urban transport needs of a large portion of the world's population.

Brisbane, Australia  
Delft, The Netherlands

Dorina Pojani  
Dominic Stead

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## About the Editors



**Dorina Pojani** is a Lecturer (Assistant Professor) of urban planning at the University of Queensland in Australia. Her research is focused on urban transport in both developed and developing countries. She has lived, worked and/or studied in Albania, Austria, Belgium, Italy, The Netherlands, and the USA.



**Dominic Stead** is an Associate Professor of urban and regional development at Delft University of Technology, The Netherlands. His current research interests include comparative urban and regional governance, and policy transfer.

## About the Authors

**Priscilla Connolly** is a distinguished professor at the Universidad Autónoma Metropolitana, Azcapotzalco, Mexico City, where she lectures on urban sociology, urban planning, and environmental policy. At present, she is coordinating several financed studies on the different dimensions of automobility—spatial, personal, social, and economic—which condition the mobility afforded by the city.

**David Dewar** is currently emeritus professor and senior research scholar in the School of Architecture, Planning and Geomatics at the University of Cape Town.

**Yuan Gao** is a Ph.D. candidate at Curtin University Sustainability Policy Institute, Australia. The topic of her research is resilient Chinese urban transport. In 2013 she was a recipient of the Intergovernmental Panel on Climate Change Scholarship granted by the prestigious Prince Albert II of Monaco Foundation.

**José Gomez-Ibañez** is the Derek C. Bok Professor of Urban Planning and Public Policy at Harvard University, where he teaches courses on policy analysis, transportation, and economics. His research interests focus on the role of transportation and other forms of infrastructure in supporting urban development and on the advantages and disadvantages of private provision of infrastructure.

**Roger Gorham** is a transport economist and urban development specialist with the World Bank, with over 20 years of experience in urban transport, land use, air quality, and climate change. His current portfolio centers on Africa, with work on urban transport projects in Lagos, Addis Ababa, and Nairobi. He also works extensively with the Africa Transport Policy Program (SSATP), on urban transport and sustainability policy. He holds master's degrees in city planning and transportation from the University of California at Berkeley.

**Dario Hidalgo** leads EMBARQ's international team of transport, planning, and environment specialists, which is involved in sustainable transport and urban development projects in India, Mexico, Brazil, Turkey, the Andean Region, and China. He also coordinates the Observatory of the BRT-ALC Center of Excellence. In the past 20 years, he has partaken in urban transport projects and lectured in more than ten countries of Latin America, Asia, and Africa. He holds Ph.D. and M.Sc. degrees in transportation planning from Ohio State University.

**Du The Huynh** is a senior lecturer at the Fulbright Economics Teaching Program in Ho Chi Minh City. His teaching and research interests are urban economics, infrastructure development, and finance and banking. He received his doctorate from Harvard Graduate School of Design.

**Tri Basuki Joewono** is lecturer in the Department of Civil Engineering, Faculty of Engineering, Parahyangan Catholic University, Indonesia. He holds a master's degree in transportation from Bandung Institute of Technology, Indonesia, and a Ph.D. from Saitama University, Japan. His research interests include public transportation, travel behavior, and transportation in developing countries.

**Jeffrey Kenworthy** is professor of sustainability at Curtin University, Australia. He has spent 35 years in the transport and urban planning fields. His research focuses on large international comparisons of cities from a transport and land-use perspective. He has received two awards from the German government for his research and teaching in the field, including a Mercator Guest Professorship (Goethe University) and is currently a guest professor at the University of Applied Sciences in Frankfurt.

**Jen JungEun Oh** is a senior transport economist at the World Bank. She has led several World Bank investment operations and advisory projects on urban transport and low-carbon transport. More recently, her work has focused on the transition economies of Eastern Europe and Central Asia. Before joining the World Bank, she worked in the USA and South Korea, in transport policy-making, public financing policies, and transport demand analysis and modeling, with partners in government and academia. She holds a Ph.D. in transportation systems and a master's degree in economics from Purdue University, USA.

**Sujaya Rathi** is a principal researcher at the Center for Study of Science, Technology and Policy (CSTEP) in India. She has more than 15 years of experience in land-use and transportation research and planning in India and the USA. Recently she has assisted the Planning Commission of the Government of India in developing future development scenarios for India, based on systems analysis. She holds a master's degree in community and regional planning from Iowa State University, USA, and a master's degree in economics from Jadavpur University, India.

**Ali Soltani** completed his graduate studies in Australia and completed postdoctoral residencies in Australia, Japan, and Turkey. He is associate professor at Shiraz University in Iran. His research interests include sustainable transport, urban design/planning relevance to travel patterns, and urban modeling techniques.

**Yusak Octavius Susilo** is associate professor at the KTH Royal Institute of Technology, Stockholm, Sweden. His research interests include travel behavior, activity-based analysis, land use, and transportation in developing countries. He received his Ph.D. from the Department of Urban Management, Kyoto University, Japan. Before joining KTH, he was a postdoctoral fellow at Delft University of Technology, the Netherlands, and a senior lecturer in transport and spatial planning at the Centre for Transport and Society at the University of the West of England, UK.

**Ela Babalık Sutcliffe** is associate professor in the Department of City and Regional Planning of the Middle East Technical University, Turkey. She holds a Ph.D. in urban rail systems from the University College London, Centre for Transport Studies. She has carried out a number of research projects on sustainable mobility, accessibility, public transport planning, and organizational reforms in transport service delivery. She is a member of the Permanent Scientific and Technical Committee of Cooperation for Urban Mobility in the Developing World.

**Fabio Todeschini** is currently emeritus professor and senior research scholar in the School of Architecture, Planning and Geomatics at the University of Cape Town.

**Eduardo A. Vasconcellos** is a civil engineer and a sociologist. He holds a Ph.D. in public policy and conducted his postdoctoral training on urban transport in developing countries at Cornell University, USA. Currently, he is the technical advisor for the Brazilian Public Transport Association (ANTP) and director of Instituto Movimento, in São Paulo, Brazil.

**Juan Miguel Velásquez** is a research associate at EMBARQ, where he works on evaluating the impact of transport projects, improving decision-making for transit vehicles and fuels, planning sustainable urban transport solutions, and supporting the Centre of Excellence in Bus Rapid Transit (BRT). Prior to joining EMBARQ, he was a researcher and lecturer at the Regional and Urban Sustainability Research Group at Universidad de los Andes, in Bogotá, Colombia. He holds a master of science degree in transport from Imperial College and University College in London.

# Chapter 3

## China

Yuan Gao and Jeffrey Kenworthy

Capital city	Land area	Total population	Urban population	GDP per capita	Passenger cars
Beijing	9,596,960 sq. km	1,400 million	53% (720 million)	\$6,807	54 / 1,000 people



Data source: World Bank  
 Maps source: d-maps.com

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Y. Gao (✉)  
 Curtin University Sustainability Policy (CUSP) Institute, Curtin University, Perth,  
 Western Australia  
 e-mail: yuan.gao7@postgrad.curtin.edu.au

J. Kenworthy  
 Curtin University Sustainability Policy (CUSP) Institute, Curtin University, Perth, Western  
 Australia  
 e-mail: J.Kenworthy@curtin.edu.au

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## 1 Introduction

China has been undergoing a huge economic boom for several decades and by 2010 was the second major global economy (Barboza 2010). Between 1978 and 2013, the disposable income per capita in China skyrocketed, experiencing more than a 50-fold increase (NBSC 2014a). Besides the growing economy, a package of national and municipal incentives increased the prosperity of the Chinese car industry. In 2009, China overtook the United States as the giant of the global automobile market through three auto-encouragement policies<sup>1</sup> when the United States went through a precipitous tumble in 2008 due to the global financial crisis (Ferrazzi and Goldstein 2011). China's rise to ascendancy in the global automobile market has seen the proportion of cars produced in China grow from 0.4 % in 1958 to 55 % in 2013.

As a powerful and relatively new automobile player in the global economy, China's expanding clout has attracted worldwide attention. However, it is simultaneously in the throes of negative impacts, both socially and environmentally, from having too many cars packed into urban areas that were not designed for them, but for nonmotorized modes instead (Figs. 3.1 and 3.2). This trend, combined with burgeoning urbanization, which has witnessed China's urban population increase from 26 % of the national population in 1990 to 55 % in 2014 (NBSC 2015a), creates major urban management and air quality problems for Chinese cities, especially its influential megacities such as Beijing, Shanghai, and Guangzhou.<sup>2</sup>

The cities of Beijing and Shanghai are directly controlled municipalities under the national government. Beijing, the capital, whose population has grown at a very rapid rate from 10.4 million in 1990 to 21.5 million in 2014 (Beijing Municipal Bureau of Statistics 2015), functions as the national center of politics, culture, and foreign relations. Shanghai serves as the national financial and economic hub and has also experienced massive population growth from 12.8 million in 1990 to 24.3 million in 2014 (Shanghai Municipal Bureau of Statistics 2015). Meanwhile, Guangzhou, the provincial capital of Guangdong and the most important port city for international trade, has undergone rapid growth from 6.8 million people in 1990 to 13.1 million people in 2014 (Guangzhou Municipal Bureau of Statistics 2015). In 2013, the cities of Shanghai, Beijing, and Guangzhou ranked as the top three in terms of Gross Regional Product across the whole of China (NBSC 2015b).

The trajectory of China's rapid urban growth, linked to an extraordinary rise in city expansion and urban motorization, has been accompanied by an equally severe rise in energy use, land consumption, and other problems. Specifically, China has overtaken the United States as the biggest energy consumer, accounting for more than 18 % of global energy consumption (Kennedy 2011). With regard to food security for a nation of nearly 1.4 billion people, much cultivated land has been

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<sup>1</sup>Plan for Automobile Industry Restructuring and Revitalization (2009) announced three auto-encouragement policies in response to the 2008 global financial crisis, including (1) Purchases Duty Preferential, (2) Bring Automobiles into Countryside, and (3) Car-Scrapping.

<sup>2</sup>See, for example, a new documentary entitled *Under the Dome*, concerning air pollution in China.



**Fig. 3.1** Cars and motorcycles are difficult to accommodate in China's dense and space-constrained cities (Shanghai)



**Fig. 3.2** Major public areas which were previously used for other functions such as footpaths, cycleways and social interaction are now taken over by cars, motorcycles and commercial vehicles (Zhengzhou)

developed for housing, roads, parking, and other urban uses as the pressure to accommodate China's soaring urban population and vehicle fleet has increased. Land around urban settlements is traditionally the most fertile and productive, and the long-term continuation of excessive land consumption for new urban areas (exacerbated by falling population densities) is not sustainable. From a global perspective, major increases in food import demands from a country of China's size would also be destabilizing for world food markets. The global competition for remaining conventional oil supplies has already shown potential for conflict. Global competition over food or water could have more severe consequences.

China has started making moves to face the challenges in meeting its responsibilities to weigh societal and environmental benefits against economic development in regard to the car industry and private motorization, particularly in megacities. This is not only beneficial for the inhabitants of the three megacities, but it also offers models of sustainable urban transport for other Chinese cities. Although China has been booming and continues to be the world's most vibrant economy, within the country, economic growth and urban expansion are by no means equal (Gao et al. 2013). More specifically, the coastal region including Beijing, Shanghai, and Guangzhou is much more developed than the western, northern, and middle areas due to a raft of national strategies adopted in the 1980s, which have privileged the coastal region.

As a result, the Chinese government is trying to foster more equitable development patterns across the country through its "West Region Development Strategies" (1999), "Revitalization of the Northeast Old Industrial Base" (2002), and "Central Rise" policy (2004)—strategies aiming to increase urban competitiveness based on enhanced economic, social, and environmental performance. There is the possibility that the early urban development and transportation lessons learned in the larger cities in the eastern parts of China during rampant motorization may be gradually applied when the other regions develop more.

## 2 Urban Land Use Patterns and Spatial Structure

Old Chinese cities featuring square or rectangular based dense urban forms, which generated the grid street network such as the *Hutong* in Beijing and *Longtang* in Shanghai, were traditionally built around walking, cycling, and other nonmotorized transport (Gao et al. 2015b) (Fig. 3.3). The employment system (referred to as *Dan Wei* in Chinese) in state-owned sectors provided employees with nearby housing as a part of work-related welfare and contributed to shorter commuting distances by foot and bike (Zhao et al. 2014). The typical "gated community" characteristic of such areas, with a mixture of residential, commercial, and recreational land use, also favored walking and bicycle trips for local residents to meet their daily demands.<sup>3</sup> From the beginning of the car industry up to as late as about the mid-1990s, Chinese

<sup>3</sup>As opposed to the typical western single-family detached housing model which consists almost exclusively of low density single story construction.



**Fig. 3.3** The walking- and cycling-oriented Chinese city featured here rapidly gave way to motorcycles and cars (Kunming). Photo by Jeffrey Kenworthy

cities were the world's greatest walking and cycling environments and also had very high public transport use, mainly buses. The cities were extremely dense with intensively mixed land uses, and private cars were very uncommon. A vibrant and public urban culture prevailed.

In a very short space of time, particularly since the start of the twenty-first century, the automobile penetrated Chinese urban environments in a dramatic way, leading many Chinese megacities to develop substantial automobile-based land use. The resulting soaring housing costs and deteriorating air quality, along with the urbanization and motorization, pushed local residents to resettle in the suburbs, both voluntarily and involuntarily.

In this context it is remarkable that temporary residents migrate from rural areas or other cities to the urban center of megacities for more chances of jobs or better education for children, notwithstanding the worsening environmental conditions. Migrant workers tend to reside in migrant villages to avoid the unaffordable housing-related costs closer in.

Industrial suburbanization refers to the relocation of heavy-industry factories and newly constructed technology parks into the peri-urban areas. The cities sprawl outwards to the urban fringe along massive new roads. Congestion has dramatically increased as dependence on automobiles has grown, pushing travel times well beyond the typically accepted daily travel time limit (or Marchetti Constant) of about 65–70 min/person/day (Marchetti 1994).

In Beijing, the average traffic speed in core areas decreased from 45 km/h in 1994 to 12 km/h in 2003 (Peng 2004). The need to increase speeds has been a driving

factor in the rapid development of Beijing's metro system. Five new subway lines have been built in Beijing's suburban areas since 2010. Meanwhile, Beijing continues a further outward expansion through the construction of highway loop roads. The Seventh Ring Road is currently under construction, while the Second Ring Road was completed in 1992 (Beijing Municipal Government 2015).

China is now looking towards urban public transport development to address its automobile-related problems. Its traditionally dense and linear form of urbanism has laid a good foundation for the growth of mass transit. The growth of rail transport with higher passenger carrying capacity and higher travel speeds has resulted in a slowing down of car use growth (see below). The future urban land use trends are likely to be based on a much stronger combination of nonmotorized modes and transit, which are the most sustainable for high-density Chinese cities.

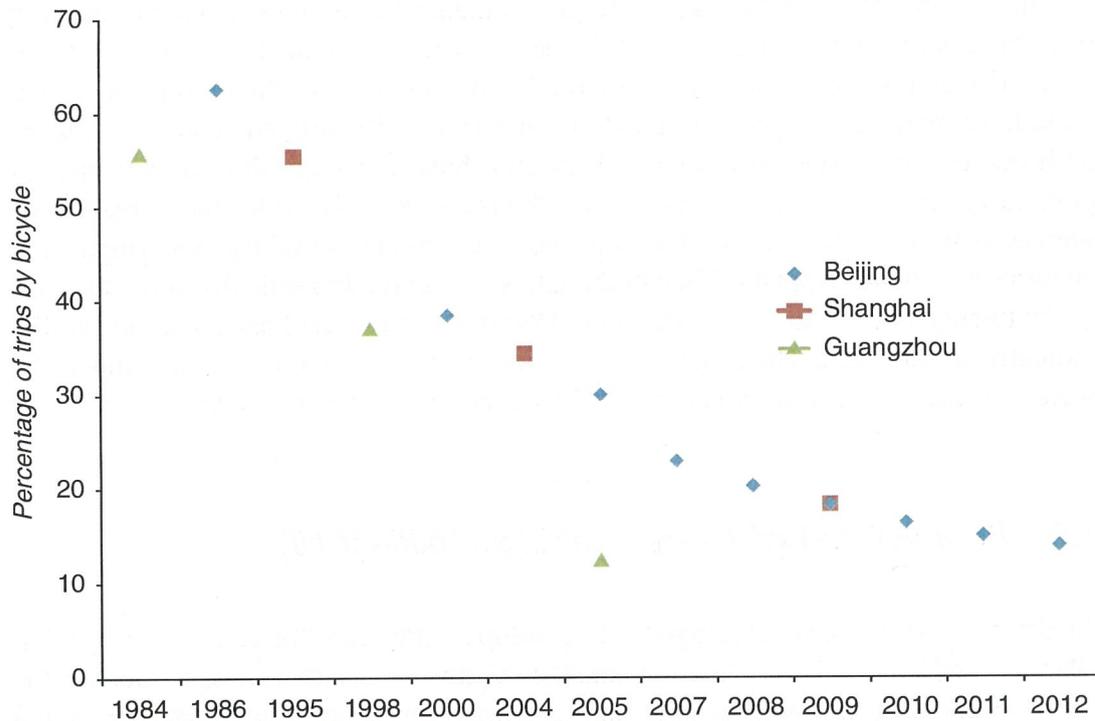
### 3 Trends in Transport Use and Mobility

#### 3.1 *Bicycle-Led Urban Mobility (Late 1940s to Mid-1990s)*

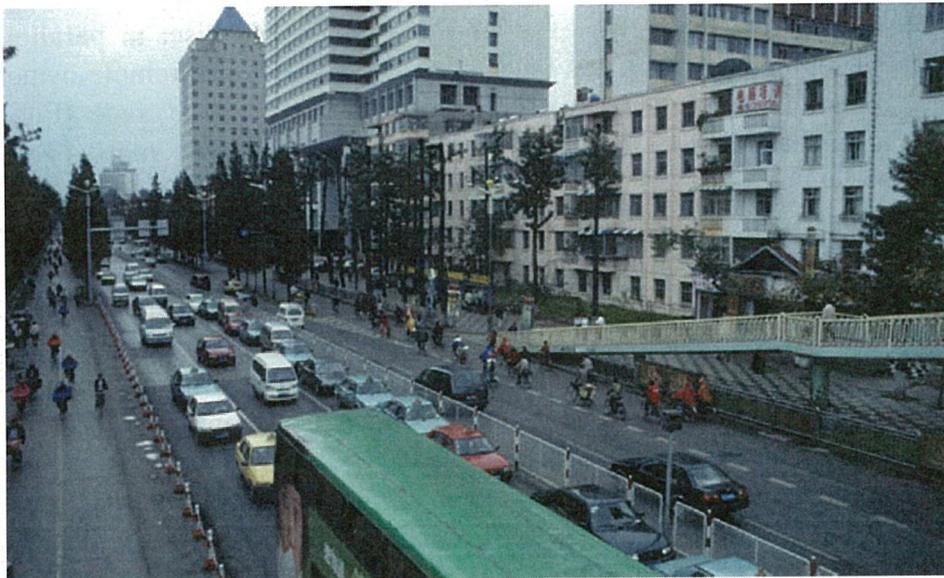
In the 1940s, when the population of China was 540 million, the total number of bicycles was around 0.5 million (Yang et al. 2014). Since the institutional transition from a command economy into a socialist market economy at the end of the 1970s, the Chinese bicycle industry entered a rapid period of growth, which peaked in the late 1980s (NBSC 2014b). China, which was widely acknowledged as the "bicycle kingdom" in the mid-1980s, experienced the prosperity of a bicycle-based society for many years. Over recent years, however, cycling has been on a dramatic downwards path. In the three megacities, there was a general decimation of bicycle trips from the mid-1990s onwards, and a continuous drop until 2012 (Fig. 3.4). In the 1980s, Beijing had a similar level of bicycle ridership to Shanghai, and higher than Guangzhou. In 1986, more than 60 % of daily non-pedestrian trips were made by bike in Beijing but this had plummeted to 14 % by 2012.

The relatively flat topography and agreeable northern Chinese climate in Beijing and Shanghai are part of the reason why bicycle trips are still favored by some local residents. Guangzhou, on the other hand, is mostly characterized by hilly terrain as well as a subtropical climate, which reduces the popularity of cycling.

Nationally, ill-advised attempts to tackle and alleviate the growing number of collisions between motorized and nonmotorized travelers have reduced the public willingness to ride bicycles. The lack of separation between cyclists and motorized vehicles has created potential threats to the safety of both cyclists and pedestrians. Unacceptable traffic behavior, in particular uncontrolled roadside parking, has damaged the connectivity of what were previously very good bicycle pathway systems in Chinese cities. The rights-of-way on the road for cyclists continue to be impaired because the designated bicycle lanes have gradually been eroded to cater for motorized transport (Fig. 3.5). The majority of Beijing's pedestrians regard walking environments as either unsafe or unsatisfactory (Pan et al. 2010).



**Fig. 3.4** Mode share of cycling (% trips by bicycle, excluding walking) in Beijing, Shanghai, and Guangzhou (1984–2012). *Sources:* Beijing Transportation Research Centre (2013), Deng and Xie (2000), and Lu and Gu (2011)



**Fig. 3.5** Generous bicycle paths in Chinese cities have been rapidly eroded by expanded roads (Kunming). Photo by Jeffrey Kenworthy

The bicycle has experienced a dramatic change in fortunes in China, starting from the luxury status of bikes in 1897 when they were first officially imported into China (Esfehani 2003) and only available for the wealthy, to the cultural icon and must-have marriage property of the 1980s and 1990s. Towards the end of the twentieth century, however, bicycles and bicycling have been spiraling downwards in popularity across the nation, mostly since the mid-1990s. Bicycles have come to be seen as symbols of poverty and backwardness, as China has rapidly modernized and become an economic power. The situation has worsened dramatically since the start of the twenty-first century, when the era of private vehicles and private motorization radically accelerated. However, this position may be changing again under the weight of the severe problems generated by cars and traffic (see below).

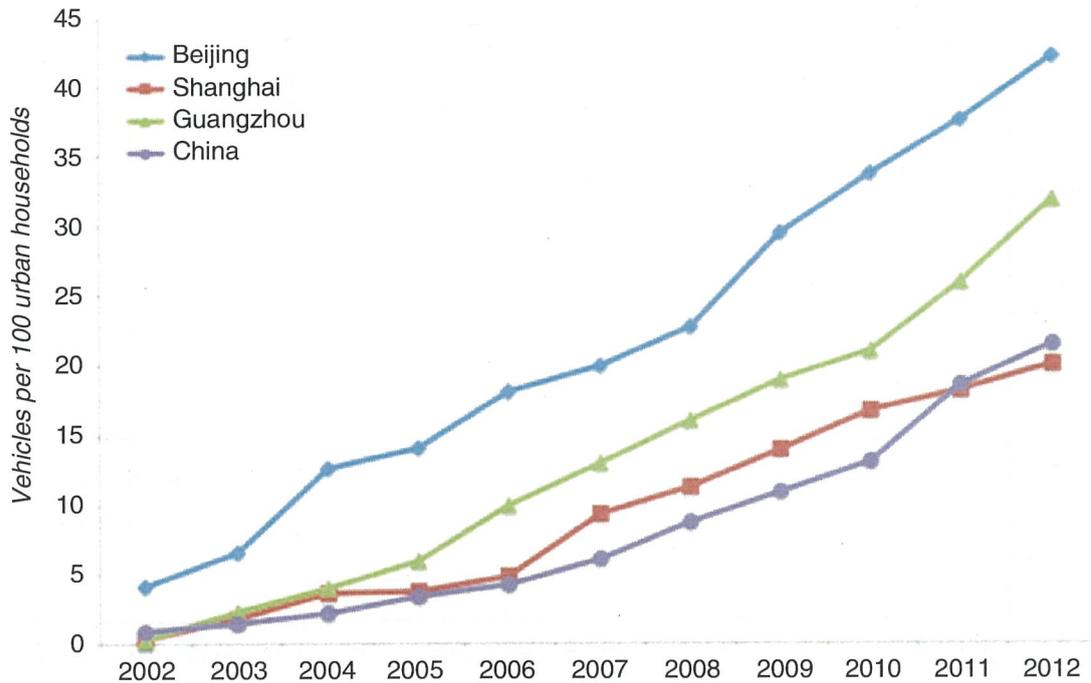
### 3.2 *Private Car-Led Urban Mobility (2000–2010)*<sup>4</sup>

At the time that many developed cities stepped into the “peak car use” period (Puentes and Tomer 2009; Newman and Kenworthy 2011), there was a boom in the Chinese car industry with double-digit growth rates since the beginning of the twenty-first century (e.g., as high as 55%). This was partly due to China’s entering the World Trade Organization as the 143rd member in 2001 and the Tenth Five-Year Plan (2001–2005), which encouraged families to purchase cars (Gao et al. 2015a). In terms of private vehicle ownership per household (including cars, vans, and other private vehicles, but excluding motorcycles), there was a dramatic increase in the decade between 2002 and 2012, with an approximate growth rate of 37% per annum. The three megacities have also experienced a continuous rise, in parallel with national development. Beijing has the highest level of private vehicle ownership, while Shanghai is lowest and closely reflects the national average (Fig. 3.6). Shanghai is the least private transport-oriented city in this sample, partly because of its long-standing and stricter restrictions on car ownership and use (see below).

With respect to private vehicle use, the proportion of daily trips by private motorized modes gradually increased along with the booming car industry and the decline of the bicycle culture. More recently, however, a few factors have helped somewhat mitigate automobile use at the municipal and national levels. These include the termination of three national auto-encouragement policies designed to help overcome the 2008 global financial crisis (MOF 2011a, b, c), the introduction of restrictions on private vehicle ownership and use (see below), and the preferential treatment in the national Five-Year Plans of urban public transport, especially urban rail transit since the Twelfth Five-Year Plan (2011–2015) (Peoples Congress of the People’s Republic of China 2011).

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<sup>4</sup>While vehicle ownership per hundred urban households has continued to grow beyond 2010 (Fig. 3.6), the more significant share of daily trips by private motorized vehicles (i.e., actual use of private vehicles) began to stabilize and decline around 2010 in Beijing, Shanghai, and Guangzhou (Fig. 3.7). It indicated an important change in orientation of urban transport in China, as developed in more detail later in the chapter.

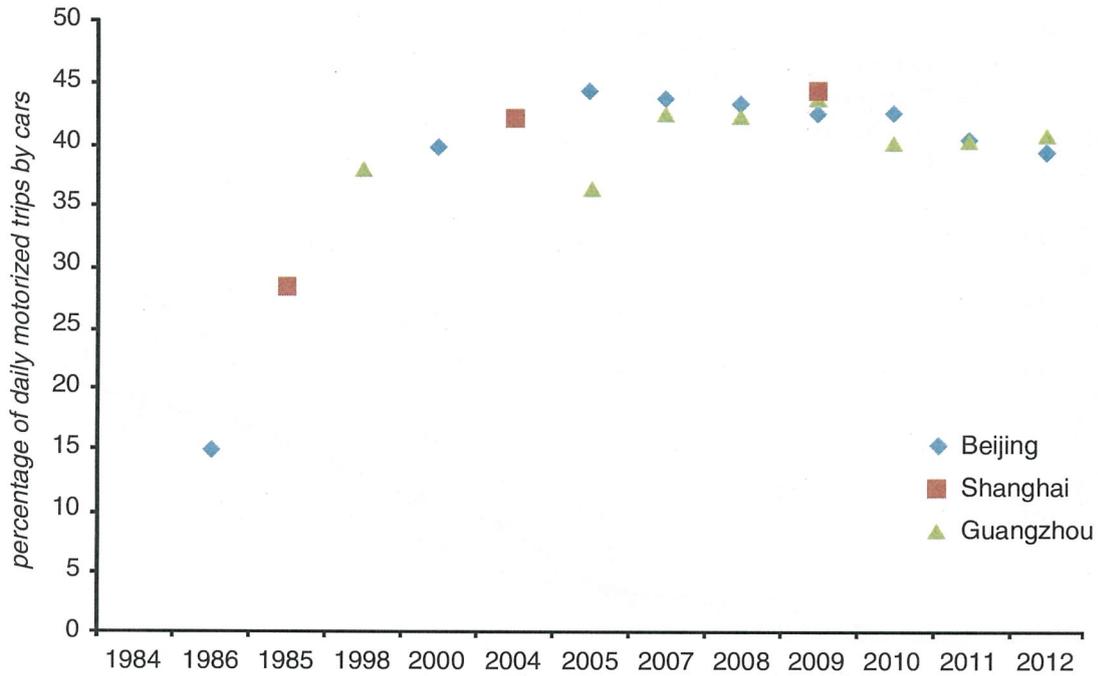


**Fig. 3.6** Vehicle ownership (vehicles per 100 urban households) in 2002–2012. *Sources:* NBSC (2012) and Guangzhou Municipal Bureau of Statistics (2012)

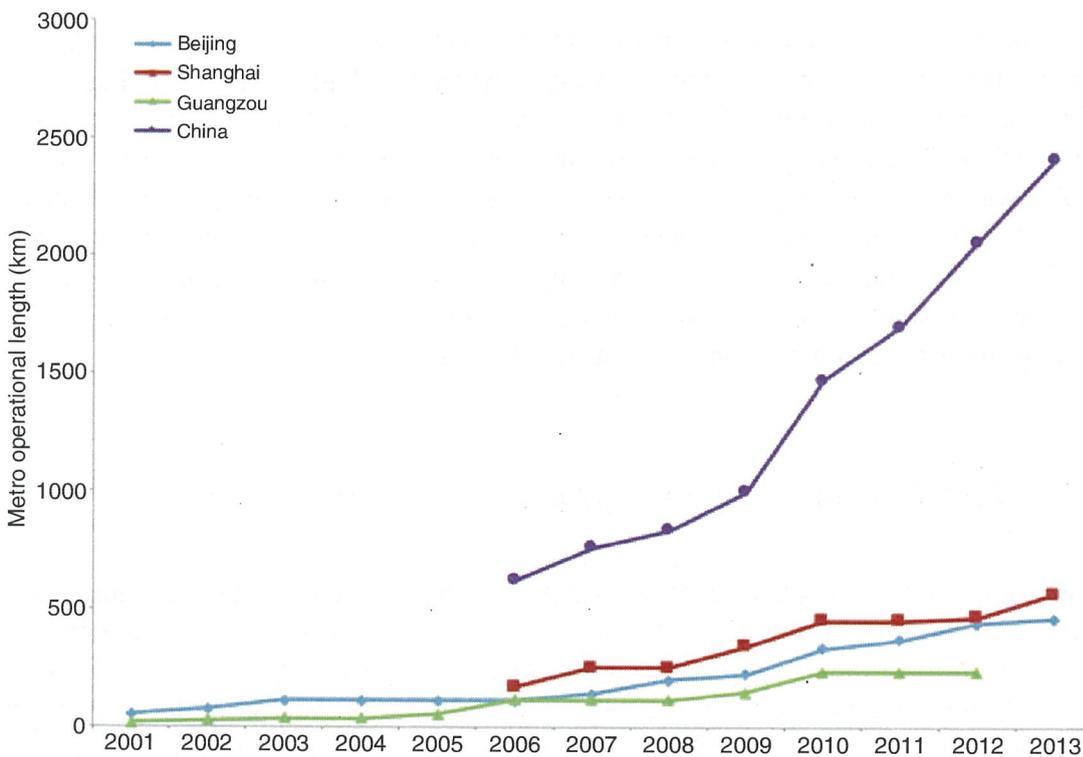
The share of total daily motorized trips by private vehicles stabilized or experienced decline since around 2010 in Beijing, Shanghai, and Guangzhou (Fig. 3.7). Compared to automobile-dependent cities in the West, which generally have 80–95% of total daily trips by private motorized transport (Kenworthy 2014; Newman and Kenworthy 2015), these Chinese cities actually had quite a low share of private motorized trips (40–45% or even lower if walking and cycling trips are included). In other words, notwithstanding the prosperity of the Chinese car industry, major Chinese cities are far from what could be termed “car dependent,” even though their road systems may be “saturated” with cars.

### 3.3 Rail Transit-Led Urban Mobility (2011–the Present)

The modal split changes in cycling and private vehicles have generated numerous problems such as traffic gridlock, atmospheric pollution, and unpleasant public space as most of the urban fabric was simply not designed around the car. The situation facing Chinese cities has become a major topic of local and global concern (Pucher et al. 2007). As a result, China is in a process of transition from unquestioned support for the car industry, towards prioritizing the development of urban public transport, especially metro systems within cities (Fig. 3.8) and high-speed rail lines between cities.



**Fig. 3.7** Modal share of private vehicles (percentage of total daily motorized trips) in Beijing, Shanghai, and Guangzhou (1984–2012) (The data for Beijing and Shanghai have been recalculated to exclude walking and cycling in order to match the Guangzhou data. Therefore, the share of car trips appears artificially high). *Sources:* Beijing Transportation Research Centre (BTRC) (2013), Deng and Xie (2000), and Lu and Gu (2011)

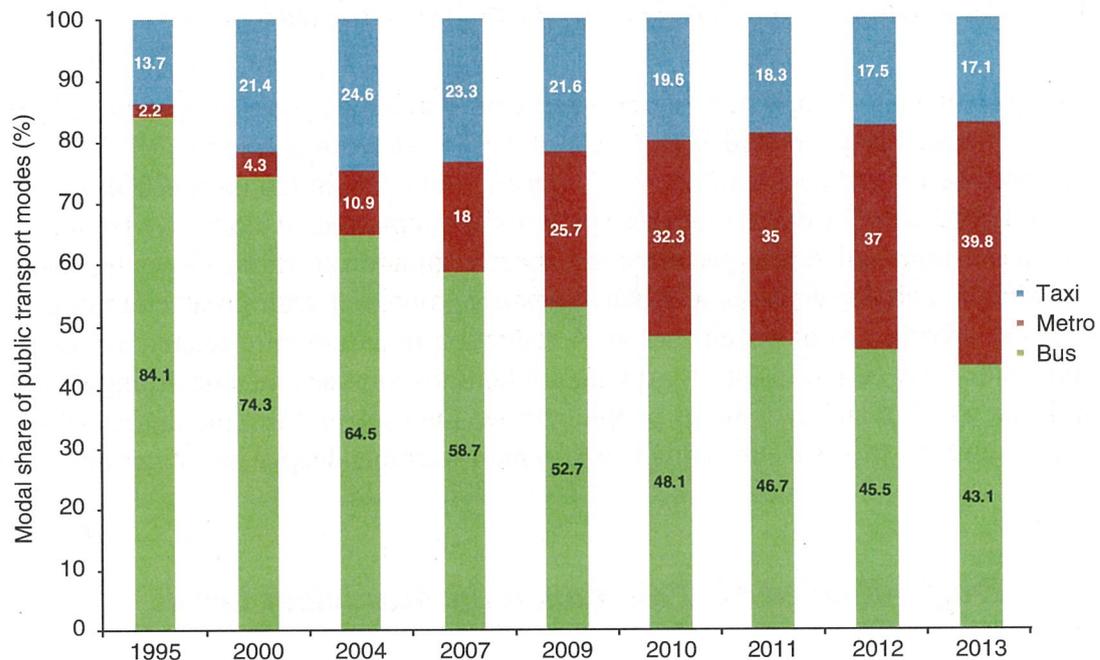


**Fig. 3.8** Development of national and municipal metros systems (length in km). *Sources:* BTRC (2013), Guangzhou Transport Planning Research Institute (GTPRI) (2012), and NBSC (2013a)

Chinese urban rail transport started in 1969 in Beijing for military defense purposes (Strickfaden and Devlieger 2011). By 2014, 95 metro lines had come into service in 22 cities (China Association of Metros 2015). Beijing's rail transit commenced commercial operations in 1981 but developed slowly for some years because of political and technological constraints. In the early 2000s, its operational length and annual patronage rose steeply, particularly from around 2007. Beijing's subway is now the second longest in China after Shanghai.

Shanghai first opened a metro line in 1993 (the southern section of Line 1, only 4.4 km long). By 2014, the city had 15 metro lines (including the Transrapid or Maglev Train, a magnetic levitation train), totaling 578 km (643 km of urban rail transit in total). Shanghai now has the longest metro system in China and the third biggest metro system in the world, all developed in the space of two decades. The proportion of journeys by metro has risen from a mere 2% to nearly 40% over this period. In 1995, the new metro system catered for 230,000 trips per day which rose to a staggering 6,870,000 per day by 2013—a 30-fold increase. The bus is still the dominant public transport mode in Shanghai, but its share and daily patronage has shown a significant fall over the 18-year period as the metro has taken over (Fig. 3.9).

The city of Guangzhou launched its metro system in 1997 as the fourth Chinese city after Beijing, Tianjin, and Shanghai. By the end of 2014, its metro system ranked the third longest and busiest nationally. There were no newly built metro lines in Guangzhou from 2010 to 2012, but its patronage still increased 10% compared to the 9% decrease in regular bus transit during the same period (GTPRI 2012). Its urban rail transport operational length per 10,000 persons came last in comparison with its two other mainland rivals and was only about half of the Hong



**Fig. 3.9** Modal share of public transport modes in Shanghai (1995–2013). *Sources:* Shanghai Municipal Government (2010) and Shanghai City and Transportation Research Institute (2014)

**Table 3.1** Density of network and intensity of usage of urban rail transport in five selected Asian-Chinese cities in 2012

City	Density of urban rail transport (km/10,000 persons)	Intensity of passengers by urban rail transport (10,000 persons/km/day)
Beijing	0.21	2.13
Shanghai	0.20	1.61
Guangzhou	0.18	2.15
Hong Kong	0.31	1.67
Singapore	0.23	1.23

*Note:* The density term refers to the ratio of metro and other urban rail transit operational length to local inhabitants. The intensity terms refers to the daily ridership by metro and other urban rail transit per unit of operational length

*Source:* GTPRI (2012). Data on intensity of utilization for Singapore and Hong Kong are for 2005 and 2006 (Newman and Kenworthy 2015)

Kong level and significantly below Singapore. However, it was the most intensively utilized of all five cities (Table 3.1).

China now also has the longest high-speed rail network in operation (11,132 km compared to the whole of Europe with 7,351 km), representing 48.5 % and 41.2 %, respectively, of the global totals as of 2014 (International Union of Railways (UIC) 2014).

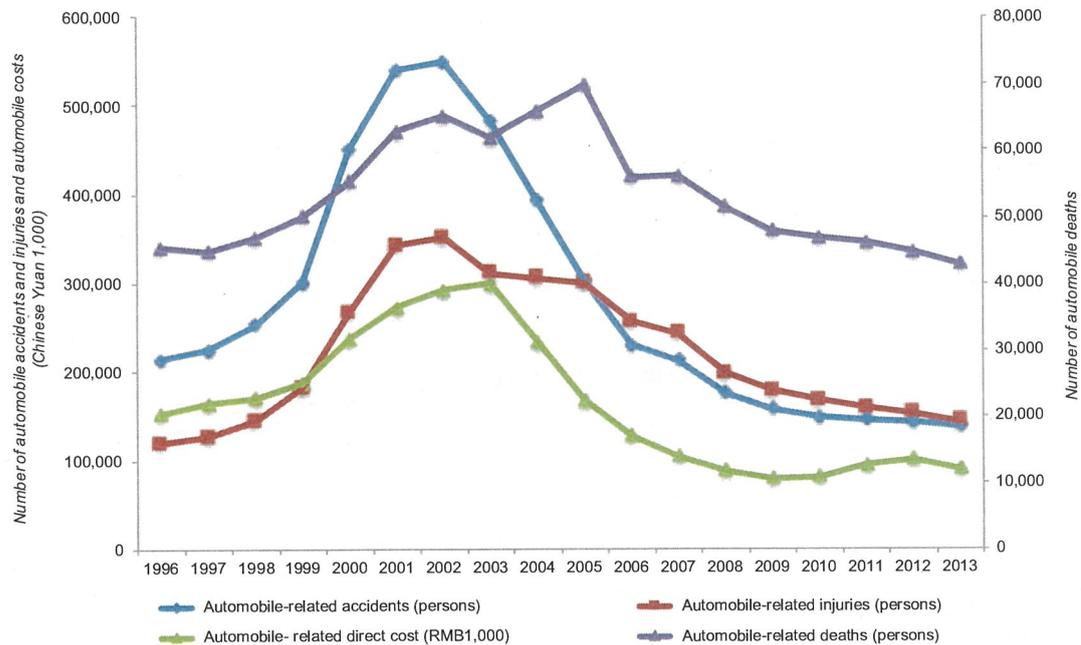
## 4 Urban Transport Problems

### 4.1 *Automobile-Related Accidents at the National Level*

The introduction of such huge numbers of cars into Chinese cities in such a short space of time has generated high levels of traffic-related externalities (Fig. 3.10). Automobile-related accidents, deaths, injuries, and costs in China reached a peak around 2002–2005. Reasons for these patterns are numerous. Automotive technologies have improved safety performance, more regulation of traffic flows has been introduced, and driver skills and behavior have improved with greater familiarity with car driving and better education. A reduction in automobile-related accidents and deaths may be the result of growing public transport use and a declining modal split for walking and cycling, as people remove themselves from the danger of the road. However, this is a surprising result, which warrants deeper investigations.

### 4.2 *Traffic-Related Air Pollution at the Municipal Level*

The worsening nitrogen oxides (NO<sub>x</sub>) and particulate matter (PM) concentrations in Chinese cities have displaced sulfur dioxide (SO<sub>2</sub>) as the biggest pollutants, indicating that the rapid rate of motorization is playing a growing role in anthropogenic



**Fig. 3.10** Automobile-related accidents, deaths, injuries, and costs at the national level in China (1996–2013) (Missing data for 2004). *Source:* NBSC (2013b)

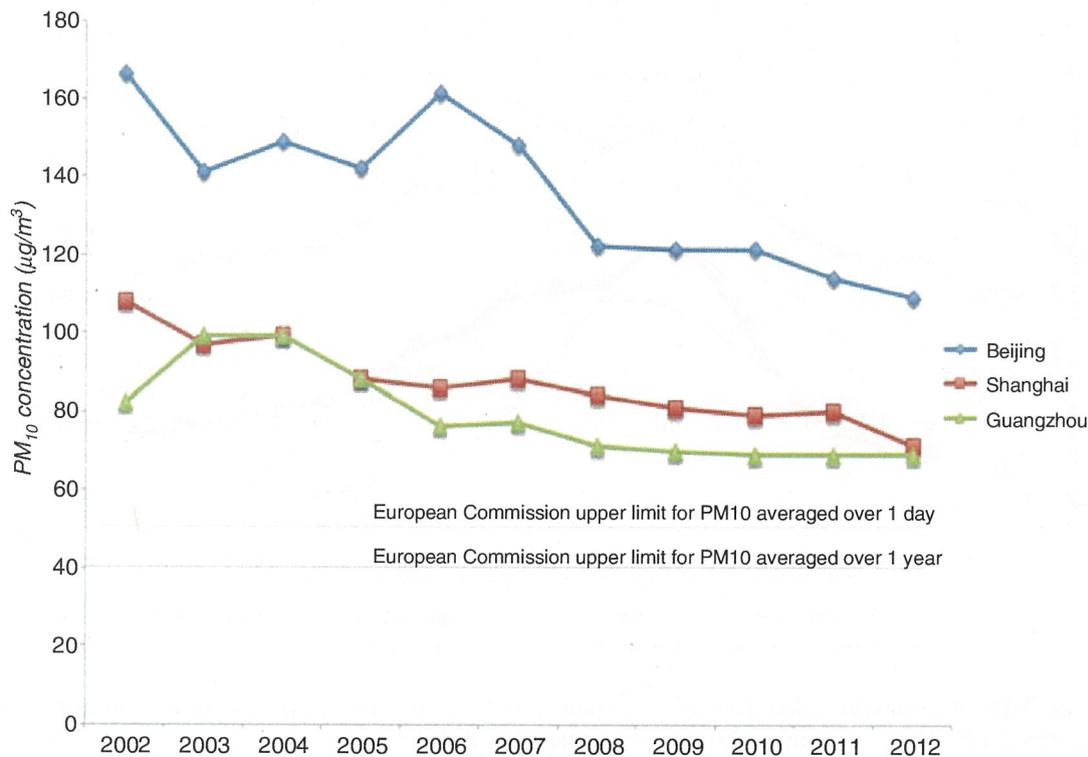
atmospheric pollution (Hao and Wang 2005). For example, nearly a third of the total  $PM_{2.5}$  emissions are from vehicles (Beijing Municipal Environmental Protection 2015). According to statistics, the concentration of  $PM_{10}$  in major cities has been decreasing since 2002, which contradicts popular perceptions of what is happening in China with air pollution (Fig. 3.11).

Despite the falling trend, these three Chinese cities far exceed both the recommended European daily and yearly averages for  $PM_{10}$ —45 and 50  $\mu g/m^3$ , respectively (European Commission 2015). In 2012, Beijing stood at 109  $\mu g/m^3$ , or nearly threefold the healthy limit, while Shanghai and Guangzhou were around 70  $\mu g/m^3$ , or nearly twice the limit. Clearly, Beijing is the most polluted of the three large cities, which coincides with its status as the city with the highest private car ownership in China.

## 5 Urban Transport Governance, Decision-Making, and Financing

### 5.1 Transition of National Policies on the Car Industry

The vigorous development of the national automotive industry was included in China's First Five-Year Plan (1953–1957), which favored a transition from an agrarian country to an industrial power. The First Automobile Works factory was



**Fig. 3.11** Traffic-related particulate matter ( $PM_{10}$ ) emissions ( $\mu\text{g}/\text{m}^3$ ) in 2002–2012 (annual average for Beijing and Guangzhou and daily average for Shanghai) Sources: BTRC (2013), GTPRI (2012), and Shanghai Environmental Protection Bureau (2013)

listed as one of the first set of “156 Projects”<sup>5</sup> with a proposed annual output of 30,000 vehicles (Sit and Liu 2000). With its construction in 1956, the Chinese automotive industry was officially established and made concerted efforts in the field of heavy-duty vehicle production. This was designed to protect against possible foreign attack during the cold war and to help achieve the level of economic construction demanded from the establishment of New China (Gan 2003). However, it imposed restrictions on product diversification, especially passenger cars.

Along with Nanjing, Shanghai, and Jinan, Beijing founded the First Automobile Accessory Factory in 1954, principally to provide automotive components for the national First Automobile Works (Gan 2003). In contrast to the First (and later Second) Automobile Works focusing on heavy vehicles, Beijing’s automotive industry came to specialize in the production of light-duty and passenger vehicles. Under Mao’s Great Leap Forward (1958–1960), the Beijing factory successfully manufactured a passenger car named “Jinggangshan” (named after a mountain range) in 1958 and the factory was renamed Beijing Automobile Works. In the same year the “Red Flag” brand passenger car was produced in the First Automobile Works (Gao et al. 2015a). In 1960, Beijing developed a new car, the “Dongfanghong” (literally, “the East is red”). In 1983, the Beijing Automobile Works closed a deal

<sup>5</sup>There were 156 newly developed projects under technical support from the former Soviet Union during the First Five-Year Plan. They covered energy, machinery, and other heavy industries.

with the American Motors Corporation to build a Sino-foreign joint venture, the first of its kind in Chinese automotive history. These events facilitated the popularization of motor vehicles amongst Beijing residents.

The far-reaching 1978 “Reform and Opening-up” Policy gave more autonomy to Chinese industries, including the automobile sector. The change from adjunct to executive powers allowed individual car producers to become relatively independent through the “Separation of Enterprise from Administration” policy (Liu and Dicken 2006). There was an explicit countrywide move away from a solely military focus towards emphasis on the development of the civilian automobile industry, along with the evolution of China’s consecutive Five-Year Plans (Gao et al. 2015a).

Nevertheless, there were still limitations under the rigorous state controls in the beginning of economic restructuring. For example, passenger cars were first produced by the First Automobile Works in 1958. Later, between 1978 and 1985, the planned production fluctuated around 3000–6000 units annually. This accounted for less than 3% of China’s whole vehicle production during that period. It would be more correct to say that this was the Chinese truck industry era rather than the Chinese automotive industry era.

The local underproduction resulted in the first import peak of passenger cars in 1985, soon after the private purchase of vehicles was legalized in 1984 (China Automotive Research Center 2010). The Automotive Industrial Policy of 1994 and the Tenth Five-Year Plan (2001–2005) provided official encouragement for individuals and families to purchase passenger vehicles. As a consequence, the industrial structure began to formally prioritize passenger cars over freight vehicles.

The decrease in import tariffs (reduced to 25% by 2006) and the removal of restrictions on car import permits following World Trade Organization commitments in 2001 strongly stimulated the Chinese car industry, which experienced a period of boom. In 2002, the annual production had more than tripled compared to a year earlier. At the same time, Chinese megacities started rolling out Transportation Demand Management policies to ameliorate and tackle the traffic-based pressures. Besides these measures, which could only delay escalating private motorization, there were more effective actions, including prioritizing the development of urban public transport, especially rail transit. These actions have reduced the growth in private motorized modes since around 2011.

## ***5.2 Municipal Restrictions on Private Vehicle Ownership and Use***

Shanghai and Beijing were the first two cities in China to pioneer restrictions on private vehicle ownership by limiting the issue of license plates (Table 3.2). Shanghai adopted an even stricter stance towards the quotas on new car registration, with an average price of about \$5,040 in 2008. Guangzhou is the fourth Chinese city (after Guiyang in 2011) to implement a similar policy through an integrated distribution system, with an emphasis on new energy vehicles.

**Table 3.2** Comparison of municipal restrictions on private vehicle ownership

City	Year issued	Approach	Quotas
Shanghai	1994	Singapore-style auction system	Less than 10,000/month
Beijing	2010	Lottery system	20,000/month (2011); 15,000/month (2014)
Guangzhou	2012	60 % by lottery system (10 % for new energy vehicles)+40 % by auction system	10,000/month

Sources: Beijing Municipal Commission of Transport (2010), Hao et al. (2011), and Guangzhou Transport Bureau (2012)

In terms of limiting private vehicle use, the Beijing and Guangzhou governments successively built on interventions for the 2008 Olympic and Paralympic Games (Beijing Traffic Management Bureau 2008) as well as the 2010 Asian Games (Guangzhou Municipal Government 2010) hosted by Beijing and Guangzhou, respectively. These two cities employed similar approaches for road space rationing to alleviate traffic. Privately owned vehicles with odd/even plate numbers are only allowed to drive during the odd/even dates of the year. During the implementation period from October 2008 to February 2009, arterial traffic flows increased by 4 % (BTRC 2009). Meanwhile congestion levels fell and vehicle emissions decreased. However, in the long run, the effect was offset by the ever-increasing vehicle population. The average arterial traffic speed in the morning peak (7–9 am) in Beijing stabilized to about 23 km/h between 2008 and 2012.

### 5.3 Economic Growth

Economic development (i.e., government investment in automobile facilities and rising individual purchasing power) is considered as one of the principal drivers of increased motorization in China (Mok 2000). For example, Beijing invested up to \$7.6 billion in 2010 in road infrastructure, compared to \$2.9 billion in 2001. Consequently, the length of freeways surged from 335 km to 903 km during the 9-year period between 2001 and 2010 (BTRC 2001, 2011). On the car supply-side, the Chinese car industry increased production, supported by state investment. The ownership of consumer goods such as cars is becoming progressively more affordable as personal incomes exceed subsistence levels (Riley 2002). In the wealthier national capital, for example, motorization reached 229 cars per 1000 persons in 2008—nearly fourfold the national average (China Association of Automobile Manufacturers (CAAM) 2011).

## 6 Proposed Urban Transport Solutions and Implementation Issues

### 6.1 Resurgence of Cycling

Until the mid-1990s, nonmotorized travel modes were the dominant form of urban mobility in China. Booming economic growth and a prosperous car industry promoted motorized transport, particularly the use of private vehicles, which encroached on the road space for cycling and consumed sidewalks for car parking (Figs. 3.12 and 3.13). However, given that even in megacities, shorter trips prevail, there may be signs of a return to cycling (in Beijing daily trips of less than 5 km accounted for 55 % of all trips in 2012; BTRC 2013).

Bicycle-sharing programs are helping revive the cycling tradition. The Public Bike scheme was introduced in Beijing in 2005 and developed rapidly around the time of the 2008 Olympic Games. In 2010, this system was officially brought under the direct management of the “Green Trip” program, overseen by the Beijing Municipal Government. It has an affordable “free+paid”<sup>6</sup> business model and the bikes are located near commercial, tourist, and residential areas, as well as railway stations.

By 2014, the total number of shared bicycle fleets and stations in China was 582,816 and 16,139, respectively. This makes China the largest bicycle-sharing country in the world (according to the Climate Environmental Service Group). Not only is cycling an environmentally-friendly mode for whole trips, but also the solution to the “last kilometer” connection problem faced by public transport users.

Today, cycling in China has an added dimension: electric bicycles. As many as 250 million electric bicycles (mostly e-bikes, or what are often referred to as pedelecs, as well as e-scooters) are used on Chinese streets nationwide. Besides government support, public awareness on environmental issues, as well as the influence of bicycle enthusiasts, is also encouraging more people to cycle.

### 6.2 Emerging Technologies

China has introduced a whole array of Transportation Demand Management policies to curb excessive private motorized travel demand. It has posed limits on conventionally powered private vehicles and has made commitments to develop alternatively fueled vehicles. As of 2014, many cities had already joined in efforts to curtail privately owned cars through limiting quotas on new car registrations (Shanghai 1994, Beijing 2010, Guiyang 2011, Guangzhou 2012, Shijiazhuang 2013, Tianjin 2013, and Hangzhou 2014).

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<sup>6</sup>There are different fees in different districts of Beijing. In the six inner districts, the first hour is free and then a flat rate of 1 Yuan/h (\$0.16) applies, with a maximum charge of 10 Yuan (\$1.6) in 24 h.

**Fig. 3.12** Sidewalks have been taken over in Chinese Cities for on-street parking (Dalian) Photo by Jeffrey Kenworthy



**Fig. 3.13** People have to walk around cars or on the road as on and off-street parking has encroached upon pedestrian sidewalks (Dalian) Photo by Jeffrey Kenworthy

The idea of New Energy Vehicles was introduced in Chinese transportation planning in the 1990s when Battery Electric Vehicles were listed among the “National Key Science and Technology Industrialization Projects” detailed in the Ninth Five-Year Plan (1996–2000). Battery Electric Vehicles were listed again as one of seven national strategic emerging industries in the Twelfth Five-Year Plan (2011–2015).

The “Ten Cities, Thousand Vehicles” program launched by the central government in 2009 to great fanfare aimed to achieve a New Energy Vehicles sales target equaling 10 % of car sales by 2012 (Wan et al. 2015). The actual sales of New Energy Vehicles totaled about 66,000 by 2014, 82 % of which were being used in a public service capacity (Li 2014). No cities achieved these targets: Zhejiang, Hefei, and Shanghai came closest to reaching the targets, while Beijing and Guangzhou fell far short of their targets.

Other emerging technologies and social trends have affected urban transport in Chinese cities. Several smartphone apps allow for the customization of traditional public transport services and are extremely popular with younger travelers. Didi Taxi, a Chinese taxi service similar to America’s Uber, entered operation in 2012 and offers a platform for planning taxi trips in real time through smartphones. This benefits both the drivers and the passengers as drivers can choose jobs closest to their location and passengers can decrease their waiting time. The convenience of this service can reduce the number of single-occupant private vehicles on the road, with benefits for pollution and congestion. The smartphone-supported car-sharing apps function similarly by matching trip origins and destinations between car service providers and consumers. However, current regulation means that Didi is caught in the dilemma of legality.

### 6.3 *Prioritizing Rapid Mass Transit*

The Twelfth Five-Year Plan (2011–2015) stressed the importance of developing public transport, especially rapid mass transit. This includes Bus Rapid Transit (BRT) and subway/metro within cities, as well as high-speed rail<sup>7</sup> between cities. BRT can potentially raise the operating speed of buses in urban China from around 10 to 20 km/h (Creutzig and He 2009), due to the application of fully dedicated rights-of-way (busway/bus lane).<sup>8</sup> While a median bus lane was built in Kunming in 1999, real BRT was not implemented in China until Beijing’s BRT saw the light in 2005 (Fjellstrom 2011). Guangzhou opened its BRT in 2013 and, after Bogotá, is the world’s busiest in terms of daily and peak-hour passenger trips (based on data from the Institute for Transportation and Development Policy). Qinhuangdao-Shenyang, the first high-speed rail line in China, was put into operation in 2003 (Fig. 3.14). By 2020 the total length of dedicated Chinese passenger lines is expected to be 12,000 km (based on the “Medium- and Long-Term Railway Network Planning” issued in 2004).

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<sup>7</sup>High speed rail or “bullet train” is defined as either an existing upgraded railway (operating speed  $\geq 200$  km/h) or an entirely new track system (operating speed  $\geq 250$  km/h) (Utah Foundation 2010).

<sup>8</sup>This is a significant improvement, however, 20 km/h will generally not compete with cars travel speeds and is very much less than a typical metro average speed of 30 to 40 km/h.



**Fig. 3.14** China has rapidly developed a vast network of high-speed rail (Xi'an). Photo by Yuan Gao

## 7 Other Country-Specific Issues

Rapid change is a key implementation strength in China. Although China has become more susceptible to severe transportation and motorization problems in recent years, it has demonstrated its capacity to adapt to rapid changes and even deal with some of the negative impacts constructively. This is due to a number of factors, not the least of which has been a booming economy which has helped China to accumulate the massive capital and investment required to enact meaningful and effective change, especially in transportation infrastructure. The stellar rise in the number of metro systems and the high-speed rail network serves as evidence of this ability. More evidence is found in the extraordinary rate of Chinese urbanization, such as the growth of Shenzhen from a fishing town with a population of about 0.3 million in the early 1980s, to a metropolis of 11 million people by 2014 (Shenzhen Municipal Bureau of Statistics 2015). China's potential for rapid change is therefore inextricably linked to its tremendous population momentum, despite the earlier one-child policy. China's dualistic centrally planned, yet successful market-based economy, also allows the country to implement its plans (in particular its Five-Year Plans) with greater authority and success than might occur in other nations. Employing both government regulation and control and market economics, China has shown a keen ability to rapidly change direction when needed.

## 8 Conclusion

Chinese cities adapted themselves to walking, cycling, and bus-based public transport for job accessibility and other social activities from the establishment of New China until the mid-1990s. These modes of urban transport are in accordance with the traditional dense and mixed-use Chinese urban settlement patterns. With economic growth, urban development, and the boom in the Chinese car industry, privately

owned cars—the symbol of a modern economy—became more available and affordable from the beginning of the twenty-first century. Private cars became a major transportation mode, replacing bicycles on the streets of Chinese cities, which in turn resulted in many Chinese megacities drowning in traffic.

Chinese cities will become more livable again if their urban transport systems are integrated, with a better balance between nonmotorized transport, private vehicles, and public transport, especially rail-based modes. This will not only ensure that daily travel demand is met and traffic-related pressure is eased, but it will also help protect the integrity of urban public environments. Such an integrated system will need to include the following:

1. Cycling, walking, and public transport (BRT, light rail, and metro) will need to become the key modes for city centers and for linking subcenters. The old (and new) walking city and transit city fabrics within Chinese cities must be respected, protected, and extended (Newman et al. 2016) (Figs. 3.15 and 3.16).
2. Rail transport must become the main mode for commuting between centers and in connecting suburban areas. It can be supplemented by regular buses and para-transit feeder modes, as well as trams or light rail in certain cases.
3. High-speed rail can offer intercity transport services, which are quick, affordable, and sustainable. The growing network of high-speed rail is an important way of keeping intercity car and plane travel across China to a minimum, thereby helping to reduce fossil fuel use and CO<sub>2</sub> emissions.



**Fig. 3.15** China is beginning to protect and expand its more traditional walking-based fabrics and vibrant street life and commerce (Dalian). Photo by Jeffrey Kenworthy



**Fig. 3.16** An attractive and spacious pedestrian zone in central Shanghai. Photo by Yuan Gao

4. Economic development should be decoupled from coal and oil (Newman and Kenworthy 2015). Electric mobility based on renewable energy, both for public transit and for private modes, such as electric bicycles and electric cars, has been developing rapidly. China therefore has the chance to lead the world in transformations to transportation systems that dramatically lower dependence on fossil fuels and reduce CO<sub>2</sub> output.

These lessons and trends may offer a silver lining to the dark cloud that has caused prosperity up to now to largely bypass regions such as in central China. If and when these regions can also develop many larger cities, they may be able to build in a competitive advantage from the beginning through a more livable and ecologically sustainable approach to urban development and transportation, therefore offering more attractive lifestyles and opportunities.

In summary, a few small signs of a possible transition to more sustainable forms of transport can be detected in China. However, much more needs to be done to achieve socioeconomic development and environmental livability. A key to the future of the car in China revolves around a continued reduction in the built-in need to own and use cars, especially in cities, and a reformation of the nature of the cars that are produced.

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## Published papers

*PAPER 4: Gao, Yuan Peter Newman and Jeffrey Kenworthy. 2016. Are Beijing and Shanghai Reaching Peak Car? Cities (Under Review)*

### Statement of Contributions of Authorship

**Gao, Yuan** (PhD Candidate) (60% Contribution)

*Preparation and completion of the manuscript, establishment of theoretical framework, data collection, preparation of figures and tables, policy analysis.*



*Yuan Gao, PhD Candidate*

**Newman, Peter** (Principle Supervisor) (30% Contribution)

*Supervising, revising and editing the manuscript.*



*Professor Peter Newman, Principle Supervisor*

**Kenworthy, Jeffrey** (Co-supervisor) (10% Contribution)

*Supervising, revising and editing the manuscript.*



*Professor Jeffrey Kenworthy, Co-supervisor*

**The attached Paper is an exact copy of the journal paper cited above**

# Are Beijing and Shanghai Reaching Peak Car

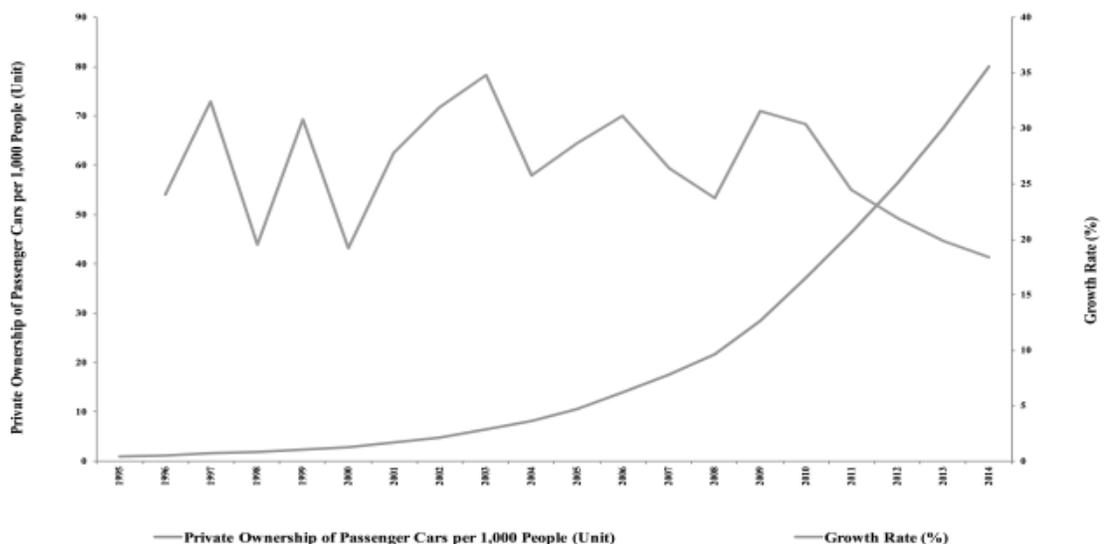
## Abstract

Chinese cities have primarily evolved around walking, bicycling and public transport with their dense, linear form and mixed land use. The recent urban growth spurt has involved private motorization, but because of land constraints and not fearing urban density, as in Anglo-Saxon cities, the same dense urbanism has been maintained. This means that automobiles do not easily fit into this traditional fabric and especially the historic walking fabric. Issues like congestion and air quality have become major constraints to further growth; hence all Chinese cities are re-evaluating their automobile dependence.

Using Beijing and Shanghai as case studies, the next phase of urban and transport development now appears to be peak car use and dramatic growth in urban rail as in most developed cities in the 21<sup>st</sup> century. This has occurred much sooner than could have been expected based on economic models, but the theory of urban fabrics does explain this pattern. The application to other Chinese cities and emerging cities is now possible following Beijing and Shanghai's lead.

## Introduction

Urban population growth and economic growth have led to growth in private ownership of passenger cars (see Figure 1). Administrative guidance and political imperatives have also significantly affected the level of automobile ownership in China (Gao et al., 2014) (see Section 2).

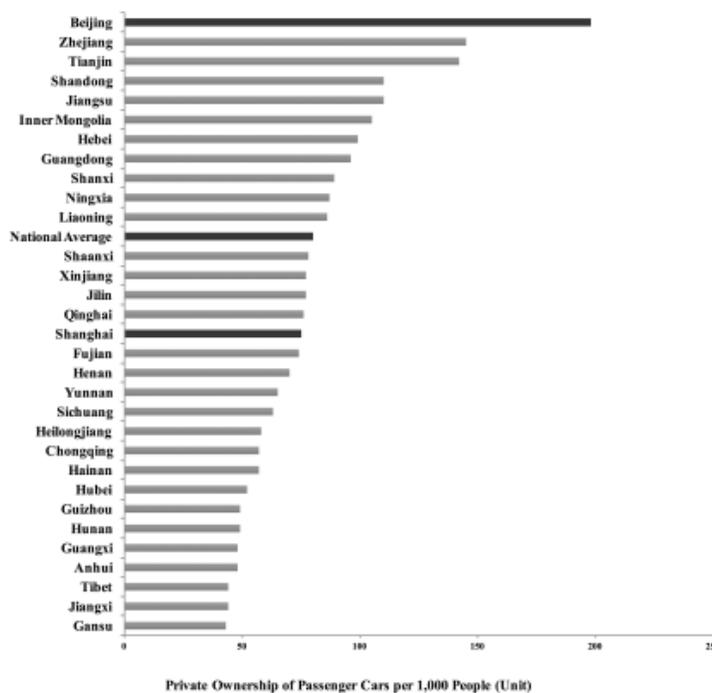


**Figure 1.** Private ownership of passenger cars<sup>1</sup> per 1,000 people in China (Unit) and its annual growth rate (%) from 1995 to 2014.

Source: Compiled based on data provided by the NBSC (2016b).

Chinese cities, along with their respective provinces, have increased in car ownership over recent years and now provincially range in car ownership from a meagre 43 per 1,000 persons in Gansu, up to 198 per 1,000 in Beijing, with a national average of 80 per 1,000 persons (see Figure 2). 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 2005/6, cities in the USA averaged 640 cars per 1,000 persons, Australian cities 647, Canadian cities 522, and European cities 463 per 1,000 persons (Newman and Kenworthy, 2015). Even between China's two most significant cities, Shanghai and Beijing, the difference is very large (78 compared to 198 cars per 1,000 persons respectively), partly due to Shanghai having implemented car management policies<sup>2</sup> from 1994.

Thus Chinese provinces and cities, even during what could be called a rampant period of motorisation, had by 2014 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.



**Figure 2.** Private ownership of passenger cars per 1,000 people across China<sup>3</sup> in 2014 (unit)

Source: Compiled based on data provided by the NBSC (2016b).

Added to this perspective we now find that recent car ownership growth rates are falling. The question to be addressed in this paper is therefore whether a structural change is starting to occur in Beijing and Shanghai, like in many developed cities and whether, like these developed cities, the two Chinese cities are now reaching a peak in

their car use (Newman and Kenworthy, 2015). This paper will thus seek to answer two specific questions:

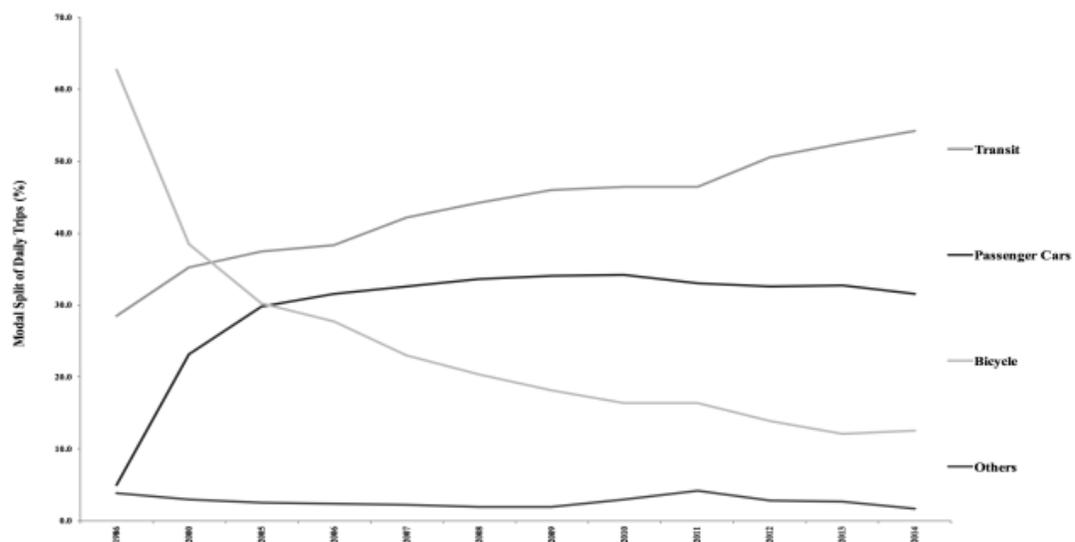
- Are Beijing and Shanghai transitioning to peak car and if so, are they different from other global cities in their associated new transport and land use patterns?
- Can the “Theory of Urban Fabrics” (Newman et al., 2016) help explain Chinese and other emerging cities’ transition in their urban transport?

The paper begins by examining some trends in Beijing and Shanghai that suggest their car use is plateauing and beginning to decline in key areas.

## 2. Have Beijing and Shanghai Stepped into the Era of Peak Car Use?

### 2.1 Beijing

Beijing, like all Chinese cities, was dominated by bicycling in the 20<sup>th</sup> century and as shown in Figure 3 had over 60 per cent of daily trips by cycling in 1986 but this quickly was overtaken by a rapid growth in car use; these modes crossed in 2005 and from there a different story emerges than would have been expected in a rapidly emerging global city. Car use begins to plateau in the 2000’s and peaks at 34 per cent in 2010. The growth trajectory that then takes over is transit as cycling continues to fall.



**Figure 3.** Modal split<sup>4</sup> of daily trips (excluding walking) in Beijing (1986-2014) (%)

Source: Compiled based on data provided by the (Beijing Transportation Research Centre (BJTRC), 2002-2014; 2015).

The Beijing transit system is shown by mode in Figure 4. The dramatic growth after 2007 that has impacted so strongly on modal share with cars is the role of the metro

that continues to grow significantly right through to the most recent data. Beijing was the first city in China to inaugurate metro rail into its transport infrastructure, with the first line opening in 1969 (Strickfaden and Devlieger, 2011). This development was further pursued and received a promotional boost leading up to the 2008 Olympics Games held in Beijing (Gao et al., 2015). The metro has been expanded ever since and has been embraced by the residents of Beijing with a daily patronage of around 9 million using the fast, high quality system. This follows the rapid expansion of Beijing’s metro system from an operational length of 142 km in 2007 to 555 km by 2015. Beijing’s metro is now the second largest after Shanghai (588 km) in China (Fan et al., 2016). The metro has become a significant transport mode, though the traditional bus is still the predominant travel choice of public transport. As this is measured in boardings, it would be more favourable to metro if passenger kms were used as bus trips tend to be shorter.



**Figure 4.** Annual patronage by different public transit modes in Beijing from 1998 to 2014 (10,000 Boarding)

Source: Compiled based on data provided by the BJTRC (2002-2014; 2015).

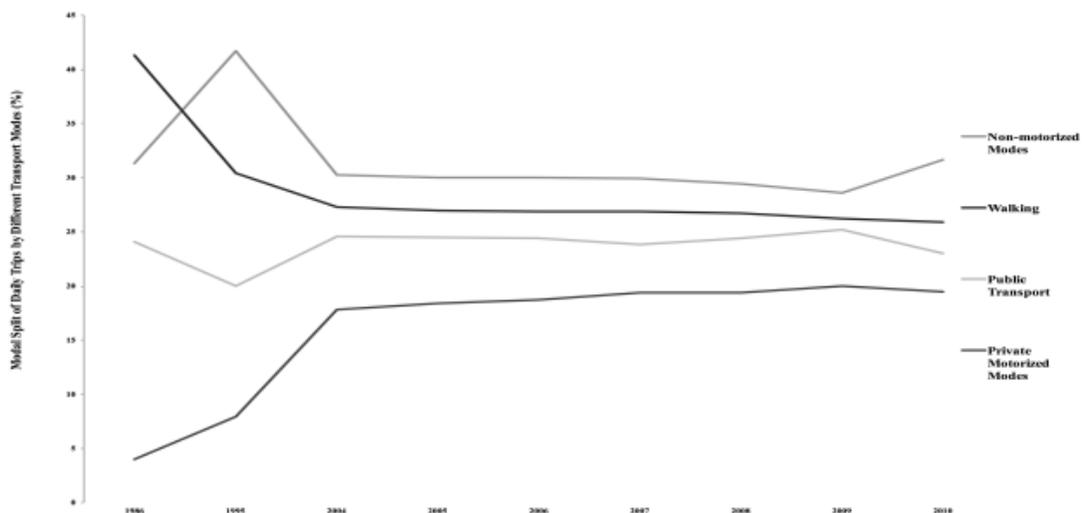
The increase in public transport in Beijing was made possible largely through the priority, which the government placed on bus and train infrastructure development. This occurred at both a local and national level in accordance with the central government’s Twelfth Five-Year Plan (FYP) (2011-2015). As part of this shift away from the automobile, Transportation Demand Management (TDM) initiatives were also introduced in an effort to further curb the ownership and use of private automobiles across China. These included:

- Restrictions on the operation of private automobiles on certain days throughout the 2008 Olympic Games, based on license plate end numbers;
- Limitations on the number of driving licenses made available to the public, a process initiated in 2010; and
- Since 2011, termination of three pro-car policies designed to help overcome the 2008 Global Financial Crisis (GFC).

As a result of these initiatives, automobile modal split in Beijing plateaued in 2010 before starting a downward trend. This is despite an increase in private automobile ownership in Beijing which would have had the potential to counteract this fall.

## 2.2 Shanghai

Shanghai's transport data is different to Beijing as it includes walking as well as other non-motorised modes<sup>5</sup> besides bicycling in the modal split as set out in Figure 5. But like Beijing, Shanghai was dominated by walking and non-motorised transport in the 20<sup>th</sup> century with over 70% of daily trips by these modes in the 1980's and 1990's. However, as in Beijing, the 21<sup>st</sup> century has seen a dramatic drop in these modes as car use began to grow in Shanghai. Then a plateau in car use began in the 2000's and by 2010 had peaked at less than 20% of daily trips (even lower than the 34% in Beijing). Again it would appear that transit has stemmed this car growth, though non-motorised transport has had more growth in the latest data as well.

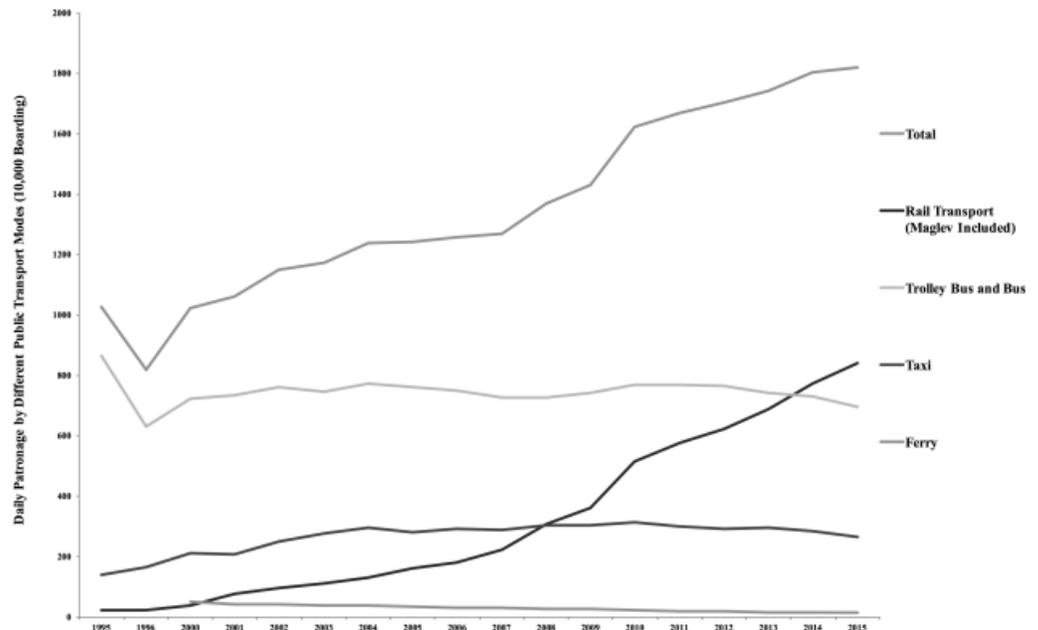


**Figure 5.** Modal split of daily Trips by different transport modes<sup>6</sup> in whole city of Shanghai from 1986 to 2010 (%)

Source: Compiled based on data provided by the Shanghai City Comprehensive Transportation Planning Institute (SCCTPI) (2011) and (Lu and Liu, 2012).

Figure 6 sets out the transit data by mode in Shanghai; this again indicates the dramatic growth of the metro. From the 1970's through to the beginning of the 1980's the trolley bus and bus were the main transit modes in Shanghai. The Shanghai metro

began in 1993 but was quite small until it was extended for the 2010 Shanghai World Expo. It is now the world's largest rapid transit system by route length and second largest by number of stations with 14 lines and 364 stations, and a total length of 588 km. On an average workday it carries 10 million passengers while the record patronage was 11.3 million on April 1<sup>st</sup> 2016.



**Figure 6.** Daily patronage by different public transit modes<sup>7</sup> in Shanghai from 1995 to 2015 (10,000 Boarding)

Source: Compiled based on data provided by the SCCTPI (2011; 2015).

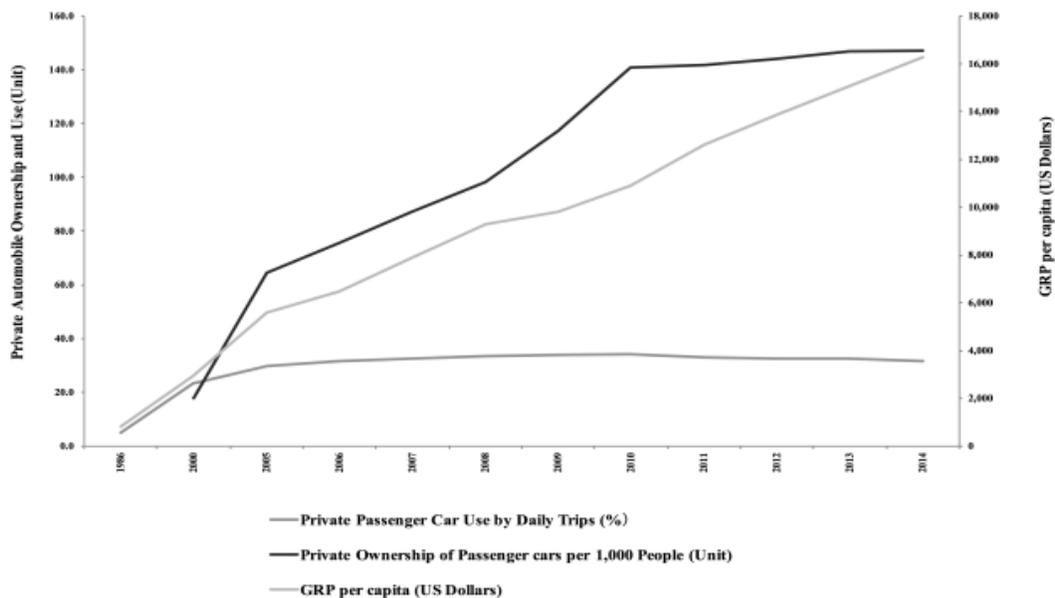
While private vehicle ownership in both Beijing and Shanghai is still increasing, actual automobile use as measured by modal split has in fact peaked (around 2010). They both appear to have reached peak car use<sup>8</sup>. Beijing went further along the automobile path than Shanghai but both turned dramatically once a quality metro alternative was provided. Shanghai also continues to have a very high walking and non-motorised component in its transport system (over 50% of daily trips). Both Beijing and Shanghai have much less private motorization than would have been expected due to their rapid growth in income.

### 3. What are the Contributors to Peak Automobile Use?

#### 3.1 Economic factors

Economic factors play a much more significant role in determining automobile ownership compared to actual usage (Newman and Kenworthy, 1996). Unlike automobile ownership, the actual need for automobile use has been shown to have decoupled from the financial capacity to pay for it; for example, the amount of car

driving per unit of real Gross Domestic Product (GDP) significantly declined between 1995 and 2005 in a large sample of world cities (Kenworthy, 2013; Newman and Kenworthy, 2015). Taking Beijing as an example, Figure 7, which depicts the number of passenger cars per 1,000 permanent residents, a continuous growth trend is in evidence in tandem with the ever-increasing Gross Regional Product (GRP) per capita. However, the level of private automobile use grows to the inflection point in 2010 and then starts dropping, despite a continuing improvement in the urban economic performance of Beijing. This is similar to the phenomenon of peak car use, where many developed cities have witnessed a plateau in per capita car use (Puentes and Tomer, 2009; Stanley and Barrett, 2010; Newman and Kenworthy, 2011). Furthermore in Beijing, personal income generally decreases from the city centre to the city fringe, whereas the use of the automobile increases in the opposite way. This suggests other factors than economic drivers are leading to the plateau and peak in car use as the decoupling seems to have set in well before other cities in terms of GRP levels.



**Figure 7.** Relationships between economic performance and private automobile ownership and 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 BJTRC (2002-2014; 2015).

### 3.2 Cultural and political factors

Wealth increases have certainly led to higher levels of car use in most cities, but the peak car phenomenon suggests something is causing an end to that growth as the decoupling of wealth and car use is becoming evident in most developed cities (Newman and Kenworthy, 2015). One of the other factors would appear to be a cultural and political intervention that makes other modes more attractive. Japanese cities began the peak car reversal several decades before other developed cities and this could be related

to a range of cultural and political interferences as well as city form factors outlined in the next section. Oil vulnerability was a major factor in Japan from the 1970's, which led to considerable electric rail building (Okada, 1995). Having a strong pro-density urban tradition has created cities that are not nearly so car dependent.

### **3.3 Urban form factors**

Peak car use has been related to the reversal of urban density in developed cities, which has been occurring for the past 20 years; as density increases car use declines exponentially (Newman and Kenworthy, 2015). Chinese cities have been historically high in density (Kenworthy and Hu, 2002) and as will be shown below have been increasing in density. Urban form factors are likely therefore to be a strong explanatory factor in why both Beijing and Shanghai reached peak car use well before they were expected to do so based on usual predictions based on income growth. This factor will therefore be expanded to help explain the early on-set of peak car in the two main Chinese cities.

## **4. Using the Theory of Urban Fabrics to Explain Peak Car Use**

The “Theory of Urban Fabrics” is a new way of explaining how transport and land use patterns are completely enmeshed. Hence it is being used here to explain how peak car use is happening and then it is applied to Beijing and Shanghai.

There have been three distinct urban fabrics created by the three key transport infrastructure systems through time: Walking city, Transit city and Automobile city. The global travel time budget of around one hour per day<sup>9</sup> has been universally demonstrated in history and across a great variety of cities (Newman and Kenworthy, 1999; Standing Advisory Committee for Trunk Road Assessment (SACTRA), 1994; Marchetti, 1994; Zahavi and Talvitie, 1980). This has led to three urban fabrics shown below:

- Walking city (4 km across): High density, mixed use, organic structures<sup>10</sup> with narrow streets; no set-backs; and no infrastructure to support later transit systems;
- Transit city (10 to 20 km across): Medium density, linear corridors following tram lines and “pearls on a string” centres based on rail lines with walking city fabric around stations; streets wide enough for trams and buses; some set-backs; and infrastructure to support the tram and rail systems; and
- Automobile city (50-80km across): Low density, filling in all available land between transit corridors; wide streets; large set-backs; and significant parking infrastructure.

These three fabrics are summarized below (see Table 1).

**Table 1** Three types of urban fabric based on the Marchetti “Travel Time Budget”

<b>Urban Fabric</b>	<b>Function Year</b>	<b>Transport Priority</b>	<b>Speed</b>	<b>City Radius</b>	<b>Land Use Pattern</b>
<b>Walking City</b>	8,000 years ago	Walking	3-4 km/h	2 km	Dense (over 100 persons/ha) and mixed-land use;
<b>Train-based Transit City (Outer Areas)</b>	1820's/1850's	Train, fast metro or fast light rail <sup>14</sup>	20-40 km/h	10-20 km	Less dense (around 50 persons/ha) and mixed land use along rail lines; Walking-based nodal centres;
<b>Tram-based Transit City (Inner Areas)</b>	1890's	Tram or light rail <sup>15</sup>	10-20 km/h	5-10 km	Linear medium density development along tram routes; Regular grid or strip streets;
<b>Automobile City</b>	1950s onward	<b>Automobiles</b>	50-80 km/h	20-40 km	Low density (Less than 20 persons/ha and 35 persons/ha maximum); Dispersed and decentralized; Automobile-reliant suburbs;

Source: Compiled based on data provided by Newman and Kenworthy (2015) and Newman et al. (2016).

As Newman and Kenworthy (2015) argue, the phenomenon of peak car use can be partly explained by the re-urbanisation of walking and transit urban fabrics that are now favoured for economic, social and environmental reasons. Economic reasons include the knowledge economy/services economy, which requires intensive face-to-face interactions, and the awareness that automobile city infrastructure and spatial patterns are extremely expensive and should not be subsidized any longer; time sensitive workers also are very keen not to waste time in long commutes so they tend to live and work in high density areas (Glaeser, 2011). Social reasons include the culture of social media, which makes the automobile less appealing as mobile devices cannot be used in cars to the intense degree that they can while using public transport (Florida, 2010). This is especially appealing to younger people whose use of public transport is growing everywhere and the rate at which they are obtaining driver's licenses has been falling for about a decade (Davis et al, 2012; The Fifth Estate, 2012). Environmental reasons include the need to stop urban sprawl impacts and the move to low carbon, less-auto based cities.

The importance of the Theory of Urban Fabrics to this paper is that it may be able to explain why the kind of fabric found in Chinese cities, and perhaps other emerging cities, is just not suitable for much automobile-based growth.

## **5. What are the Features of Beijing and Shanghai's Urban Fabric?**

### **5.1 Traditional low rise and high-density urban form and short blocks**

The low rise, high density blocks which characterise China's traditional way of building local neighbourhoods<sup>14</sup> 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 distance (Ewing and Cervero, 2010). Finally, this type of urban form helps to facilitate and operate more efficient public transport for these communities.

### **5.2 Central square and linear corridor form of urban development**

As well as the organic density of traditional cities there has been a long commitment to planning the city into a central square and linear corridor. This is known as the imperial-centred and axisymmetric urban form, which is affected by the Doctrine of the Mean<sup>15</sup> (Sit, 2010). The Kao Gong Ji<sup>16</sup> document presents a city centre based on a square or rectangular shape, a pattern that was developed during the Dynasty of Western Zhou (1046 BC-771 BC) 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 19<sup>th</sup> century (Gao et al., 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 lower 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.

### **5.3 Traditional employment system**

The socialist welfare-oriented housing within walking or cycling distances of work was provided by state-owned sectors under the traditional employment system (so-called Dan Wei in Chinese) during the period of the Planned Economy in China. However, the end of this system of nearby housing provision, which came with the 1978 Reform and Open-up process, largely destroyed what was quite a tight jobs-housing balance and increased the frequency and distance of the journey-to-work. However, they did not at any stage build urban fabric that was automobile dependent but continued to build dense, high rise-based corridors of urban fabric.

### **5.4 Traditional acceptance of high-density living**

Chinese villages, towns and cities have always been very dense. There are various theories about why density is accepted in some cultures and not others, for example, Anglo-Saxon culture has a long history of anti-density tradition which has been passed on to New World cities (King, 1978; Burton et al., 2003). The theories about density in Chinese cities suggest it is a combination of their:

- Military history: The need to have walled cities for security meant that a more urban culture became essential;
- Religion: Confucianism has a strong emphasis on community responsibilities that build networks of close dependence within and between families; and
- Economy: The reality of Chinese economic history is that they have built very big centres of economic wealth based on trading textiles, handicrafts and cultural activity that could only work efficiently if it was intensively conducted.

Together these theories suggest that the Chinese economy depended on these big cities that were made of traditional walking city fabric, highly dense and mixed for many centuries, rather than being a set of low-density rural villages based around agriculture (Kostoff, 1991; Lin, 2007; Gaubatz, 1999).

### **5.5 Resulting urban form**

These various traditions and planning paradigms have resulted in the typical Chinese urban form that has been explored in this paper. The same kind of urban fabric can be found in both cities examined; key differences were much higher urban density in some districts of the central city and a more walkable form of urban development in Shanghai compared to Beijing (see Table 2). The urban density of both central cities are similarly more than 200 persons/ha. However, the urban density of the whole city and suburb areas is higher in Shanghai than Beijing. This is perhaps due to Beijing's scattered urban areas around the Ring Roads. Some districts of the central city of Shanghai are super dense with more than 600 persons/ha urban density (like Huangpu, Luwan, Jingan and Hongkou) while the highest urban density in Beijing is around 300 persons/ha.

Shanghai's super dense urban form result in the dominance of walking and non-motorized transport modes in the whole city, as shown in the data outlined in Table 2.

**Table 2.** Comparisons of urban density by different districts between Beijing and Shanghai from 1980 to 2014

Year	Central City <sup>20</sup>		Whole City		Suburb Area <sup>21</sup>	
	Beijing	Shanghai	Beijing	Shanghai	Beijing	Shanghai
1980	268.37					
1985	271.97					
1990	278.3					
1995	277.19					
1996		227.37		66.32		36.95
2000	273.32					
2004		214.02		57.87		
2005	222.1	226.44	47.61	74.07	24.61	49.62
2006	223.08	224.46	48.31	76.59	24.94	
2007	223.94	224.32	49.1	76.46	25.31	
2008	225.46	225.6	50.19	74.35	26.11	
2009	228.49	225.6	51.97		27.07	
2010	234.01	241.34	57		32.04	
2011	232.71	242.54	58.67		33.16	
2012	237.58	244.39	60.14		34.15	
2013	239.42	244.57	60.86	79.97	34.54	
2014	239.53	243.41		77.65		

Source Compiled based on date provided by the Shanghai Municipal Bureau of Statistics (SMBS) (1996-2015; 2016), the Shanghai Municipal Planning and Land Resource Bureau (SMPLRB) (1998, 2007) and the BJMSB (1982-2015; 2016).

## 6. Fitting Cars into Beijing and Shanghai's Urban Fabrics?

The old walking city centres and the transit-oriented linear form of urban development together with dense land use patterns facilitate the development of public transport systems as well as walking and cycling in Beijing and Shanghai. However, especially in the super-dense city centres where there is continuous rebuilding at higher densities, these areas are becoming more and more unsuitable for cars but at the same time are beyond the affordability of most citizens. This is not just an issue in Chinese cities as the revival of the walking and transit city fabric in most developed cities is also associated with major issues surrounding equity (Burton, 2000). The newer urban areas in outlying areas created in the last 20 years to provide more affordable housing, are more automobile dependent but are still nothing like the sprawling suburbs of American and Australian cities. These areas in Chinese cities are well-served now by fast metro

systems as well as having considerably more local services and work; however they are clearly going to have more car use than the traditional areas and will need to find new ways of dealing with this.

Table 2 shows that the central city of both cities is still a really dense urban environment of close to 250 persons per ha (characteristic of walking city fabric). The whole city, together with all its other component parts, is also getting denser despite the “urban sprawl” in outlying areas. The urban density of the whole city is more than 50 persons/ha, which is typical of European transit-oriented regions. The lowest densities are the outer suburbs in Beijing, but even here these are above 25 persons/ha, which is the high end of auto city fabric. These areas do not go down to typical auto city densities of 7 to 20 persons/ha or so but they will still need to continue to minimise such areas if they are to keep reducing their car use.

## **7. What is Beijing and Shanghai to do?**

Beijing and Shanghai are the two most representative cities in China in terms of their political, economic and cultural influences. They both feature Chinese traditional urban fabrics of walking centers with transit linear corridors all with dense, mixed land use patterns that favor public transport and walking and cycling. These areas are also where the major job growth and urban activity is focused and thus private vehicle use has decoupled from wealth and has now peaked in terms of modal split. This paper suggests that this is strongly affected by their walking and transit urban fabrics, which are not built for much car use.

The question then becomes whether the rationale for maintaining these urban fabrics is likely to continue or will Chinese cities succumb to automobile dependence by building automobile city fabric around their cities? There would appear to be a number of strong reasons why this will not happen:

1. The need to preserve agricultural land on the urban fringes is a major consideration for future planning and is strongly stated in the recent Thirteenth Five-Year Plan (2016-2020) (The National Peoples Congress of the People's Republic of China (NPC), 2016a);
2. The need to continue to reduce air quality problems in the big cities will cause more and more pressure on the contribution from vehicle exhausts (NPC, 2014, 2015; Ministry of Environmental Protection of the People's republic of China (MEP), 2015);
3. The need to reduce greenhouse emissions will continue to grow under the Paris Agreement. China has taken a strong stand that it will meet their commitments of 60-65% reduction in carbon dioxide emissions per unit of GDP by 2030 from the 2005 level (NPC, 2016b);
4. The need to maintain a strong global economy; Beijing and Shanghai are the two most global Chinese cities and there is continuing global economic pressure to make cities less car dependent as part of their need to be competitive through walkability (Newman and Kenworthy, 2015);

5. The need to preserve Chinese culture; Chinese culture has continued to embrace high-density living and is not likely to move away from millennia of community culture based on high-density urbanity (Gaubatz, 1999; Lin, 2007).

More than likely the response will be to continue the peak car use trend and enable Chinese cities to become more and more a model for any other emerging cities that are trying to face up to a future with less automobile dominance in their cities.

## Notes

1. It includes large, medium, small and mini-sized passenger cars.
2. Shanghai has adopted the Singapore-style Paid Auction System to limit new car registration since 1994.
3. Beijing and Shanghai are two of the four municipalities directly under the central government. Hence, this comparison is made with other provinces rather than cities.
4. “Others” in Figure 3 indicates shuttle buses.
5. Electric bicycles have replaced bicycles as the dominant non-motorized transport modes in China, which has been well known as “Bicycle Kingdom” in the middle of 1980’s. The actual bicycle use per day in Shanghai has decreased 70 per cent from 2009 to 2014 while there is a sharp increase in actual use of electric bicycles by 68 per cent during the same period (SCCTPI, 2011, 2015).
6. Non-motorized Transport Modes cover bicycle and moped. Public Transport modes include trolley bus and bus, rail transport, taxi and ferry. Private Motorized Modes consist of passenger cars, coaches and motorcycles.
7. The sharp decrease in daily patronage by Trolley Bus and Bus in the year of 1996 is largely due to the cancellation of monthly pass in 1995 and bus system reform in 1996.
8. Peak car use in our publications has always been based on the peak in VKT per capita but another way to measure it is with a peak in car use based on modal split.
9. The actual figure is 65 to 70 minutes per day.
10. Walking cities pre-date modern town planning, but many were planned nonetheless. The Romans always planned their settlements on two principal axes, the *Cardo Maximus* and *Decumanus Maximus*, while historical maps of some Greek settlements, as well as many in Asia, such as Beijing and Kyoto, show they were planned on a rigid grid system of streets (see next section).
11. The outer transit urban fabric is supplemented by feeder buses or BRT (Bus Rapid Transit) with limited stops to the city center. Busways and bus-only lanes on freeways and arterials function in the newer areas of the outer transit urban fabric without a rail system.
12. Bus, which has been the main transport mode in the near areas of small inner transit city since 1950, serves as supplementary to trams or light rail in most big and some intermediate-size cities.
13. Local neighborhoods in Chinese context evolves from quadrangle courtyard (shaped before the establishment of New China), collective compounds (dominated during Planned Economy before 1978 as a part of social welfare) and

- commercial residential buildings with entrance guard (popular in the modern economy). It is now mostly enclosed by walls or fences for privacy, security and property rights.
14. The Doctrine of the Mean is one of the Four Books of Confucianism and also regarded as the highest level of moral code and natural law in China.
  15. This document records the specification and technology of crafts in Ancient China, playing a significant role in urban planning of Chinese cities, especially the capital cities and political cities.
  16. Central City in Beijing covers Dongcheng, Xicheng, Chongwen and Xuanwu. It covers 9 old districts in Puxi (Huangpu, Nanshi, Luwan, Xuhui, Changning, Jingan, Putuo, Zhabei Yangpu) in Shanghai.
  17. Suburb Area in Beijing covers the rest districts except central city and Chaoyang, Fengtai, Shijingshan and Haidian. It covers the rest districts except Central City and Pudong New Area in Shanghai.

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## Published papers

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**Gao, Yuan** (PhD Candidate) (70% Contribution)

*Preparation and completion of the manuscript, establishment of theoretical framework, data collection, preparation of figures and tables, policy analysis.*



*Yuan Gao, PhD Candidate*

**Kenworthy, Jeffrey** (Co-supervisor) (15% Contribution)

*Supervising, revising and editing the manuscript.*



*Professor Jeffrey Kenworthy, Co-supervisor*

**Newman, Peter** (Principle Supervisor) (10% Contribution)

*Supervising, revising and editing the manuscript.*



*Professor Peter Newman, Principle Supervisor*

**Webster, Philip** (Research Assistant) (5% Contribution)

*Revising and editing the manuscript.*



*Philip Webster, Research Assistant*

**The attached Paper is an exact copy of the journal paper cited above**

**Yuan GAO**

**Jeffrey KENWORTHY**

**Peter NEWMAN**

**Philip WEBSTER**

**ANALYSIS OF THE COMPETITIVE CAPACITY  
OF SIX PROVINCES IN CENTRAL CHINA:  
TOWARDS “CENTRAL RISE”**

**INTRODUCTION**

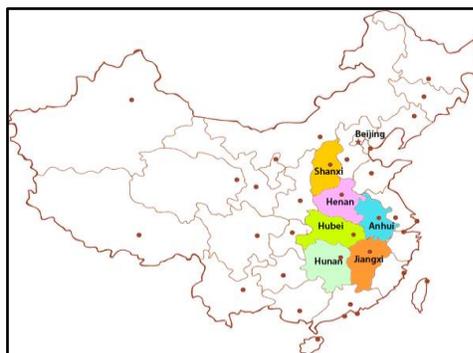
In the process of global economic development, economic globalization is accompanied by regional integration. Regions have gradually become the growth poles and supporting points of wealth creation nationwide. Since the European Economic Community was created in 1958, the European Union and other mature political and economic zones have been formed, which promote coordinated development regionally and internationally. In China, from the ‘Promoting Coordinated Development of Regional Economy’ proposed by the 16<sup>th</sup> National Congress of the Communist Party of China (CPC) in 2002 to the ‘Recommendations for the Eleventh Five-year Plan’ which was issued by the CPC Central Committee and passed in the Fifth Plenary Session of the 16<sup>th</sup> Central Committee in 2005, it is now clearly demonstrated that regions in China have already become the new units for promoting overall national competitiveness.

In the 1980s, strategies for developing the Coastal Regions were adopted and these shifted the national centre of economic development to the south-eastern coastal area. The West Region Development Strategies launched in 1999 have given priority to the western regions to some extent. Since the Revitalization of the Northeast Old Industrial Base, proposed in the 16<sup>th</sup> National Congress of the CPC in 2002, the economic development of north-eastern China has been greatly boosted. However, the economies of landlocked provinces have been in a state of stagnation due to the lack of policy support, namely "Central

Downfall". The previous privileged development strategies broke links between eastern, middle and western areas of China, which has seriously hindered integrated development at the national level. In order to turn the current situation around, central governments have decided to implement the "Central Rise" strategy, which facilitates China's graduated, and coordinated regional development.

In March 2004, the then Prime Minister Jiabao Wen definitively put forward the "Central Rise" idea in the government work report for the first time, and in the same year the "Central Rise" strategy was officially proposed in the Fourth Plenary Session of the 16<sup>th</sup> Central Committee. The midlands area includes Shanxi Province (Jin), Anhui Province (Wan), Jiangxi Province (Gan), Henan Province (Yu), Hubei Province (E), and Hunan Province (Xiang). Taiyuan, Hefei, Nanchang, Zhengzhou, Wuhan and Changsha are their capital cities respectively. The six provinces are located in the hinterland of China, with an area of 1,970,000 square kilometres, occupying 20% of the entire national land area. In addition, this area housed around 28.1% of national population and contributed approximately 19% to the national GDP (Gross Domestic Product) in 2004. As the base of grain production and raw materials supply in China, these provinces have rich mineral resources, convenient transportation links which extend in all directions nationwide, and they contain profound cultural heritages. The spatial differentiation of provincial resources and the complementarity of interior industrial structure are fundamental to the coordinated development among these six provinces.

**Figure 1: Map of Six Provinces in central China**



Source: Own Graphic

Research pertaining to the competitiveness of these six provinces in central China has been conducted from different perspectives, including overall competitiveness (Zhong, Peng and Peng, 2003) provincial competitiveness (Li, Li and Gao, 2007), capital city competitiveness (Yang and Fang, 2007; Ni, 2006) and competitiveness of urban agglomerations (Zhu and Tong, 2010). The existing research outcomes undoubtedly examine the development situation of central China to some degree. However, analyses concerning variations in competitiveness since the implementation of the “Central Rise” strategy at provincial and urban levels, will provide a more comprehensive and dynamic understanding.

### **DEFINITION OF COMPETITIVENESS**

Since Adam Smith introduced the competitive principles into economics, related theories have become the interest of research both nationally and internationally. However, the focus is basically on national competitiveness, macroscopically (Lodge and Vogel, 1987; Hämäläinen, 2003; Snieška and Drakšaitė, 2007) and urban competitiveness, microscopically (Kresel and Singh, 1995; Webster and Muller, 2000; Begg, 2002; Buck et al., 2005). There is not enough attention paid to provincial or regional competitiveness, which is now a major contributor to competitive capacity both at national and urban levels in many countries.

National competitiveness is defined as the ability to create national wealth based on the incorporation of inherent resources with acquired production activities, while at the same time considering the capacity of that country to consistently increase its economic growth rate and improve its living quality (Dong-Sung and Hwuy-Chang, 2005). Since 1989, joint efforts by the IMD and WEF have been made to enrich and develop notions, indicators and approaches to national competitiveness. *The Global Competitiveness Report* (Lopez-claros, 2005), which was issued by the IMD and WEF in 1994, restated that nationwide competitiveness refers to the ability of a country to produce more prosperity in comparison with rivals in the global market (Ge, Liu and Fu, 1995).

Michael E. Porter, an American economist, put forward the Competitive Advantage Theory based on systematic research outcomes, which include *Competitive Strategy* (Porter, 1980), *The Competitive Advantage* (Porter, 1985) and *The Competitive Advantage of Nations* (Porter, 1998). These studies are generally conducted from the national perspective. However, Porter claimed that results relating to national competitive advantage could also be applied into sub-areas, namely regions and cities, which are more appropriate units. Webster and Muller (2000) defined urban competitiveness as the competence of urban regions to yield superior goods and services to other cities.

When it comes to provincial competitiveness, nationally-documented research is now available in China (Xu, 2007). Ni (2006) has determined that provincial competitiveness in China is commonly recognised as the integrated ability of cities within a province (refers to the special spatial and economic region being assessed), to bring about economic growth, social development and human well-being enhancement. The extent of provincial competitiveness is affected by provincial political, economic, social and other driving factors (Li, 2011).

## **ESTABLISHMENT OF INDICATORS AND ASSESSMENT**

### **Establishing the System of Indicators**

Indicators do not only contain components or processes to reflect the status of systems, but also provide feedbacks to various target groups for decision-making (Huang, Wong and Chen, 1998). The proposed system of indices in this paper, which are derived from previous outcomes and distinct features in China, includes twenty-eight indicators to assess the status of development in different provinces and different periods (Table 1).

**Table 1: System of Indicators for Assessing Regional Competitiveness**

$X_1$	Gross Regional Product (100 million Yuan)
$X_2$	Growth Rate of Gross Regional Product (%)
$X_3$	Gross Regional Product per capita (Yuan)

X <sub>4</sub>	Income per capita (Yuan)
X <sub>5</sub>	Fiscal Revenue (10,000 Yuan)
X <sub>6</sub>	Household Savings Deposit (100 million Yuan)
X <sub>7</sub>	Total Investment in Social Fixed Assets (10,000 Yuan)
X <sub>8</sub>	Total Investment of Foreign Funded Enterprises (100 million USD)
X <sub>9</sub>	Total Value of Imports and Exports (10,000 USD)
X <sub>10</sub>	Transition Value in Technical Market (10,000 Yuan)
X <sub>11</sub>	Proportion of Gross Regional Product by Secondary Industry (%)
X <sub>12</sub>	Proportion of Gross Regional Product by Tertiary Industry (%)
X <sub>13</sub>	Proportion of Employed Persons by Secondary Industry (%)
X <sub>14</sub>	Proportion of Employed Persons by Tertiary Industry (%)
X <sub>15</sub>	Employment Rate (%)
X <sub>16</sub>	Number of Theatres
X <sub>17</sub>	Number of Licensed (Assistant) Doctors in Health Care Institutions per 1,000 Persons (Person)
X <sub>18</sub>	Number of Undergraduate Enrolments (Person)
X <sub>19</sub>	Number of Books in Public Library per 100 persons
X <sub>20</sub>	Popularization Rate of Mobile Phones (sets/100 persons)
X <sub>21</sub>	Number of Public Transport Vehicles under Operation (unit)
X <sub>22</sub>	Area of Paved Roads per capita (m <sup>2</sup> )
X <sub>23</sub>	Percentage of Greenery Coverage in Built-up Area (%)
X <sub>24</sub>	Output Value of Products Made from Utilization of Waste Gas, Water and Solid Wastes (10,000 Yuan)
X <sub>25</sub>	Percentage of Industrial Effluents Emissions in Line with Standard (%)
X <sub>26</sub>	Percentage of Industrial SO <sub>2</sub> Emissions in Line with Standard (%)
X <sub>27</sub>	Treatment Rate of Consumption Wastes (%)
X <sub>28</sub>	Percentage of Disposed Domestic Sewage (%)

**Source:** China Statistical Yearbook (NBS 2005, 2011)  
China City Statistical Yearbook (Wang and Chen 2005; Chen 2011)

## Evaluating Method

Data for the established indicators was collected from the *China Statistical Yearbook* (NBS 2005, 2011), *China City Statistical Yearbook* (Wang and Chen, 2005; Chen, 2011). and other published documents or websites. Then the correlation matrix, which is calculated through the statistics application

SPSS17.0, reflects the obvious relevance among selected indicators, namely they need to be simplified and sorted because of the multi-collinearity. KMO and Bartlett's Test of Sphericity was also carried out to test the feasibility of the Factor Analysis (FA), which is employed here to assess provincial competitiveness.

These indicators are made dimensionless based on their Z-Score. On the basis of Principal Component Analysis (PCA), three common factors are extracted whose cumulative contributions to variance are more than 85%. According to the factor loading matrix, indicators are categorized into three types, namely economic performance, social performance and environmental performance (Table 2).

**Table 2: Analysis of Common Factors**

<b>Common Factors</b>	<b>Explained Indicators</b>
F <sub>1</sub> (Economic Performance)	X <sub>1</sub> , X <sub>2</sub> , X <sub>3</sub> , X <sub>5</sub> , X <sub>6</sub> , X <sub>7</sub> , X <sub>8</sub> , X <sub>9</sub> , X <sub>11</sub> , X <sub>12</sub>
F <sub>2</sub> (Social Performance)	X <sub>4</sub> , X <sub>10</sub> , X <sub>13</sub> , X <sub>14</sub> , X <sub>15</sub> , X <sub>16</sub> , X <sub>17</sub> , X <sub>18</sub> , X <sub>19</sub> , X <sub>20</sub> , X <sub>22</sub>
F <sub>3</sub> (Environmental Performance)	X <sub>21</sub> , X <sub>23</sub> , X <sub>24</sub> , X <sub>25</sub> , X <sub>26</sub> , X <sub>27</sub> , X <sub>28</sub>

**Source:** Own Indicator Groups

In terms of economic performance, the indicators of Gross Regional Product, Fiscal Revenue, Total Investment in Social Fixed Assets, Household Savings Deposit, Total Investment of Foreign Funded Enterprises and Total Value of Imports and Exports, are included in the category of “economic scale” for demonstrating the size of the economy locally, nationally and internationally. The proportions of Gross Regional Product by Secondary and Tertiary Industry are chosen to indicate the degree of optimization of the industrial structure. Growth rate of Gross Regional Product and Gross Regional Product per capita show the comparative efficiency of the local economy.

The dimension of social performance consists of eleven indicators which represent the living quality of urban residents (Income per capita), employment structure (Employment Rate, Proportion of Employed Persons by Secondary Industry and Tertiary Industry), health care condition (Number of Licensed/Assistant Doctors in Health Care Institutions per 1,000 Persons), scientific and technology education (Number of Undergraduate Enrolments and

Transition Value in Technical Market), communication facilities (Popularization Rate of Mobile Phones), infrastructure (Area of Paved Roads per capita) and public recreation (Number of Theatres; Number of Books in Public Library per 100 persons).

As to environmental performance, which is not only the prerequisite for external investment and internal living quality (Xu, 2007), but also the basic support for the sustainable development of economy and society, there are seven indicators for denoting the greenery coverage, public transport, and the treatment and utilization of industrial and domestic wastes.

The total value for each province is calculated according to the formula:

$$F=W_1F_1+W_2F_2+\dots+W_mF_m$$

Where:

$W_i$  represents the weight of each principal component; and

$F_i$  represents principal component.

A negative value implies that the competitiveness of the targeted province is below the average.

Factor Analysis (FA) is carried out for the dataset of the six provinces of central China shown in Figure 1 for the years 2004 and 2010. After that, the changes of total competitiveness and the three key dimensions of Economic Performance, Social Performance and Environmental Performance in the provinces are explored. Finally, the evaluating method is repeated for the capital cities of each province in 2004 and 2010 in order to help show the contributions of these capital cities to the competitiveness of each of the provinces.

## QUANTITATIVE AND QUALITATIVE ANALYSIS

The SPSS17.0 (Factor Analysis Method) is utilized for data processing to quantitatively calculate the provincial and urban competitiveness for the years 2004 and 2010. The paper then explores the critical issue of the variations in competitiveness at a provincial level (Table 3) and an urban level (Table 4) since the “Central Rise” strategy was implemented.

**Table 3: Provincial Competitiveness of the Six Provinces in central China in 2004 and 2010**

Province	Provincial Competitiveness		Economic Performance		Social Performance		Environmental Performance	
	2004	2010	2004	2010	2004	2010	2004	2010
<b>Shanxi</b>	-0.69	0.01	0.03	-0.73	-0.8	0.44	-1.13	-0.6
<b>Anhui</b>	-0.23	-0.14	-0.31	-0.17	-0.26	-0.34	0.09	-0.46
<b>Jiangxi</b>	-0.5	-0.88	-0.64	-0.67	-0.51	-0.4	0.37	0.59
<b>Henan</b>	0.77	0.21	1.21	0.59	0.5	-0.09	0.43	-0.46
<b>Hubei</b>	0.52	0.68	0.09	0.69	0.14	0.86	0.55	0.17
<b>Hunan</b>	0.12	0.12*	-0.37	0.28	0.93	-0.46	-0.32	0.77

Note: The exact competitiveness of Hunan in 2004 and 2010 is 0.11673 and 0.12048.

Source: Own Data Compiled Using SPSS17.0

**Table 4: Urban Competitiveness of the Capital Cities of the Six Provinces in central China in 2004 and 2010**

Capital	Urban Competitiveness		Economic Performance		Social Performance		Environmental Performance	
	2004	2010	2004	2010	2004	2010	2004	2010
<b>Taiyuan</b>	-0.36	-0.12	-0.29	-0.21	-0.38	-0.21	0.11	-0.41
<b>Hefei</b>	-0.65	-0.28	-1.05	-0.32	-0.5	-0.35	0.67	0.13
<b>Nanchang</b>	-0.47	-0.62	-0.52	-0.71	-0.54	-0.63	0.3	0.67
<b>Zhengzhou</b>	-0.14	-0.26	0.78	-0.03	-0.11	-0.18	-0.12	-0.92
<b>Wuhan</b>	1.28	1.16	1.29	1.2	1.21	1.26	-1.27	-0.08
<b>Changsha</b>	0.34	0.12	-0.21	0.07	0.32	0.12	0.31	0.62

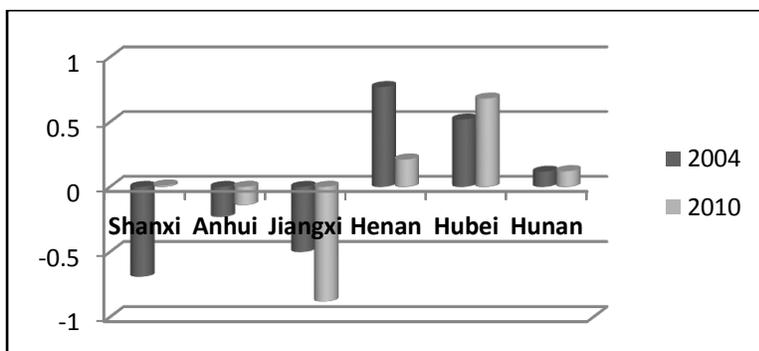
Source: Own Data Compiled Using SPSS17.0

### ANALYSIS AT THE PROVINCIAL LEVEL

At the provincial level, it is clearly shown in Table 3 that there are remarkable improvements in overall provincial competitiveness in Shanxi (101%), Anhui (39%), Hubei (31%) and Hunan (3.2%), while the provincial competitiveness has reduced by 66% and 73% in Jiangxi and Henan respectively. It appears therefore that the dominant effect of the “Central Rise” strategy and related

polices in these six provinces is positive. Four out of the six provinces have improved their competitive strength in the span of six years. However, the extent of progress made in the four improved provinces is considerably different, while of course two provinces appear to have gone backwards under the same central government strategy. Fundamental reasons for these varied developments in the six provinces, all subject to the same strategic support, are now explored from economic, social and environmental perspectives.

**Figure 2:** Provincial Competitiveness in 2004 and 2010



**Source:** Own Graphic Using Excel and Table 3 Data

### **Analysis of Economic Performance**

There is an identical trend between total competitiveness and economic performance in Anhui, Jiangxi, Henan, Hubei and Hunan (both indices move in the same direction, either up or down) whereas the reverse is true in Shanxi where overall competitiveness has risen but economic performance has declined significantly. In fact, half the provinces have performed negatively in economy from the year 2004 to 2010, but most striking, is the more than 25 times reduction in economic wellbeing in Shanxi, despite an overall rise in provincial competitiveness, based on very much improved social and environmental performance. In Shanxi the absolute values of the economic scale variables have mostly remained at the same comparative ranking among the six provinces during the selected six years, while the indicator “Household Savings Deposit” has even moved up one place to third in 2010. In the meantime, however, all the indicators reflecting economic structure and effi-

ciency in Shanxi have reduced to some extent. The ranking of “Growth Rate of Gross Regional Product” in particular has plummeted from the top position to fifth amongst the six provinces. The findings can also be applied within the other provinces, which are not only improved but also diminished in economic performance.

When the indicator “Growth Rate of Gross Regional Products” is extracted to examine the relationship with economic performance, it can be concluded that there is a marked positive correlation between the trend of gross regional products and the changed economic enhancement. Notably, the degree of optimal industrial structure has played an accelerated role in developing this tendency. The higher the proportion of tertiary industry within the gross regional product, the more progress in the economy that has been made than in other provinces in which there are similar improvements in overall provincial competitiveness. The indicator “Growth Rate of Gross Regional Products” is easily accessible, however, excessive attention is paid in China to improving and maintaining a high growth rate for this factor and this, it is claimed, has led to “GDPism” in China (Mou, 2009). In other words, local governments are overly concerned about economic quantity rather than its quality. They have become aficionados of blind investment in some industries, which can promote a surge in the local economy, but this is on the back of heavy environmental and social costs (e.g. the “Three High Industries”: High Polluting, High Energy-wasting and High Emissions).

### **Analysis of Social Performance**

Half the provinces in central China have obtained benefits in social performance, although to different extents. About five times greater improvement have been acquired in Hubei, followed by Shanxi (155%) and Jiangxi (22%), while the ability to make residential life more convenient and varied has been weakened in Henan, Hunan and Anhui. Undoubtedly, personal income, as the simplest indicator for demonstrating the life quality of residents, has increased markedly in absolute values in each province (around four times). However, there are some noticeable variations in provincial ranking as well, particularly in Anhui, which has surged from the lowest to the highest during six years.

Taking Shanxi as an example, although the economy has dropped at an amazing rate, its total competitiveness has doubled, to which its improved social performance has contributed greatly. What therefore are the driving forces in boosting the community? Based on comparing the 2004 and 2010 data of all social indicators, it is found that the structure of employment, information and public services (recreation and medical care) have outweighed the others indicators of social performance. Significantly, the proportion of employment in tertiary industry affects social progress more than the ratio of the workforce in secondary industry. This finding was also present in the case of Henan, which has always been the leader in central China, but now Hubei has become the new leader under the national strategy. Likewise, the amount of transition value in the technical market, which signifies the provincial ability to apply research findings into industrial production, also significantly accelerates social progress.

### **Analysis of Environmental Performance**

Environmental performance in Hunan has been improved so that it now ranks first compared to fifth in 2004, followed by Jiangxi and Hubei, which has dropped from the first position in the year of 2004. Henan and Anhui, which have even fallen below the regional average in 2010, experienced a drastic decline in environmental performance. Although there is around a 47% increase in environmental performance in Shanxi, it has remained last on this factor both in 2004 and 2010. When examining the individual indicators of environmental performance, it is found that the level of public transport (reflected by the number of public transport vehicles) and utilization of the main three wastes (waste gas, wastewater and solid waste) greatly determines the degree of environmental improvements.

The important effect of public transport on the environment has gradually been recognized since the 1960s. Ieda (2010) argues that private vehicles should be subordinate to mass transit in future urban transport planning. Transit-oriented development (TOD) not only helps to create urban wealth, but it also reduces environmental vulnerability due to acute car dependence (Newman, 2012). Among the six provinces in the middle part of China, the

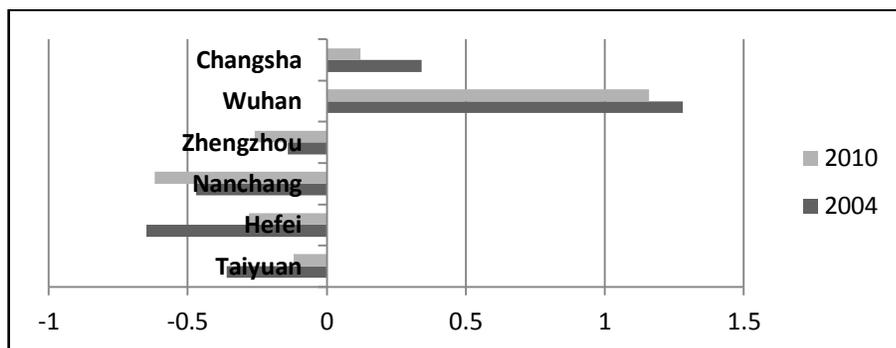
number of public transport vehicles in Hunan is nearly twice as many as it is in Shanxi, which is the area with the worst SO<sub>2</sub> pollution (MA, 2013). Consequently, building good public transport systems is a promising solution to alleviate SO<sub>2</sub> emissions and environmental pollution based on reducing automobile dependence (Newman, Beatley and Boyer, 2009).

It is found that there is no significant difference between the provinces in greenery coverage and household and industrial refuse disposal, which have all been at a relatively high level of development in urban China (China Green Development Forum, 2010). However, there is a dramatic gap in the extent of utilization of the three waste streams throughout China. This can also be verified among these six central provinces. In 2004, the value of products that are made from wastes in Hubei, which ranked as the top, was far ahead of Hunan. However, the situation changed tremendously six years later. Hunan, which has placed emphasis on the development of the Recycling Economy (RE), has obtained an encouraging return. It is ranked the best province for the amount of output from the recycled use of wastes, and even doubles the recycled use output of Shanxi.

### ANALYSIS AT THE URBAN LEVEL

Figure 3 presents the results of the trend in urban competitiveness in the six provinces.

**Figure 3: Urban Competitiveness in 2004 and 2010**



Source: Own Graphic Using Excel and Table 4 Data

The competitiveness of Changsha and Wuhan, which have overridden the other four capital cities both in 2004 and 2010, both still remain above average, although they have experienced drops of 65% and 9% respectively. The findings in Table 4, are worthy of further inspection. Among the capital cities in which there are inferior competitive capacities in the year 2004, Zhengzhou has an overall decline, both in total and in the three individual dimensions, with the largest declines occurring in overall urban competitiveness and environmental performance. Furthermore, Taiyuan and Hefei are the only two cities where there are 67% and 57% advances in the entire competitiveness. However, they are also the only two cities that have declined in environmental performance, besides Zhengzhou, suggesting that this rise in overall competitiveness has been to some extent at the expense of the environment.

## CONCLUSIONS

The period between 2004 and 2010 has seen the national competitiveness of China increase dramatically in world rankings, from 46<sup>th</sup> in 2004 up to 27<sup>th</sup> in 2010 (Lopez-claros, 2005; Sala-i-Martin et al., 2010). China, which has been the second largest economy after the United States since 2010 (Wang and Zhang, 2011), has experienced tremendous economic growth, social progress and environmental improvement. However, imbalanced development among different regions in China is, to some degree, an obstacle for integrated development nationwide. The “Central Rise” strategy undoubtedly has contributed to alleviating the gap between central regions and other parts of China. Six provinces in central China, which had all edged themselves into the “Trillionaire Club<sup>1</sup>” by 2011, have a higher growth rate in Gross Regional Product than the national average. Additionally, the State Council has issued a series of supportive policies, which include *Several Opinions on Promotion to Central Rise Strategy* (Gazette of the State Council of the People’s Republic of China, 2006) and *Several Opinions on Vigorously Enforcing the Promotion to Central Rise Strategy* (Gazette of the State Council of the People’s Republic of China, 2012), for the purpose of stabilizing present achievements and acceler-

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<sup>1</sup> This refers to the provinces in China (except Hong Kong, Macao and Taiwan) where the Gross Domestic Product has reached or exceeded one trillion Chinese dollars.

ating future growth.

This paper has appraised the competitive capacity of these six provinces at both provincial and urban levels from economic, social and environmental perspectives. It has quantitatively examined provinces and their capitals, which have enhanced their competitive edge under the “Central Rise” Strategy, as well as others, which have not. Qualitative analysis of the incentives and barriers to different changes among the six provinces has also been conducted. Conclusions from the findings of the study and for promoting integrated development of these central regions can thus be drawn as follows.

Hubei has become the new leader of central China by replacing Henan in terms of overall competitiveness. There is a total decline in economic, social and environmental performance in Henan and the competitive capacity of society and environment has even deteriorated beneath the regional average. However, progress in the dimensions of economy and society in Hubei has been made at the expense of the environment.

It is clear that the array of adopted policies under the “Central Rise” strategy have boosted development in central regions to some degree. However, it also seems apparent that supportive measures tailored to each province are required to formulate and enforce this trend. In the meantime, the ascendancy of Hubei in competitiveness within central China should be brought into full play in producing a new paradigm about the rational utilization of policies and also in promoting cooperation with other neighbouring provinces.

The findings of this paper also show that the growth rate of Gross Regional Product has played a determining role in measuring the provincial potential for economic growth in the short run. In order to avoid the negative consequences resulting from recklessly expanded local economies, the long-term strategy is to achieve an optimized and upgraded industrial structure. Accordingly, cooperation between industries and institutes should be strengthened for improving the local capacity for independent innovation, which is essential to High-tech industries. Compared with traditional pollution, High-Tech Pollution, which refers to the new kind of environmental damages from High-tech industry, should be solved based on the vigorous development of a Recycling Economy.

Transport is regarded as one of the vital components for enhancing environmental competitiveness. Transit-Oriented Development (TOD) is a universally accepted approach to alleviate and repair automobile-dependent cities in the coming uncertain future. The daily demand for trips in the central part of China, which is the most populous region, is huge. TOD should be based on the preferential development of rail transit, which can best meet maximum public demand for mobility, but with minimal environmental cost. Besides improving mass transit systems inside cities, the six provinces should develop intercity and interprovincial bus systems, which can provide higher transport capacity and more convenient and punctual transport services between different cities and provinces.

Importance should also be attached to strengthening the competitive capacity of provincial capitals, which have a major role in provincial competitiveness. For instance, Wuhan has always stayed on the peak, while Zhengzhou has dropped to below the regional average. The trend of changes in provincial competitiveness is consistent with that of capital competitiveness. Provincial capitals with more political, economic and cultural advantages also have an exemplary and guiding effect for other cities throughout the various provinces.

Most significantly from this analysis, coordinated development in a regional context needs to be taken into consideration so as to avoid duplication, which easily results in excess capacity in certain fields and virulent and unnecessary competition. The strong similarity of geographical conditions, natural resources and industrial structure in central China has caused repetitive manufacturing. The Central Plains Economic Region (CPER), which has been approved by the State Council in 2012, covers Henan, Shanxi, Anhui and other provinces. Another new strategy which contains Hubei, Hunan and Shanxi was put forward by Hubei afterwards in 2012. They aim to achieve a win-win situation instead of zero-sum game through integrated development regionally and even nationally. This is an important subject facing the six provinces in the central part of China.

Promoting the midlands region is not only an issue for the development of the central provinces themselves, but also critical for the enhancement of national competitiveness. Only if these six provinces of central China can become the

solid junction of the East and the West parts of China, can an overall equilibrium and integrated structure be achieved, which will help China realise the strategic goal of national modernization.

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**Yuan Gao** - Curtin University Sustainability Policy Institute, Australia

**e-mail:** yuan.gao7@student.curtin.edu.au

**Dr. Jeffrey Kenworthy** – Professor, Curtin University Sustainability Policy Institute, Australia

**Dr. Peter Newman** – Professor, Curtin University Sustainability Policy Institute, Australia

**Philip Webster** - Curtin University Sustainability Policy Institute, Australia

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