

Future Perspective of Electric Bicycles in Sustainable Mobility in China

by

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“Before we can even ask how things might go wrong, we must first explain how they could ever go right.” – F. A. Hayek

Abstract

The thesis seeks to analyse the electric bicycle (e-bike) transition phenomenon in China by applying the Multi-Level Perspective (MLP) Transition Theory and Multi-scalar Perspective MLP. The research is performed with abductive case studies drawn from mixed methods. Firstly, we synthesised secondary data to investigate the e-bike transition at the national level (China) and the city level (“mini” case studies of Beijing and Fuzhou) to explore the research questions of 1) Can socio-technical transition occur without deliberate policy support (RQ1)? 2) How can we explain the rapid emergence and enduring popularity of e-bikes in China (RQ2)? Then we performed exploratory research in Cardiff, UK and Nanjing, China using semi-structured interviews. The interview results are used to help design survey questionnaire in Nanjing case study. It is the key research step and addresses the following research questions: 1) How are e-bikes embedded in the current transport regime (RQ3)? 2) How much longer can e-bikes continue to be embedded in the transport regime (RQ4)? 3) What are the mechanisms underlying the rapid emergence of e-bikes (RQ5)? To analyse the data collected from the survey, Generalised Linear Models and Binomial Generalised Linear Models are adopted to investigate current mode choice behaviour and predict future choice.

In the theoretical aspect, the thesis applied the Multi-scalar Perspective MLP, filling the gap that traditional MLP does not take into account geographical, socio-political heterogeneity. In addition, we paid attention to the individual role in travel mode behaviour. From a practical perspective, the thesis uses substantial empirical data to provide a comprehensive understanding of the e-bike transition. We invited various groups in the survey, including e-bike users, bicycle users, car drivers, pedestrians and traffic police. The thesis explores a wide range of influencing factors, such as user anxiety, feelings related to e-bike adoption, e-bike user charging behaviour, other travel mode users and traffic police attitude towards e-bike development which have not been studied in previous e-bike literatures.

The main findings are: 1) The fast emergence of e-bikes in China is spontaneous, without direct policy support from governments; 2) E-bike transition in China begins with transformation pathway (P1), followed by de-alignment and re-alignment pathway (P2); 3) E-bike users in China are mainly young career-aged commuters and have a much higher education level than average, which are different from other countries; 4) E-bikes are well embedded in the current transport regime and they are adopted widely in many aspects of people’s daily lives, including commuting, going shopping, and collecting children; 5) The underlying reasons for the selection of e-bikes are they provide affordable personal mobility due to the advantages of effort saving, flexible trip times, time saving in traffic jams, and high accessibility, whereas environmental and health factors are negligible; 6) E-bikes are possibly an intermediate mode on Nanjing’s motorisation pathway.

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Publications

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List of Acronyms & Abbreviations

AIC	–	Aikake’s Information Criterion
ASA	–	American Sociological Association
BEVs	–	Battery Electric Vehicles
CNIBEE	–	China North International Bicycle & E-bike Exhibit
CO ₂	–	Carbon dioxide
CPPCC	–	The National Committee of the Chinese People’s Political Consultative Conference
DDC	–	Dian Dong Che net
DF	–	Degree of Freedom
E-bike	–	Electric bicycle
EVs	–	Electric Vehicles
FCVs	–	Fuel Cell Vehicles
GLM	–	Generalised Linear Model
JPPCSC	–	Jiangsu Provincial People’s Congress Standing Committee
JPPC	–	Jiangsu Provincial People’s Congress
MIIT	–	Ministry of Industry and Information Technology of The People’s Republic of China
MLP	–	Multi-Level Perspective
NCSC	–	Nanjing Municipal People’s Congress Standing Committee
NGOs	–	Non-government Organisations
NMP	–	Nanjing Mainland Pigeon Tech Co., LTD.
NPC	–	The National People’s Congress of the People’s Republic of China
PM2.5	–	Particle Pollution 2.5
QQDCW	–	QuanQiuDianChiWang
TIS	–	Technological Innovation System

TM	–	Transition Management
SBQTS	–	The State Bureau of Quality and Technical Supervision
SNM	–	Strategic Niche Management
SO ₂	–	Sulfur dioxide
State Council	–	The State Council of the People’s Republic of China

Chapter 1

Introduction

1.1 Electric bicycles in China

With its fast development and growing population, China is confronted by a severe energy crisis and environment pollution, and these negative effects will also propagate to other countries due to China's role in global economics. Hence, it would be a great contribution to the global sustainability if China could achieve sustainable development. To reach this goal, a sustainable form of transport is especially important, for the reason that the traffic sector is central to the manufacturing industry and closely related to people's social practices. Traditional methods of mobility depend on fuel to a great extent, which leads to a large consumption of energy and is hazardous to the environment.

A promising alternative to fuel-based transport is the electric bicycle (e-bike), which has developed rapidly in China in recent years and exhibited huge potential for its energy-saving and environmentally friendly features. However, e-bikes have not drawn sufficient attention from academics and the government as they deserve. It is urgent to understand why and how the e-bike industry has developed in China in order to further boost its development.

1.2 Research approach and research questions

This research follows an abductive case study approach to explore the e-bike transition process in different dimensions. The Multi-Level Perspective (MLP) theory

serves as a framework for analysing the socio-technical transition of e-bikes in China. In addition, Multi-scalar approach is used as a specific tool to explore the e-bike transition process in the context of China with a complex geographic and political structure. This research is guided by five main research questions (RQ):

RQ1. Can socio-technical transition occur without deliberate policy support?

A number of previous transition studies claimed that direct policy support is essential in promoting, nurturing and accelerating sustainable technologies, sustainable production systems, and sustainable consumption (Geels and Schot, 2007; Smith *et al.*, 2010; Foxon *et al.*, 2010). However, from the e-bike literature, the e-bike emergence in China seems to occur largely without state support, which is rather different to the majority of the existing transition studies. Therefore, this research attempts to address the question of whether socio-technical transition can occur without deliberate policy support by using e-bike transition in China as an example.

RQ2. How can we explain the rapid emergence and enduring popularity of electric bicycles in China?

RQ2 is intended to provide an insight to the e-bike transition process. The transition theory is used for analysis because it is an ideal theoretical tool for explaining socio-technical transition. Especially, we adopted the transition pathway framework by tracking the e-bike transition process with historical analysis. In this sense, it aims to understand how e-bikes are developed from the niches level, the role policy played on e-bike transition, which transition pathways e-bikes followed, when e-bikes started to develop rapidly, and how e-bike coped with the landscape change and regime re-construction.

RQ3. How are e-bikes embedded in the current transport regime?

In the existing transition study literature, there are few discussions on how incremental innovations are embedded in the current regime and how they interact with other sectors on a regime level. In our case, RQ3 is intended to explore how e-bikes are embedded in the current regime, and how e-bikes re-align with other regime sectors. Specifically, we need to know: 1) How e-bikes co-exist and interact with other transport modes, such as private cars, bicycles, buses, the metro and taxis, on a regime level; 2) How e-bikes re-align with the movement of the seven components in the regime, including industry, policy, science, culture, technology, market, and user practice. In order to answer these question, e-bike users, non-e-bike users and traffic police are surveyed, investigating the attitudes towards e-bike transition, the positive and negative impact of e-bike development on the transport regime, and how e-bikes users interact with other e-bike users, non-e-bike users, and traffic police.

RQ4. How much longer can e-bikes continue to be embedded in the transport regime?

The future development of e-bikes faces two challenges: 1) the competition with other travel modes; 2) the possibility of e-bike ban policies in a large number of cities. We need to know how e-bikes can find a way to survive in the future transport regime, or which alternative transport modes will otherwise replace e-bikes. Specifically, we focus on the following questions: 1) What factors influence the future choice of e-bike use? 2) What alternative travel modes will be available and what factors influence the corresponding choices? 3) Are e-bikes a future sustainable mobility or only an intermediate mode to cars?

To answer these research questions, e-bike users are asked which alternative transport mode they would choose in the absence of e-bikes, under which conditions would they stop using them, how much longer they intend to keep using e-bikes, and suggestions on future e-bike development in terms of technology, infrastructure, business models, and policy.

RQ5. What are the mechanisms underlying the rapid emergence of e-bikes?

In the absence of direct policy support, individual behaviours play a crucial role in determining or altering transport mode. It is unclear why users select e-bikes from a variety of transport modes, how e-bikes fit into their life settings, and to what extent e-bikes satisfy their personal mobility needs. The answers of these questions constitute the mechanisms underlying the rapid emergence of e-bikes. However, the individual behaviours are neglected by traditional transition theory in transport studies and therefore our thesis seeks to fill this gap. In doing so, e-bike users were asked who they are (demographic information), where they are from (previously used mode), the trip purpose for using e-bikes, the reasons for selecting e-bikes, their favourite e-bike types, where they charge e-bike batteries, the feelings associated with e-bike adoption, the use anxiety when using e-bikes, and the drawbacks of e-bikes.

1.3 Research Scope

This research used a mixed method approach by combining qualitative and quantitative methods. The data collection methods included secondary data, semi-structured interviews, and survey questionnaires.

To answer RQ1 and RQ2, the case studies of China (national level) and Beijing and Fuzhou (at city level) were performed, based on the secondary data. The secondary data included a wide range of sources from previously published research, such as statistics data from government-published year books, publicly available policy documents, published journal papers, conference papers, published books, social media, e-bike user forum, and online sources.

To address RQ3, RQ4, and RQ5, we performed Exploratory Research in Cardiff, UK

and Nanjing, China and more importantly, conducted surveys in Nanjing. The Exploratory Research adopted semi-structured interviews and the interview results were used to shape the questionnaire design of the survey in Nanjing. The semi-structured interviewees were e-bike users, non-e-bike users and e-bike retailers. The survey questionnaire participants were e-bike users, bicycle users, car drivers, pedestrians, and traffic police. The collected data from the survey were analysed using statistics models.

1.4 Thesis structure

Chapter 1 (Introduction) introduces the research questions and gives a brief introduction to the research approach employed in this work.

Chapter 2 (Literature review of transition theory) introduces four socio-technical transition theory strands, including Transition Management, Strategic Niche Management, Technological Innovation Systems, and the Multi-Level Perspective (MLP). Then, the reason why the MLP is chosen as the theoretical base of the study is justified and the concept of the MLP is discussed in detail. After that, the literature of transition pathways and the MLP in transport study is reviewed. We identify two main research gaps in the MLP theory: 1) the MLP lacks a capability of considering the system with complicated geographical and socio-political structures; 2) the MLP applied into the sustainable mobility transition field only focuses on the institutional and organisational transition and interactions, ignoring the effect of individual and institutional-individual behaviour. The first problem can be solved by applying the Multi-scalar MLP to e-bike transition in China. To fill the second research gap, we reviewed the literature on individual behaviour and incorporated the corresponding questions in the survey to investigate the travel mode choices.

Chapter 3 (Literature review of e-bike research) reviews the previous literature

studying electric bicycles.

The e-bike literature in social science is limited compared with its research in the engineering area. We compared the literature of e-bike research in China and that in other countries, identifying the distinct properties of e-bike development and the characteristics of e-bike users in China.

The existing e-bike literature has several limitations: 1) Most of the survey questionnaire studies demonstrate self-selection bias; 2) Information is limited about the interaction between e-bike users and other vehicle users; 3) The e-bike user charging behaviour is not clear; 4) Transition theory were not applied.

Chapter 4 (Research design) describes a research design based on a single embedded case study that was built on a mixed methods approach informed by the MLP and Multi-scalar MLP perspectives.

We firstly explain and justify why we choose critical realism as our philosophy standpoint, and explore the relationship between critical realism and the MLP.

Secondly, we explain that the design of the research is an abductive, single embedded case study. The rationale for selecting a mixed method approach is also verified. A detailed research plan is provided and the research data collection methods vary according to different research questions.

Then we explain and justify the rationale for three data collection methods: secondary data, semi-structured interviews, and survey questionnaires. The detailed sample selection method, question design and data analysis methods are provided. In addition, the quality criteria of this research design, and also the ethical considerations of the research design, are given.

Chapter 5 (An overview of e-bike industry and transition in China) describes the main e-bike industry regions, the policy structure of China, the current e-bike policies issued in the different cities and areas of China. More importantly, it explains the e-bike transition process in China using transition theory to answers RQ1 and RQ2.

We analysed the reasons for the formation of current e-bike industry cluster region distribution. To explain how the e-bike policy is made and excised, the policy structure of China is introduced. According to the heterogeneous spatial dimension and hierarchical political structure of China, it is divided into three scalars or levels from the Multi-scalar perspective.

The Multi-scalar MLP is applied in an institutional setting with the specific case of China. Then, it is used to explore the transition pathways occurring in macro-level (the entire China) and micro-level (Beijing city and Fuzhou city) based on secondary data.

Chapter 6 (A case study of electric bicycles in Nanjing: sustainable transport consumption behaviour and socio-technical transition part 1) studies the results of survey questionnaires conducted in Nanjing City, including the demographics of e-bike users, e-bike mode choice behaviours, attitudes to e-bike adoption, consumption behaviours, battery use patterns, and interaction with non-e-bike users. The analysis of the survey results answers RQ3 and RQ5.

Chapter 7 (A case study of electric bicycles in Nanjing: sustainable transport consumption behaviour and socio-technical transition part 2) investigates the future mode choice behaviour of e-bike users. The Generalised Linear Model (GLM) and Binomial GLM are applied to study the future model choice behaviour of e-bike users.

Firstly, we use the model to identify the factors influencing e-bike choices. Secondly,

supposing that an “e-bike ban policy” is issued, we identify the most feasible alternative modes (buses, the metro, private cars, walking and bicycles), and investigate the factors leading to these choices. The analysis in this chapter answers RQ4.

Chapter 8 (Conclusion) summarises the thesis and suggests future work.

Chapter 2

Literature Review of Transition Theory

2.1 Introduction

This chapter provides the theory base of the present thesis. In social-technology transition theory, there are four main strands: the Transition Management, the Strategic Niche Management, the Technological Innovation System, and the Multi-Level Perspective (MLP). In the four research strands, the Multi-Level Perspective (MLP) is adopted as the main research theory in the thesis to explain the e-bike transition process. The first reason for adopting the MLP is because it explains historical socio-technical change through many theoretical perspectives rather than only as a policy instrument. The MLP is comprised of a wide range of perspectives, such as policy, culture, user practice, market, technology, industry, and science, which allows a discussion of the e-bike transition from a large variety of dimensions. Secondly, the MLP offers a flexible framework to understand the permeation of socio-technical change across time and space, which is crucial in understanding the success of technological innovations in historical and spatial terms. This is closely related to the research question of the thesis, that is, how e-bike achieved rapid development in China during the last decades (RQ2). Thirdly, the typology from Geels and Schot (2007) provides a framework in which there are six potential transition pathways to analyse the transition process, offering a more elaborated guidance to explore the e-bike transition process. Fourthly, the MLP does not only focus on any specific level, but also emphasises the interactions among the landscape level, regime level, and niche level, and thus can better explain the process that a radical innovation enters regime level; for example, the exponential development of

e-bikes from 0.054 million in 1998 to 35 million in 2014 (Ruan *et al.*, 2014; Tian, 2015). Last but not the least, the MLP has been successfully applied to explore the socio-technical transition of various travel modes, such as steam ship transition process (Geels, 2002), the co-evolution of waste and electricity regimes in the Netherlands (Raven, 2007), and the emergence of car regime (Geels and Kemp, 2012). These successfully applied case studies gave us more confidences and further guidance to use MLP to study the e-bike transition process.

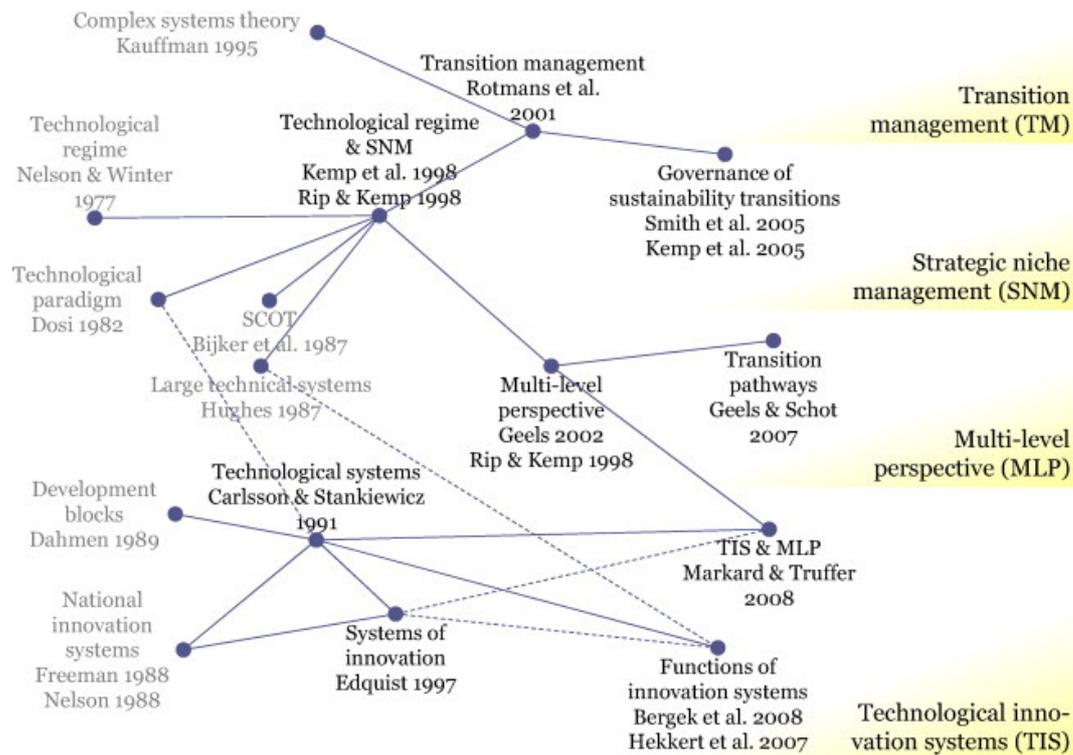
The chapter is organised as follows. Firstly, an overview of the four strands of socio-technology transition theories is given in Section 2.2. Then the Multi-Level Perspective (MLP) is detailed because it serves as the main research theory in the thesis. Followed is the section introducing six transition pathways with some illustrative examples. After that, the MLP in transport study is reviewed in Section 2.5. Section 2.6 discussed the limitations of the MLP, in which the Multi-scalar MLP is introduced as an extension of the traditional MLP to explain the transition process occurring in a heterogeneous geographical and socio-political system. The role of individual behaviour is also stressed in this section. Section 2.7 further discussed individual choice in the context of travel behaviour, which is followed by the conclusion of the chapter.

2.2 Review of socio-technology transition theory

Socio-technical transition is a set of transition processes involving different dimensions such as technology, institution, culture, economy, and policy (Kemp, 1994; Schot and Rip, 1996; Geels, 2006). There are four main research strands of socio-technology transition studies, including the Strategic Niche Management (SNM), the Technological Innovation System (TIS), the Transition Management (TM), and the Multi-Level Perspective (MLP). See Figure 2.1. We will firstly review the origin of the four strands, and then give an introduction to each strand.

These four research strands are derived from the concepts of “regime” and “niche” (Figure 2.1). On the one hand, from the perspective of regime, the “technological regime” concept identified by Nelson and Winter (1977) is the antecedent of socio-technical transitions. The current regime concept is developed by combining the ideas of evolutionary economics (*e.g.* technological regime) (Nelson and Winter, 1977; Dosi, 1982) with the history and sociology of technology. It is intertwined with scientific knowledge, social practice, institutional structure and technologies (Bijker *et al.*, 1987; Hughes, 1987; Kemp *et al.*, 1998). The key of socio-technical transition is to understand “how to deliberately reorient regimes and manage transitions toward sustainability” (Markard *et al.*, 2012). Some scholars have already published high quality papers to seek an answer to this question (Schot, 1992; Schot *et al.*, 1994; Kemp, 1994; Schot and Rip, 1996; Kemp *et al.*, 1998; Schot, 1999; Geels, 2002; Geels, 2004; Geels, 2006). On the other hand, “niche” is another important concept in socio-technology transition, which was firstly clearly identified by Kemp *et al.*, (1998) as “protected spaces where radical innovations can develop without regime pressure”. The concept of niche has a very important role in the socio-technology transition because it is the place where innovation started (Hoogma *et al.*, 2002).

As one of the research strands in socio-technology transition studies, Strategic Niche Management (SNM) is developed to support radical innovations, which could trigger off regime shifts (Kemp *et al.*, 1998; Kemp *et al.*, 2005; Geels and Raven, 2006; Smith, 2007). The earlier Strategic Niche Management literature mainly discusses how the early adoption of new technologies could contribute to sustainable development, but has not contained many policy discussions (Schot *et al.*, 1994; Kemp *et al.*, 1998). Currently, SNM not only highlights the role of policy in terms of steering niche innovations, but also concentrates on the role of various niche-internal processes such as networking, visioning, and learning processes (Schot and Geels, 2007; Schot and Geels, 2008).



Source: Markard *et al.*, 2012.

Figure 2.1 Map of key contributions and core research strands in the field of sustainability transition studies.

Technological Innovation Systems (TIS) provide another research strand in socio-technology transition studies, which is developed by deriving from the concept of development blocks (Dahmen, 1988; Enflo *et al.*, 2008), the concept of national innovation systems (Freeman, 1988; Nelson, 1988), and an innovation systems approach (Edquist, 1997). At its earlier stage, the main goal of TIS was to identify the functions that make the system perform well (Jacobsson and Bergek, 2004; Jacobsson and Lauber, 2006; Hekkert *et al.*, 2007). Currently, TIS is further developed to incorporate specific technologies, focusing on radical innovation in the early stage that may change the current regime system (Bergek and Jacobsson, 2003; Bergek *et al.*, 2008; Negro and Hekkert, 2008; Kuhlmann *et al.*, 2010; Weber and Rohracher, 2012).

The third research strand is Transition Management (TM), which is devolved by combining the base concepts with insights from complex system theory (Kauffman,

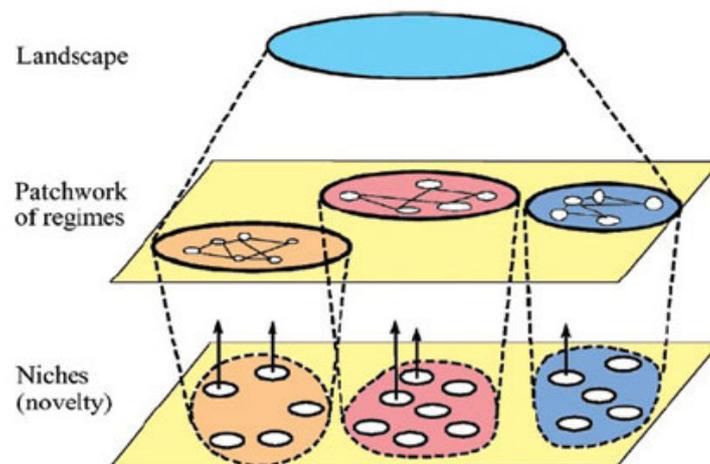
1995) and governance management (Rotmans *et al.*, 2001; Kemp *et al.*, 2005; Smith *et al.*, 2005). The aim of the Transition Management is to provide a feasible, instrumental, practice-oriented model (especially, for government) to guide and influence the current transitions towards sustainable directions (Kemp and Loorbach, 2006; Voß *et al.*, 2006; Nill and Kemp, 2009; Loorbach *et al.*, 2010). Many studies have further developed the TM by action research and participation in real policy contexts, involving multi-stakeholder arenas, new coalitions, and applied in experiments (Nill and Kemp, 2009; Kern and Howlett, 2009; Loorbach and Rotmans, 2010; Bulkeley *et al.*, 2011).

Lastly, the Multi-Level Perspective (MLP) is a significantly important research strand in socio-technical transition study, which has a series of fruitful outcomes, with more than 100 papers applying the MLP to study the socio-technical transition (Smith *et al.*, 2010; Berkhout *et al.*, 2010). As the main theory base of the thesis, the details of the MLP will be discussed in the next section.

2.3 The Multi-Level Perspective transition theory

The Multi-Level Perspective (MLP) is the main theory in the present thesis. Based on the concepts of regime and niche, the MLP is developed from the pioneering work of Rip and Kemp (1998), van den Ende and Kemp (1999). The MLP is “a middle-range theory that conceptualizes overall dynamic patterns in socio-technical transitions”, including both multi-dimensionality and structural change (Geels, 2011). The MLP possesses some advantages compared to other theories: (1) Compared with the Technological Innovation System approach (Hekker *et al.*, 2007), the MLP addresses the structural changes rather than only focusing on cultural and demand dimensions; for example, how radical innovation interacts with existing systems. (2) The advantage of MLP over the Strategic Niche Management is that the MLP not only focus on niche innovations but also the interaction between niche, regime and

landscape levels. (3) Compared with the Transition Management which mainly studies the transition governance, the MLP studies the whole transition process. (4) Compared with disruptive innovation (Christensen, 1997) and technological discontinuity (Anderson and Tushman, 1990), the MLP tolerates wider dimensions (*e.g.* culture, and policy) rather than only technology and market dimensions. (5) Compared with the long-wave theory on the techno-economic paradigm shift (Freeman and Perez, 1998) which also considers both multi-dimensionality and structural change, the MLP can be directly applied to, for example, the energy and transport systems (Geels, 2005). Furthermore, the MLP goes beyond single technology studies, such as wind power, bio fuels, and EVs (Geels, 2011). The special scope and structure of the MLP makes it widely applicable, particularly, in the study of sustainable transport socio-technology transition.

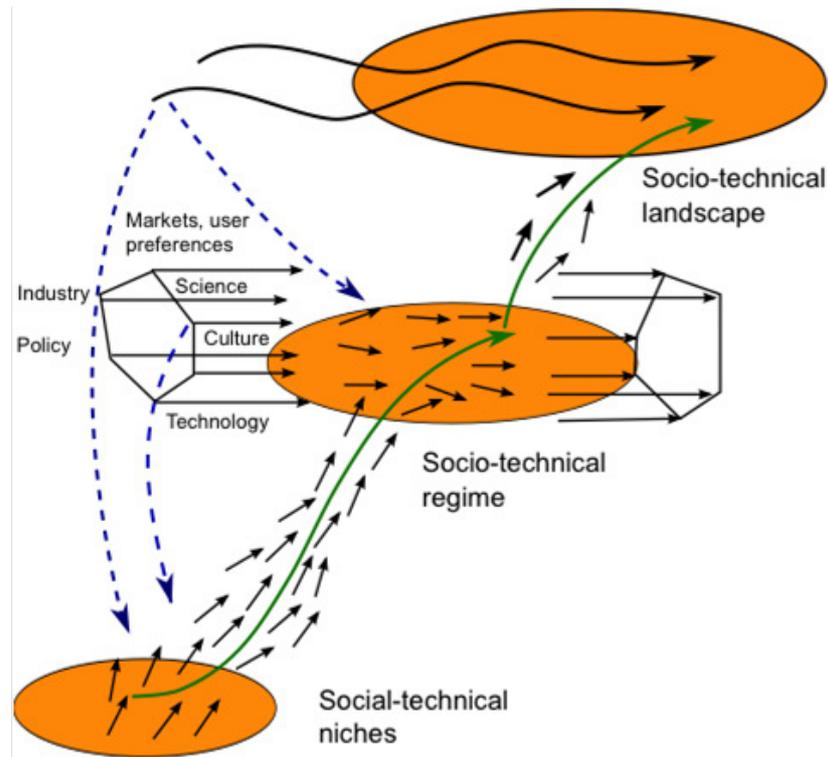


Adapted from: Geels, 2005.

Figure 2.2 Multiple levels as a nested hierarchy.

The MLP is identified as “a nested hierarchy of structuring processes” by Geels and Schot (2007), as shown by Figure 2.2. Based on three major conceptual backgrounds – evolutionary economics, science and technology studies, and neo-institutional theory – the MLP contains three levels: landscape, regime, and niche. The landscape is the macro-level, which consists of slow changing, such as geography changes and national policy changes (Geels, 2005). The regime is the meso-level regarding a stability of existing technological development (Geels, 2004). The niche is the

micro-level where many radical innovations generated and developed (Geels and Schot, 2007). Niches are the grassroots of innovations and change (Geels, 2004). It is noted that the niches are embedded in the regimes, while the regimes reside in the landscape. There are many novelties on the niche level, which attempt to enter the regime level in the context of current regimes and landscapes.



Adapted from: Geels, 2002.

Figure 2.3 Multi-Level Perspective framework

The MLP has a dynamic pattern which is demonstrated in Figure 2.3, where the arrows represent the technology development direction. As a nested hierarchy of structuring processes, the transition occurs in the structure framed by landscape, regime and niche. The landscape changes slowly with long arrows, exerting pressure on regime level. Meanwhile, with the regime transferring, landscape is also subject to the pressure from regime. These two levels are interactive (Geels, 2004). On the socio-technical regime level, there are seven components which link with each other as a nest, including technology, user practices and application domains (markets), symbolic meaning of technology, infrastructure, industry structure, policy and

techno-scientific knowledge (Geels, 2002). As the meso-level, the regime that comes under the pressure from both landscape and niche is forced to respond at all times. When the pressure from landscape is strong and intensive so that the regime is unable to adjust itself quickly and properly, a “window of opportunity” may occur (Geels, 2002). As a result, the radical innovations on niche level successfully break out of niche level, combined with the incumbent innovations on regime level to influence the landscape (Geels, 2002). The small arrows on the niche level represent the radical innovations. The radical innovations which did not break out of the niche level may fail and disappear or still develop while waiting for the next window of opportunity. The MLP reviews the socio-technology as a non-linear process (Geels, 2005).

No	Title	Authors	Source title	Citation times
1	Technological transitions as evolutionary reconfiguration processes: A multi-level perspective and a case-study	Geels (2002)	Research Policy	833
2	Typology of socio-technical transition pathways	Geels and Schot (2007)	Research Policy	595
3	Innovation studies and sustainability transitions: The allure of the multi-level perspective and its challenges	Smith <i>et al.</i> (2010)	Research Policy	205
4	Ontologies, socio-technical transitions (to sustainability), and the multi-level perspective	Geels (2010)	Research Policy	156
5	Processes and patterns in transitions and system innovations: Refining the co-evolutionary multi-level perspective	Geels (2005)	Technological Forecasting and Social Change	142
6	The multi-level perspective on sustainability transitions: Responses to seven criticisms	Geels (2011)	Environmental Innovation and Societal Transitions	128
7	The dynamics of transitions in socio-technical systems: A multi-level analysis of the transition pathway from horse-drawn carriages to automobiles (1860–1930)	Geels (2005)	Technology Analysis and Strategic Management	127
8	Can cities shape socio-technical transitions and how would we know if they were?	Hodson and Marvin (2010)	Research Policy	110
9	Rethinking the multi-level perspective of technological transitions	Genus and Coles (2008)	Research Policy	95
10	Co-evolution of technology and society: The transition in water supply and personal hygiene in the Netherlands (1850–1930) - A case study in multi-level perspective	Geels (2005)	Technology in Society	83

No	Title	Authors	Source title	Citation times
11	Dynamics in socio-technical systems: Typology of change processes and contrasting case studies	Geels and Kemp (2007)	Technology in Society	72
12	Toward a spatial perspective on sustainability transitions	Coenen <i>et al.</i> (2012)	Research Policy	70
13	A multi-level perspective on the introduction of hydrogen and battery-electric vehicles	Van Bree <i>et al.</i> (2010)	Technological Forecasting and Social Change	64
14	Developing transition pathways for a low carbon electricity system in the UK	Foxon <i>et al.</i> (2010)	Technological Forecasting and Social Change	63
15	Co-evolutionary and multi-level dynamics in transitions: The transformation of aviation systems and the shift from propeller to turbojet (1930-1970)	Geels (2006)	Technovation	61
16	A socio-technical analysis of low-carbon transitions: introducing the multi-level perspective into transport studies	Geels (2012)	Journal of Transport Geography	53
17	Exploring sustainability transitions in the electricity sector with socio-technical pathways	Verbong and Geels 2010	Technological Forecasting and Social Change	47
18	Analysing the breakthrough of rock 'n' roll (1930–1970) Multi-regime interaction and reconfiguration in the multi-level perspective	Geels (2007)	Technological Forecasting and Social Change	44
19	Legitimizing research, technology and innovation policies for transformative change: Combining insights from innovation systems and multi-level perspective in a comprehensive 'failures' framework	Weber and Rohracher (2012)	Research Policy	34
20	Socio-technical regimes and sustainability transitions: Insights from political ecology	Lawhon and Murphy (2012)	Progress in Human Geography	32

Table 2.1 The twenty most cited papers in the MLP study

In recent years, the MLP has attracted great attention in the research community. Table 2.1 lists the twenty most cited papers and orders them with the citation times. On one hand, some of the papers discussed the theoretical aspects of the MLP. For example, the paper by Geels in 2002, which is also the most cited, firstly introduced the full theoretical framework of the MLP framework. The second most cited paper further developed the MLP to six transition pathways (Geels and Schot, 2007). Papers no. 4, no.5 and no. 6 responded to the criticisms of the MLP. On the other hand, some papers mainly adopted the MLP in empirical studies. For example, no. 7 explored the

socio-technical transition pathway from horse-drawn carriages to automobiles (Geels, 2005). No. 14 and no. 17 examined the electricity system's shift towards sustainable transition by applying transition pathways (Foxon *et al.*, 2010; Verbong and Geels, 2007).

It is worth noting that Wells and Nieuwenhuis (2012) adopted the MLP to investigate the transition failure, which is ignored by many the MLP researchers who mainly concentrate on the existing successful sustainable transition or how to promote the successful sustainable transition. With the case study of the automotive industry, the paper by Wells and Nieuwenhuis (2012) has two main contributions: On the theoretical aspect, the paper filled the gap of understanding how transition fails. On the practical aspect, the paper revealed that the transition failure in the automotive industry was due to its strong regime stability, and the vehicle manufactures (dominant economic actors) maintain the regime stability.

The limitations and challenges of the MLP are also discussed in some papers, which were also highly cited and attracted much attention. The third most cited paper discussed current development of the MLP and analysed challenges of the MLP (Smith *et al.*, 2010). In these challenges, the geographical issues of transition were discussed intensively, suggesting that the MLP does not explicitly identify the spatial dimension of socio-technical transition (Smith *et al.*, 2010). Lawhon and Murphy (2012) also highlighted that MLP lacks geography consideration. The lack of geography sensitives of the MLP may lead to problematic usage, meaning that socio-technical transition could be shaped in any places such as villages, towns, cities and regions (Coenen *et al.*, 2012). In addition, without the consideration of spatial dimensions it is difficult to analyse the socio-technical transition in various contexts in practice (Hodson and Marive, 2010). To remedy this problem, Coenen *et al.* (2012) proposed a multi-scalar approach called "local node, global network" to distinguish the scalar boundaries that were not clarified in the traditional MLP. However, the multi-scalar approach proposed by Coenen *et al.* (2012) did not address the

relationship between nations and cities and to what extent they could shape the socio-technology transition. In the thesis, our study explicitly clarifies the Multi-scalar MLP regarding the relationship between different geography scales in the socio-technical transition study in China.

2.4 Transition pathways

2.4.1 Six transition pathways

Deviating from the transition pathway typology of Smith *et al.*, (2005), the MLP is further developed into six transition pathways (Geels and Schot, 2007). The six transition pathways describe how regime and niche reformed under different landscape pressures (Suarez and Oliva, 2005), based on timing and nature of multi-level interactions:

(1) In terms of the timing of multi-level interactions, Geels and Schot (2007) claimed that the timing of landscape pressure on regimes is associated with the state of niche developments. If landscape pressure happens after radical innovations are fully developed, the radical innovations have a higher probability of breaking out of niche level. Otherwise, the transition pathway will become different. They also proposed some indicators to examine whether the radical innovations are fully developed.

(2) Concerning the nature of multilevel interactions, it can be determined by the following two criteria. The one is that different landscape pressures have different effects on the regime (Suarez and Oliva, 2005). The other is that niche innovations have a competitive relationship with existing regimes (Geels and Schot, 2007). Based on these criteria, the transition pathways are identified as follows (Geels and Schot, 2007):

“

P0. *Reproduction process*: If there is no external landscape pressure, then the regime remains dynamically stable and self-reproducing.

P1. *Transformation path*: If there is moderate landscape pressure (“disruptive change”) when niche-innovations have *not* yet been sufficiently developed, then regime actors will respond by modifying the direction of development paths and innovation activities.

P2. *De-alignment and re-alignment path*: If landscape change is divergent, large and sudden (“avalanche change”), then the increasing regime problems may cause regime actors to lose faith. This leads to de-alignment and erosion of the regime. If niche-innovations are not sufficiently developed, there is no clear substitute. This creates space for the emergence of multiple niche innovations that co-exist and compete for attention and resources. Eventually, one niche-innovation becomes dominant, forming the core for re-alignment of a new regime.

P3. *Technological substitution*: If there exists much landscape pressure (“specific shock”, “avalanche change”, “disruptive change”) when niche innovations have developed sufficiently, the latter will break through and replace the existing regime.

P4. *Reconfiguration pathway*: Symbiotic innovations, which developed in niches, are initially adopted in the regime to solve local problems. They subsequently trigger further adjustments in the basic architecture of the regime.

P5. If landscape pressure takes the form of “disruptive change”, a sequence of transition pathways is likely to happen, beginning with transformation,

then leading to reconfiguration, and possibly followed by substitution or de-alignment and re-alignment.

”

The developed transition pathways provide a clear relationship between the three structural level and actors, and clarifying the transition pathways conquers the niche-driven bias of the MLP (Geels and Schot, 2007).

It is worth noting that a sequence of transition pathways could happen. That is, when landscape has “disruptive change”, transformation transition pathways would happen firstly, then other transition pathways would follow up, including substitution, reconfiguration, or de-alignment and re-alignment (Geels and Schot, 2007).

Transition Pathways	Main actors	Type of actions	Key words
Transformation	Regime actors and outside groups (social movements)	Outsiders voice criticism. Incumbent actors regime rules (goals, guiding principles, search heuristics)	Outside pressure, institutional power struggle, negotiations, adjustment of regime rules
Technology Substitution	Incumbent firms versus new firms	Newcomers develop novelties, which compete with regime technologies	Market competition and power struggles between old and new firms
Reconfiguration	Regime actors and suppliers	Regime actors adopt component-innovations, developed new suppliers. Competition between old and new suppliers	Cumulative component changes, because of economic and functional reasons. Followed by new combinations, changing interpretations and new practices
De-alignment and re-alignment	New niche actors	Changes in deep structures create strong pressure on regime. Incumbents lose faith and legitimacy. Followed by emergence of multiple resources, attention and legitimacy. Eventually one novelty wins, leading to restabilisation of regime	Erosion and collapse, multiple novelties, prolonged uncertainty and changing interpretations, new winner and restabilisation

Adapted from: Geels and Schot, 2007.

Table 2.2 Main actors and actions in transition pathways

Through the transition pathway analysis, the actors and actions can be identified for different transition pathways (see Table 2.2). For the transformation transition pathway, the main actors are outside groups who create the pressure to regime actors. As a result, the regime actors have to adjust the rules to respond to the pressure. For the technology substitution transition pathway, the main actors are the incumbent firms and new firms. The transition process is driven by the competition between incumbent firms and new firms. For the reconfiguration transition pathway, the transition actors are the regime actors and regime suppliers. The transition process is that the old suppliers under the control of regime actors introduce cumulative component changes to influence the current regime. In terms of the de-alignment and re-alignment transition pathway, the main actors are new niche actors. The transition process is that the regime structure is dramatically changed by the pressure of landscape and the successful emergence of a new niche.

2.4.2 The application of transition pathways

The transition pathways are employed to investigate various transition case studies (Table 2.3). For example, the most cited paper in the MLP (Geels, 2002) investigated the transition from sailing ships to steamships as an example of a technology substitution pathway. In the 1850s and 1860s, sailing ships dominated the regime, while the steamship was in the niche market and only used for mailing. In the 1840s, political revolutions and the Irish potato famine (specific shock landscape change) caused mass emigration from Europe to America, which created a window of opportunity for widening steamship applications (Geels, 2002). With the further development of steam technology and iron works, steamship cumulatively increased with bigger ships to carry more people and cargoes (Geels, 2002). When the Suez Canal opened in 1896, the use of steamship was booming because sailing ship could not be used in the Suez Canal (Geels, 2002). In addition, the steam technology

development provided higher coal efficiency and low transport cost. As a result, sailing ships were finally replaced by steamships in the 1890s (Geels, 2002).

Case study	Reference	Transition pathway
The transition from sailing ships to steamships	Geels (2002)	Technology Substitution
The transition from horse-drawn carriages to automobiles	Geels (2005)	De-alignment Re-alignment
The transition in water supply and personal hygiene in the Netherlands	Geels (2005)	Transformation
The hygienic transition from cesspools to sewer systems	Geels (2006)	Transformation
The transition of aviation systems from propellers to turbojets	Geels (2006)	Transformation
American factory production transition	Geels (2006)	Reconfiguration
Dutch highway system transition	Geels (2007)	Transformation
The breakthrough of rock ‘n’ roll	Geels (2007)	Reconfiguration
Energy transition of the Dutch electricity system	Verbong and Geels (2007)	Transformation
Combined heat and power technologies in Netherlands	Raven and Verbong (2007)	Reconfiguration
The transition from mixed farming to intensive pig husbandry	Geels (2009)	Transformation
The use of ICT in car sharing	Papachristos (2011)	Transformation
Policy challenges to the dominance of the private car in the UK	Dudley and Chatterjee (2012)	Transformation
German and UK transition policies for electric mobility	Mazur <i>et al.</i> (2015)	Reconfiguration

Table 2.3 Transition pathway studies

The second example is the transition from horse-drawn carriages to automobiles, which is a case study of de-alignment and re-alignment transition pathway (Geels, 2005). In the late nineteenth century, America was experienced political, social and cultural change. On one hand, these landscape changes resulted in significant pressure on the then-current horse-based urban transport regime, including concerns about hygiene associated with horse excrements on the streets, a demand for longer travel distances demanded, and the high cost of horses (Geels, 2005). On the other hand, the divergent, large and sudden landscape changes created opportunities for radical innovations on the niche level, such as electric trams, bicycles, electric vehicles, gasoline cars, and steam automobiles (Geels, 2005). Due to Ford’s mass production

system introduction (in 1908), the price of new cars decreased dramatically, which stimulated car sales. The use of electric trams declined in the mid-1920s for political, economic, culture and infrastructural reasons (Geels, 2005). As a result, the car broke out of the niche level, and then entered the regime.

Geels (2006) examined the hygienic transition from cesspools to sewer systems in the Netherlands. In this study, the main actors were outside groups, such as doctors, engineers, medical communities, and local authorities. Under the pressure from the medical regime and outside criticism, the local authorities gradually changed sewer pipe construction. This transition process is identified as a transformation transition pathway (Geels, 2006). Some similar type of transformation transition pathway case studies include the transition of aviation systems from propeller to turbojet (Geels, 2006), the transition of the Dutch highway system (Geels, 2007), the energy transition of the Dutch electricity system (Verbong and Geels, 2007), the co-evolution of waste and electricity regimes in the Netherlands (Raven and Verbong, 2007), the transition from mixed farming to intensive pig husbandry (Geels, 2009), the use of ICT in car sharing (Papachristos, 2011), and how the concept of sustainable mobility has influenced the car regime in the UK (Dudley and Chatterjee, 2012).

The transformation of American factory production (1850–1930) from traditional factories to mass production is a typical example of reconfiguration transition pathway (Geels, 2006). During this period, there appeared some important landscape-level developments, which created opportunities and pressures to factory production transition. One landscape-level development is the construction of a national rail network in the 1840s and 1850s that lowered the coal price and facilitated the transportation (Geels, 2006). Another landscape-level development is that the population increased triple times between 1850 and 1900, which expanded the market and stimulated economies of scale in production (Geels, 2006). The third landscape level development is a fact that big business and industry rapidly grew with increased production of goods after the Civil War (1861–1865) (Geels, 2006). In the same

period, there were several problems on the factory production regime, such as labour costs, insufficient lighting in mill factories, and power-distribution problems (Geels, 2006). To solve these regime problems, many radical innovations were developed on the niche level. In particular, electricity was applied for many purposes, such as telegraphy, electrometallurgy, lights, and electric motors. Then, regime has a reconfiguration with the electricity becoming dominant in this level, which motivated American factories towards mass production.

In addition to explaining the history of transition process, the transition pathways are also applied to predict the future transition process. For instance, Verbong and Geels (2010) predicted three possible transition pathways for the electricity sector's future transition, including a transformation pathway, reconfiguration pathway, and de-alignment and re-alignment pathway. Papachristos (2011) presented a model of the substitution transition pathways to forecast the new technologies transition in the future. Yuan *et al.* (2012) studied the delivering power system transition process from 2010 to 2050 in China by setting five different transition pathway scenarios, including reproduction, transformation, substitution, reconfiguration, de-alignment and re-alignment. In their assumption, if the delivering power system transition process follows transformation transition pathway, the delivering power system in China will achieve a low carbon system by 2030.

2.4.3 Limitations of transition pathways

Transition pathways have been successfully applied in many fields, because they analyse changes at the whole system level, and are able to explain both social-institutional factors and techno-economic factors and their interactions. Hence, the framework is identified as a process-based approach which explains the result of causal interactions between systems (Foxon *et al.*, 2010). This conceptual and analytical framework is appropriate to analyse the processes, actors, and dynamics of

historical transitions, and therefore is adopted in this thesis to study the e-bike transition in China.

Nonetheless, the transition pathways are not without limitations. Firstly, the framework does not in-depth explore the key role of users in the system change. Secondly, the transition pathways only focus on a single system transition, without taking into account multi-system interactions (Papachristos *et al.*, 2013). Thirdly, the six transition pathways are not able to cover all the possible transition processes. Some transition studies are found which cannot be categorised into any of the six transition pathways, such as the emergence of the computer regime (Van den Ende and Kemp, 1999), and the emergence of functional foods (Papachristos *et al.*, 2010).

2.5 The Multi-Level Perspective in sustainable mobility

Sustainable mobility is significant because transport sector is one of the most important in industry generally, and in social use, and in this sector CO₂ emissions keep increasing (Anable *et al.*, 2012). Applying the MLP to analyse suitable mobility can help understand the current transport system situation and possible transition pathways towards a more sustainable mobility (Geels, 2012). A book called “Automobility in Transition? A socio-technical analysis of sustainable transport” (Geels *et al.*, 2012) provides a significant contribution to the complexity of transport system transition. The book is a compilation of various works by different authors, aimed at understanding the stability, change and interactions between different types of change in transport system with an in-depth exploration of culture, governance, traffic management, infrastructure, the automobile industry, radical innovations, emerging niche markets and transitions (Kemp *et al.*, 2012). The key research questions of the book were “the force of stability and change and if a green technology pathway is more likely to be a broad transformation of the transport system” (Kemp *et al.*, 2012).

There were three main parts of the book. Part 1 introduced a “transport in society” perspective, which included the following aspects: 1) understood the mechanisms of lock-in and stability of the existing automobile regime in a social science perspective (Lyons, 2012); 2) explained the MLP framework and transition patterns with corresponding case studies such as add-on and hybridisation patterns in the case of sailing ships shifting to steam ships, and fit-stretch patterns with the horse-based regime transferring to the car regime (Geels and Kemp, 2012). This part provides the theory bases of the book, which leads to a good start point.

Part 2 focused on the theme of “stability and regime pressures”. The chapter by Wells *et al.* (2012) explained the reasons behind the existing automobility industry resistance, including demand for scale economy, safety regulations based on the steel body, exit barriers and entry barriers, and consumer habits, which provided a comprehensive study of interactions of industry actors, customers, and government. In the chapter by Dudley and Chatterjee (2012), they introduced how the sustainability concept diffused into the UK’s transport policy regime. Then, Docherty and Shaw (2012) further analysed the governance of transport policy in Scotland and London. Their result showed that simply replicating successful sustainable transport policy from one place to other place could result in failure. Other chapters in this part studied the road capacity of automobility (Goodwin, 2012), linking between car mobility and spatial planning (Zijlstra and Avelino, 2012), and the emergence of new cultures of mobility in the USA (Sheller, 2012).

Part 3 concentrated on the dynamics of change with the study themes of electric vehicles, transport information system and personal mobility. The chapter by Orsato *et al.* (2012) studied pure battery electric vehicles (BEVs). They stated that BEVs dominated the motor vehicle regime for a very short period around 1915. Then, there was a revival of BEVs for a short time in the 1970s and 1990s. Due to climate change, high oil prices and the success of hybrid electric cars, BEVs once again became

popular. Orsato *et al.* (2012) did not expect that BEVs will replace the existing car industry, but believed that the BEVs now were accepted culturally compared with the period of the 1970s and 1990s. Electric vehicles (EVs) were further studied by Ehret and Dignum (2012). They studied the full cell vehicles (FCVs) in Germany, finding that FCVs were regime-preserving as they fit current driver preferences as well as regime-changing as they are a disruptive innovation in the energy sector. In addition, Pel *et al.* (2012) and Lyons *et al.* (2012) investigated the role of traffic information in the transport regime transition. In particular, Lyons *et al.* (2012) pointed out that the innovation of “Intelligent transport system” would have an impact on the travellers’ mode choice behaviours. In addition, innovation in public transport was highlighted by Harman *et al.* (2012), including bus lanes, demand-dependent services, information provision about arrival times and short distance radio systems. Among the various innovations, they found that the tram-train concept was a better solution to attract more commuters and widen access to cities. Another study (Parkhurst *et al.*, 2012) suggested that the intermodal personal mobility promotion would be a possible way to achieve sustainable personal mobility. The book ended with policy proposals for transferring to a sustainable transport regime.

Overall, this book contains diverse components of the automobility regime transition, including culture, industry, historical analysis, policy, and emerging innovations, which provides a comprehensive understanding of stability and change and interactions between three levels. However, it is not without limitations. Firstly, the book almost solely focuses on the automobility transition in the Netherlands and the United Kingdom. Very little information about automobility transition in other countries is given. Secondly, the radical innovations to achieve sustainable mobility in the book are mainly the green cars, such as BEVs and FCVs, without the consideration of bicycles, e-bikes, and other transport modes. Thirdly, most chapters in the book emphasise the interactions between institutions and organisations, giving little attention to individuals. Last but not least, the book emphasises the role of governance, that is, that the strong policy support of sustainable mobility innovations

is the prerequisite for the successful sustainable mobility transition.

There are numerous journal articles studying sustainable mobility by applying the MLP, as listed in Table 2.4. These articles employed the MLP framework to interpret a range of cases but in a limited range of different regional contexts. Most studies mainly investigated the sustainable mobility transition in Europe, especially in the UK, the Netherlands, Finland, Sweden and Germany. Only a few studies focus on China and the North America.

Theme	Study Topic	Region	Reference
Niche innovation	Human Powered Vehicles	Netherlands	Brown <i>et al.</i> (2006)
	Novel transport technologies	UK, Sweden	Nykvist and Whitmarsh (2008)
	Aeromobility	United States	Cohen (2010)
	Hydrogen and battery electric vehicles	Netherlands	Van Bree <i>et al.</i> (2010)
	Hybrids, biofuels, natural Gas, hydrogen	Netherlands	Farla <i>et al.</i> (2010)
	Electric mobility	China	Tyfield (2014)
	Heavy vehicles	Sweden	Berggren <i>et al.</i> (2015)
	Biogas	Sweden	Fallde and Eklund (2015)
Mobility System	E-mobility	German	Augenstein (2015)
	Multimodal mobility in urban transport system	German	Spickermann <i>et al.</i> (2014)
Policy	Emission-free transport	Finland	Auvinen <i>et al.</i> (2015)
	Climate-related policy	UK, Finland, Sweden	Upham <i>et al.</i> (2014)

Table 2.4 Sustainable mobility case studies apply the MLP

Some of the studies focused on the niche innovations (see Table 2.4). Nykvist and Whitmarsh (2008) identified three ongoing niche developments in the UK and Sweden as follows: 1) radical vehicle technology (*e.g.* dual modes, biofuels, electric power train, and personal rapid transport systems); 2) product-to-service shift (*e.g.* an increase in public transport demand and car sharing); 3) mobility management (*e.g.* slow-modes, walking and cycling, congestion charging and road pricing). They found

that different countries have different preferences for greener transport technologies. Furthermore, they found that three ongoing niche developments had synergies with the sustainable mobility transition. They concluded that the tendency of innovation in transport is diversity, hybridisation and co-evolution of niches in the future. An important contribution of the paper is that it provides diverse ongoing niche innovations in the sustainable mobility transition rather than only focusing on radical vehicle technologies. However, as the authors stated, the study area is only concentrated on the UK and Sweden, and should be developed in a broader range of countries.

Some studies on the sustainable mobility transition mainly focused on the radical innovations of new energy vehicles and renewable energy vehicles, such as the human powered vehicle study (Brown *et al.*, 2006), the aeromobility study (Cohen, 2010), hydrogen and battery electric vehicles (Farla *et al.*, 2010), biofuels vehicles and natural gas vehicles (Van Bree *et al.*, 2010; Berggren *et al.*, 2015), and e-mobility (Tyfield, 2014; Augenstein, 2015).

The mobility system is another important research theme in these journal papers (Table 2.4). Spickermann *et al.* (2014) studied the possible multimodal mobility solutions in urban transport systems, and designed an integration of individual and public passenger transport systems for future sustainable urban mobility.

The sustainable mobility governance is also researched but not intensively (Table 2.4). Auvinen *et al.* (2015) proposed a process to support strategic decision-making and policy planning in sustainable transport policy transition by simulation and modelling with impact assessment based on the MLP framework, which developed an “emission-free transport in cities by 2050” project. Another study (Upham *et al.*, 2015) focused on the current climate-related transport policies in three countries, namely, Finland, Sweden, and the UK. They found that the climate-related transport policy supported by regime actors in these three countries mainly concentrated on

technological substitution and incremental changes rather than path-breaking innovations (Upham *et al.*, 2015).

2.6 Limitations of the Multi-Level Perspective

The Multi-Level Perspective (MLP) has been applied to a wide range of areas, suggesting that it has great flexibility and adaptability. However, there are still some shortcomings that will be discussed in this section.

2.6.1 The relationship between different scales

The traditional MLP mode is difficult to apply to a complicated system, because it does not realise that each system can contain micro-structures or sub-systems. Furthermore, the definitions of “landscape”, “regime” and “niche” are ambiguous in practice. For example, how large a scale should a landscape be compared to a regime? The whole world or a country or a city? To solve these problems, Coenen *et al.* (2012) and Lawhon and Murphy (2012) suggested to incorporate a multi-scalar system into the MLP, or called Multi-scalar MLP. That is, each system in macro-scale is comprised of numerous sub-systems or constituent elements in micro-scale, and each element has its own micro-structure with complete multiple perspectives. The interaction between the sub-systems forms the mechanism underlying the transition process in the macro-level, rendering the transition either not “homogeneous” or “synchronous”. Multi-scalar MLP is an extension of traditional MLP, and they share the same fundamental framework. Using the MLP in multi-scalar manner allows us to understand the structure of the social-technical transition depending on the scale where we investigate the system.

However, the Multi-scalar MLP proposed by Coenen *et al.* (2012) did not provide a

guideline to explicitly distinguish the scalars in the national context. In our study, the various dimensions in Multi-scalar MLP are clearly and reasonably identified according to the scale of geography and policy structure. Furthermore, the Multi-scalar MLP research in previous literatures was restricted to a concept, but our work applied it to analyse a specific transition process.

2.6.2 The role of individual actions

Due to the broad system-wide focus and consideration of “outsider” and radical and incremental innovations, the MLP provides a very useful theoretical framework for policy makers, industry, and other actors in decision-making (Smith *et al.*, 2005; Foxon *et al.*, 2009; Whitmarsh *et al.*, 2009; Köhler *et al.*, 2010). However, in transition studies, the social-technical lacks the treatment of individual roles in the context of travel behaviour, which is a limitation of the MLP from a social science perspective. The literature of social-technical transition tends to assign the role of individuals as technology consumers and users rather than citizens who have social attributes such as the roles of family members, voters, community members, employees, or employers, especially in transport research (Burgess *et al.*, 1998; Nye *et al.*, 2010). As a result, the individuals in social-technical transition studies are treated as homogenous and passive rather than heterogeneous and active (Haxeltine *et al.*, 2008; Geels, 2011).

In the transport system, individual vehicle purchase and use is important. The individuals can change their behaviour in non-technological or social ways. In addition, to achieve a sustainable transport system, the technical measures alone are not sufficient (Grubler and Riahi, 2010). At the individual and household level, one might alter one’s choice of travel according to time, income, cost, location, and even weather. The individual lifestyle and travel choice is closely related to regime level. For example, if there are bike lanes, the individuals are more likely to use bicycles.

Understanding such niche and regime relationships is a priority for future MLP research. In this case, the role of individuals in the e-bike transition process is explored in the thesis with mixed methods.

2.6.3 The role of policy

One of the main aspects of the MLP studies is the transition management which emphasises the role of policy and tends to suggest that the distinct policy intervention is fundamental to turning unsustainable practices into sustainable ones. This is because it stimulates and nurtures new production-consumption modes in the following aspects: distributing fiscal and other incentives; providing Research and Development (R&D) supports; taking charge of infrastructure development; and formulating regulatory frameworks (Schot *et al.*, 1994; Kemp *et al.*, 1998; Hoogma *et al.*, 2002, Beck *et al.*, 2013). The requirement of policy interventions in different contexts is highlighted to steer a radical innovations transition (Smith *et al.*, 2005; Smith, 2007; Genus and Coles, 2008). In contrast, the disruptions identified by Marsden and Docherty (2013) are necessary triggers of socio-technical change. In addition, these disruptions embedded in different regimes have indeed provided opportunities for e-bike development in China. The thesis will examine whether a transition can occur without a purposive policy support.

2.7 The role of individual choice in the context of travel behaviour

As mentioned above, the MLP lacks a discussion on the role of individual choice in the context of travel behaviour. Considering the significance of individual mode choice in theory and practice, this section attempts to give a review of the literature on this topic.

There is a wide variability of research projects that study individual travel behaviours. The studies vary in geographical extent, from local level (Boarnet and Crane, 2001; Ampt *et al.*, 2005) to national level (Dieleman *et al.*, 2002; Lyons *et al.*, 2002) and international level (Marchetti, 1994; Hjorthol, 2002). Some of the studies concentrated on the travel behaviour in particular types of journey purposes, such as work purposes (Cullinane, 2002; Aguilera *et al.*, 2009), leisure purpose (Anable, 2002; Anable, 2005), and shopping purpose (Van Acker and Witlox, 2010; Le Vine *et al.*, 2014). Some of the studies discussed the use of travel modes (Anable and Gatersleben, 2005; Handy *et al.*, 2005; Schwanen *et al.*, 2012). The research methods applied to study travel behaviour are also diverse, and include travel diaries (Boarnet and Crane, 2001; Schlich and Axhausen, 2003), interviews (Brown, 2005; Huang and Hsu, 2009), questionnaires (Sönmez and Graefe, 1998; Nutley, 2005), modelling (Golob, 2003; Cao *et al.*, 2009), and experiments (Gärling *et al.*, 1998; Janssens *et al.*, 2009). Many studies developed theories to further explore the underlying mechanisms behind travel behaviours, including attitude-action gap (Blake, 1999; Kollmuss and Agyeman, 2002; Mairesse, *et al.*, 2012), income effect (Deaton and Muellbauer, 1980), information integration theory (Sönmez and Graefe, 1998), and protection motivation (Sönmez and Graefe, 1998).

In addition, many studies investigated the impact factors influencing travel behaviours, which are divided into four groups: urban form; socio-demographic variables; psycho-social variables; and pricing.

(1) Urban form plays a significant role in influencing travel behaviours and travel patterns. Many studies showed that higher density land use with better access to sustainable modes increased the probability to promote sustainable travel behaviour (Handy, 1996; Cervero, 2002; Naess, 2003; Naess and Jensen, 2004; Srinivasan and Rogers, 2005). On the other hand, low and single density land use produced longer journeys and a higher probability to use cars (Goudie, 2002; Srinivasan and Rogers, 2005; Nutley, 2005; Holz-Rau *et al.*, 2014).

(2) A large number of studies explored the impact of socio-demographic variables on travel behaviours. The socio-demographic variables include age, gender, income, and household composition. Boschmann and Brady (2013) conducted a survey to explore the travel behaviour of older adults (aged 60 and over) in Denver, Colorado, USA. They found that the total trips and mean distances decreased with the increase of age (Boschmann and Brady, 2013). Newbold *et al.* (2005) also obtained a similar result when studying the travel behaviour of older Canadians (aged 65 and over) and young Canadians. They found that the older Canadians made fewer daily trips than younger Canadians. Because employment statuses changed, older Canadians took fewer daily trips. Many studies found that there is a significant difference between men and women. Compared with men, women are more likely to adopt sustainable travel behaviours (Boarnet and Sarmiento, 1998; Polk, 2003; Best and Lanzendorf, 2005; Moriarty and Honnery, 2005). Income is another very important factor. The higher the household income, the higher the probability of car ownership is (Dieleman *et al.*, 2002). In terms of household composition, Ryley (2005) found that the travel behaviour of households with children is distinct from others. These households are highly dependent on cars. Other household compositions that influence travel behaviour include gaining employment and retirement.

(3) Some studies explored the impact of psycho-social variables on travel behaviour. Anable (2005) used the Theory of Planned Behaviour (a psychological theory of attitude-behaviour relations) to study the travel behaviour of leisure travellers who are divided into different segments by multi-dimensional attitude statements through cluster analysis. She found that each traveller segment has its own unique combination of preferences, worldviews and attitudes. In addition, attitudes can significantly influence travel behaviours. Furthermore, the same attitude can be attributed to different reasons and can lead to different travel decisions. Other psycho-social factors, including the perception, and motives, also have a significant impact on travel behaviour (Pizam and Mansfeld, 1999; Cullinane, 2002; Hiscock *et*

al., 2002).

(4) The cost of travel would be an effective tool to alter travel behaviours. For example, due to the high parking cost, travellers are more likely to switch from cars to public transport (Hensher and King, 2001). Similarly, Janssens *et al.* (2009) found that environmentally friendly travel behaviour (reducing the number of trips, switching to more environmentally friendly travel modes) can vary depending on different congestion pricing scenarios by analysing stated adaptation experiments. Francke and Kaniok (2013) explored travellers' responses to different road pricing schemes. If the road pricing schemes were well designed and simple, it would be faster and easier for travellers to choose their transport modes (Francke and Kaniok, 2013).

As an important impact factor of travel behaviours, the travel cost itself can be influenced by the value of travel time and the value of travel time reliability. The former is the cost of time spent on transport, and the latter refers to the value of reducing the variability of travel time. The concept of the value of travel time has a long history based on the time allocation models. Many estimated values of travel time have been conducted to control pricing (Wardman, 1998; Wardman, 2001; Shires and de Jong, 2009; Wardman, 2004; Zhao *et al.*, 2015). The history of the value of travel time reliability research is not as long as the value of travel time research. However, there are an increasing number of papers which paid attention to this topic using two main theoretical approaches: centrality-dispersion and scheduling models (Bates *et al.*, 2001; Copley *et al.*, 2002; Tseng *et al.*, 2009; Tilahun and Levinson, 2010; Devarasetty *et al.*, 2012). The studies of the value of travel time and the value of travel time reliability provide multi-dimensions to balance the travel demand and pricing.

The literature on individual mode choice gave us some clues about how to design questions in the survey and analyse the survey results related to the factors

influencing individual behaviours in the travel mode transition.

2.8 Conclusion

This chapter introduced four theory strands of socio-technical transition, in which the MLP is reviewed in detail because it is applied as a tool to analyse the e-bike transition (RQ1–RQ5). The reason for adopting the MLP as the theory base of the thesis is due to its following advantages in studying sustainable transition: 1) The MLP provides a useful analytical framework for understanding complex socio-technology transition; 2) The MLP intertwines with different levels of actors in one context; and 3) six transition pathways in the MLP provide more realistic assumptions on future sustainable mobility transition modelling.

The limitations of the MLP are also discussed. Firstly, the heterogeneous spatial dimensions and socio-political structure of transition are not well explained by the MLP. Hence, a multi-scalar MLP is used as a framework to solve this problem. In addition, individual behaviour is an important mechanism to promote the e-bike rapid development in China (RQ5), but the MLP focuses on the interactions of the institutions and organisations rather than integrating natural, behavioural and political science to understand how behavioural-institutional change occurs (Whitmarsh, 2012). Therefore, we also reviewed the literatures on individual mode choice as a supplement to the theory, which is helpful to our questionnaire design in the survey of Nanjing City and useful to discuss the data result.

Chapter 3

Literature Review of E-bike Research

3.1 Introduction

This chapter reviews the literatures on e-bike research, aimed to investigate the current knowledge of the “e-bikes”, conveying an understanding and a critical analysis of e-bike studies, and identifying the research gaps.

Due to the significant difference of e-bike sales between China and other areas, the e-bike research themes are different accordingly. The e-bike studies in China focus on e-bike user characteristics, environment impact, safety issues and the reasons for e-bike development, whereas the e-bike studies in other countries and areas focus on the characteristics of early e-bike adopters, safety issues, and the promotion of e-bike usage. This thesis will review the e-bike research in China and other countries, respectively, seeking the answers of important questions about e-bike user demographics information, the reasons for e-bike adoption, safety, health, and environment impact.

3.2 An overview of e-bike literatures

The e-bikes in the thesis are referred to as three different types: bicycle style e-bikes, hybrid style e-bikes, and scooter style e-bikes. All three types of e-bikes have similar characteristics: two wheelers, electric assisted power, and low speed. The electric motorcycles are excluded. The reviewed papers were mainly scanned via Scopus, using the key terms such as “electric bicycle”, “electric bike”, “e-bike”, and “electric

two-wheeler vehicles”. The review was restricted to English publications and high quality Chinese literatures, including books, peer-viewed journal papers, conference papers, and conference reviews.

Figure 3.1 shows the articles relevant to e-bike topics published since 1974. The total number of e-bike articles scanned by Scopus is approximately 400. The very first article published in 1974 announced that e-bikes had been assembled in Dublin (Anon, 1974). The number of published e-bike articles is no more than five each year before 1999. However, this started to increase after 2000, which could be an indicator that e-bikes may emerge in the niche market. In the following years, the number of published e-bike articles fluctuated between 2003 and 2009. After that, the number of published e-bikes had an explosive growth, especially in 2013 and 2014, with 52 and 67 published articles, respectively. The increase in published e-bike articles may imply that the e-bike industry developed very quickly and has been a highly notable social phenomenon, and therefore attracted the attention of the academic world.

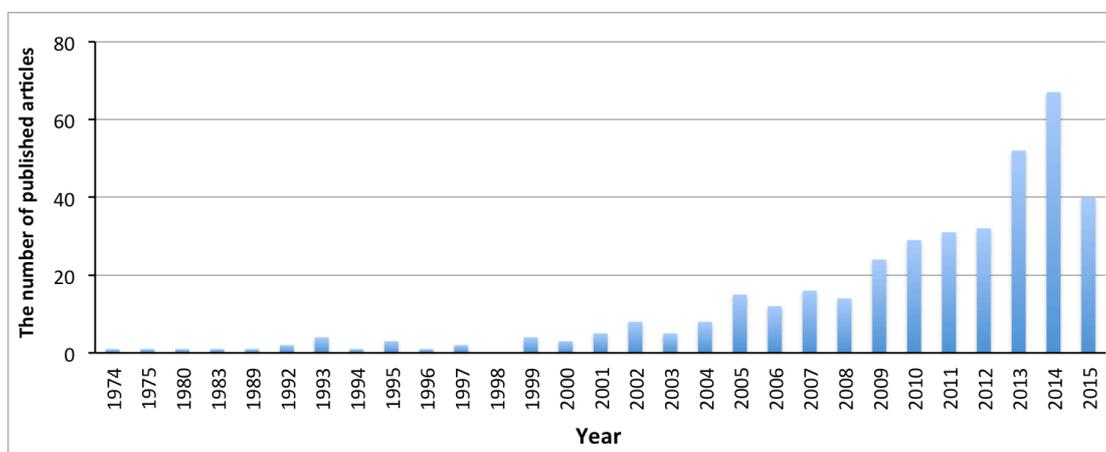
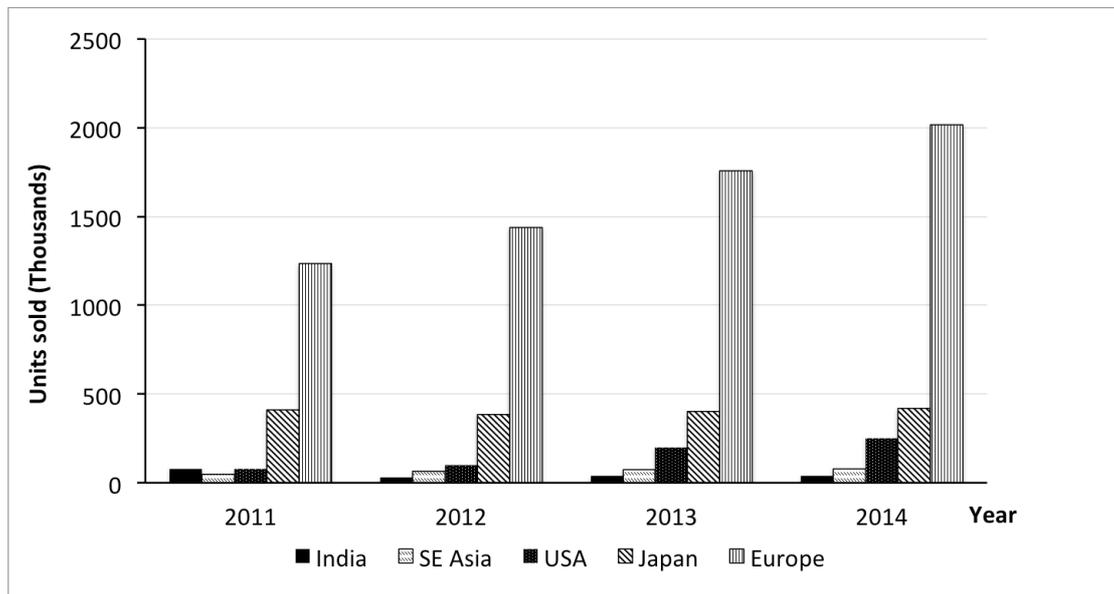


Figure 3.1 The number of articles published every year

Most of the published articles are in the engineering subject area, with only a few in the social science. The themes in the engineering subject area mainly consist of the research of batteries (Kumar, *et al.*, 1993; Yan, 2001; Hwang *et al.*, 2005; Ke and Zhang, *et al.*, 2007; Guo *et al.*, 2009; Manoj *et al.*, 2011; Zhao *et al.*, 2014; Berjoza and Jurgena, 2014), motors (Chan *et al.*, 2002; Trifa *et al.*, 2007; Son and Kang, 2010;

Lu and Jen, 2014; Wu and Lin, 2014), controllers (Haobin *et al.*, 2008; Zhang *et al.*, 2011; Zhou *et al.*, 2013; Zhang *et al.*, 2013), wheel hubs (Espanet *et al.*, 2001; Wu and Sun, 2013), frame designs (Wang *et al.*, 2001; Du *et al.*, 2008; Xiao *et al.*, 2012; Dong *et al.*, 2012), propulsion systems (Scott, 2008; Tal *et al.*, 2013; Ren and Ren, 2014), and brake systems (Liu *et al.*, 2008; Hua and Kao, 2011; Chuang *et al.*, 2012). These themes explored important technology components of e-bikes, for the purpose of breaking through the technology bottlenecks, optimising e-bike technology, and achieving e-bike industrialisation.



Adapted from: Jamerson and Benjamin, 2013; Fishman and Cherry, 2016.

Figure 3.2 Global e-bike sales (1,000 units, excluding China)

The research scopes of the e-bike studies in China and other countries are very different. China is the largest producer and market of e-bikes, with 35 million in production and 32.40 million sales in 2014 (Tian, 2015). In comparison, the market in Europe, India, the USA and Japan are still in the elementary stages (Figure 3.2). Although e-bike sales in these countries are increasing every year, they are still much lower than that in China. The unbalanced regional e-bike development leads to different preferences for e-bike research themes. Eastern studies, especially in China, tend to concentrate on the e-bike operations, technology improvement, e-bike user

characteristics, environment issues, safety issues, market growth, and the reasons for the rapid development of e-bikes. In comparison, western studies, especially in North America and Europe, focus on emerging markets, the behaviour of early adoption, and health issues. The following sections will explore the e-bike themes in China and other areas, respectively.

3.3 E-bike research in China

This section reviews the e-bike research in China, including the characteristics of e-bike users, environment impact, safety issues, and the reasons for rapid e-bike development.

3.3.1 Characteristics of e-bike users

Understanding e-bike user characteristics is useful for determining who the e-bike users are, where they are from, and their future travel mode choices, which would help understand e-bike transition and how e-bikes are embedded in the current transport regime. The investigation of e-bike users' characteristics is mainly performed through questionnaires.

Demographic information

The demographic characteristics of e-bike users are investigated in five different cities (Shanghai, Kunming, Shijiazhuang, Beijing and Hangzhou). Although these cities are different in their sizes, locations, populations, and development levels, the average ages of e-bike users are quite similar, ranging from 31 to 36.4 years old (Table 3.1), which suggests that e-bike users in China are mainly of a young age. In addition, the result shows that the average education levels of e-bike users are college degree in

Shanghai and Kunming. In terms of income level, e-bike users are at the middle range of the local income level.

City	Gender (%F)	Average Age	Education	Income (CNY)
Shanghai	41	36.4	College degree	59209 *
Kunming	51	33.1	College degree	37734 *
Shijiazhuang	51	32	NA	20000*
Beijing and Hangzhou	35	31	NA	NA

* income per household; * income per person

Adapted from: Cherry and Cervero, 2007; Weinert *et al.*, 2007; Yao and Wu, 2012.

Table 3.1 Demographic information in different cities in China

Cherry and Cervero (2007) and Weinert *et al.* (2007) also compared the demographic characteristics of e-bike users with that of bicycle users. They stated that e-bike users had higher incomes than bicycle users. In terms of educational background, the e-bikes users in Shanghai and Kunming also had a higher education level than bike users (Cherry and Cervero, 2007).

E-bike trip information

City	Year	Trip purpose*	Trip purpose^	Trip distance (km)	Trip time (min)	Speed (kph)	Trip frequency (per day)
Shanghai	2007	Commute	Shopping	4.83	25.56	13.04	2
Shanghai	2014	Commute	Shopping	11.09	31.82	19	NA
Shijiazhuang	2008	Commute	NA	5.8	27.2	14	3
Kunming	2007	Commute	Shopping	3.63	20.28	11.85	2.54
Fei County	2011	Commute	Go to school	NA	14.7	NA	2.73

* Primary trip purpose; ^ Secondary trip purpose.

Adapted from: Cherry and Cervero, 2007; Weinert *et al.*, 2007; Zhang, 2011; Ye *et al.*, 2014

Table 3.2 E-bike trip information

The primary trip purpose of e-bike adoption is commuting, which has more than 70% of the response rate regardless of the city size, location, and survey conduction time (Table 3.2). The second main purpose is shopping, followed by going to school. Combined with the aforementioned fact that e-bike users are mainly of a young age, it

could be concluded that the characteristics of e-bike users in China are that of young career-aged commuters (Weinert *et al.*, 2007).

Other trip information varies with the survey conduction year and city sizes. For instance, the survey conducted in Shanghai had very different results between 2007 and 2014 with regards to trip time, trip distance and e-bike speed. The average trip time increased from 25.56 minutes to 31.82 minutes, the average trip distance from 4.83 km to 11.09 km, the average speed of e-bikes from 13.04 kph to 19 kph, and e-bike trip distance increased by over 50% (Cherry and Cervero, 2007; Ye *et al.*, 2014). The increase of the trip time, trip distance and e-bike speed could imply that travel demand is changing and that e-bike performance is improving over time. The result could also imply that urbanisation could explain the increase of trip time.

Mode choice behaviour

	Shanghai		Kunming		Shijiazhuang		Xi'an	
	Previous mode	Alternative mode	Previous mode	Alternative mode	Previous mode	Alternative mode	Previous mode	Alternative mode
1	Bus (50%)*	Bus (55%)*	Bus (52%)*	Bus (58%)*	NA	Bike (62%)*	Bus (38.3%)*	Car (47.1%)*
2	Bike (19%)*	Bike (12%)*	Bike (38%)*	Bike (20%)*	NA	Bus (36%)*	Bike (31.4%)*	Bus (19.6%)*
3	Walk (10%)*	Walk (10%)*	Walk (11%)*	Car (8%)*	NA	Taxi (8%)*	Walk (16.3%)*	Walk (10.5%)*

* Response rate of the total participants

Adapted from: Cherry and Cervero, 2007; Weinert *et al.*, 2007; Zhang, 2011; Xu *et al.*, 2014

Table 3.3 Top three previously used modes and alternative mode choices

Table 3.3 summaries the previously used mode of e-bike users and their alternative travel modes in the absence of e-bikes. The e-bike users mainly transferred from buses, bikes and walking in Shanghai, Kunming and Xi'an (Cherry and Cervero, 2007; Weinert *et al.*, 2007; Xu *et al.*, 2014). If e-bikes were unavailable for some reason, travellers in Shanghai, Kunming and Shijiazhuang firstly considered transferring to

buses and bikes (Cherry and Cervero, 2007; Weinert *et al.*, 2008). The third best alternative mode choice varied between walking and using a car or taxi (Cherry and Cervero, 2007; Weinert *et al.*, 2007). However, the preferred alternative mode choice changed with time. In 2013, the best alternative modes were buses and bikes in Xi'an City, but afterwards changed to cars, buses and walking (Xu *et al.*, 2014). The result could imply that the demand of transportation changed over time.

Reasons for choosing e-bikes

	Shanghai 2007	Shanghai 2014	Kunming	Shijiazhuang
1	Fast (82%)*	Saving time (49%)*	Fast (72%)*	Faster than bike (80%)*
2	Less effort (20%)*	Bus inconvenience (20%)*	Public transport crowded (30%)*	Do not have to wait for bus (50%)*
3	Safer than motorcycle (9%)*	Comfort (15%)*	Cheaper than cars (28%)*	Comfortable (40%)*
4	Public transport crowded (8%)*	Saving money (12%)*	Less effort (26%)*	Bus is too crowded (38%)*
5	Cheaper than auto (5%)*	Convenience (5%)*	Safer than motorcycle (10%)*	Commuter distance too long for bike (32%)*

* Response rate of the total participants

Adapted from: Cherry and Cervero, 2007; Weinert *et al.*, 2007; Xu *et al.*, 2014.

Table 3.4 Top five reasons for e-bike adoption

Table 3.4 lists the top five reasons for e-bike adoption derived from different survey questionnaires. By comparing e-bikes with other travel modes, the reasons for e-bike adoption are summarised as faster speed, less effort, bus crowdedness, flexibility, saving time, comfortability, better performance, safety, saving money, and convenience (Cherry and Cervero, 2007; Weinert *et al.*, 2007; Xu *et al.*, 2014). The result indicates that e-bikes are a better alternative to bikes and buses (Weinert *et al.*, 2007).

The most prevalent reason for e-bike adoption is faster speed, followed by less effort, which could help conquer some physical barriers and offer commuters the ability to travel further (Popovich *et al.*, 2014). “Buses are too crowded” is another main reason why travellers shifted from buses, which indicates the insufficient public transport services in China (Cherry and Cervero, 2007; Weinert *et al.*, 2007). The other advantage of e-bikes is their “flexibility”, which is evidenced in quotes like “you do not have to wait for the bus” (Weinert *et al.*, 2007). It suggests that the demand of personal mobility emerges in China’s current transport system. In addition, e-bikes have an advantage as they allow people to achieve personal mobility.

3.3.2 Environmental impact

Generally speaking, e-bikes serve as a form of sustainable mobility (Pierce *et al.*, 2013), because the energy supply of e-bikes is electricity which can be renewable compared with petrol and diesel. Moreover, e-bikes are zero emissions in use, so do not contribute to air pollution. In addition, due to the light weight of e-bikes, energy consumption is further reduced. Compared with electric vehicles (EVs), which mean the cars driven by electric motors, the energy consumption of e-bikes is less than 2kWh/100km, which is 10% of a small EV and the carbon dioxide emission is 40 times less than a small EV (Ji *et al.*, 2012).

A report published by Asian Development Bank (2009) and a paper written by Cherry *et al.* (2009) detailed the environmental impact of e-bikes in China, which could be the most comprehensive study in this aspect, including e-bike lifecycle analysis, the comparison of e-bikes with other transport modes, and lead acid battery pollution and recycling. The environmental impact of transport modes is mainly divided into three parts: the e-bike production phase; e-bike use phase; and lead-acid batteries.

E-bike production phase

	Bicycle style electric bike	Scooter style electric bike	Bicycle	100cc motorcycle	Bus
<i>Weight of component materials (kg/vehicle) and % in total weight</i>					
Steel	18.2 (46.1%)	26.2 (46.5%)	13.0 (72.2%)	76.4 (81.3%)	6303(57.8%)
Plastic	5.7 (14.4%)	15.2 (27.0%)	2.0 (11.1%)	9.1 (9.7%)	553 (5.1%)
Lead	10.3 (26.1%)	14.7 (26.1%)	--	1.7 (1.8%)	90 (0.8%)
Nickel	--	--	--	0.3 (0.3%)	--
Fluid	2.9 (7.5%)	4.2 (7.5%)	--	--	78 (0.7%)
Copper	2.6 (6.6%)	3.5 (6.1%)	--	1 (1.1%)	109 (1.0%)
Rubber	1.1 (2.9%)	1.2 (2.2%)	2.0 (11.1%)	3.2 (3.4%)	405 (3.7%)
Aluminium	0.5 (1.3%)	0.6 (1.0%)	1.0 (5.6%)	1.5 (1.6%)	1666 (15.3%)
Zinc	--	--	--	0.8 (0.9%)	--
Glass	--	0.2 (0.3%)	--	--	490 (4.5%)
Wood	--	--	--	--	396 (3.6%)
Other	--	--	--	--	308 (2.8%)
Total weight	41.3	65.8	18.0	94	10900
<i>Associated energy and emissions of manufacturing processes</i>					
Energy use (tonne SCE)	0.179	0.261	0.045	0.188	34.345
Energy use (kWh)	1456	2127	363	1534	279605
Air Pollution (SO ₂) (kg)	1.563	2.198	0.275	1	274
Air Pollution (PM) (kg)	5.824	8.173	1.176	4	1064
Greenhouse gas (tonne)	0.603	0.875	0.097	0.284	70.601
Waste water (kg)	1488	2092	393	1397	291182
Solid waste (kg)	4.463	7.139	0.641	3	756

Adapted from: Asian Development Bank, 2009.

Table 3.5 The production phase of e-bikes and other modes

Table 3.5 shows raw material use, energy use, and emissions in the main production phase of e-bikes, bikes, motorcycles and buses. The main production processes for manufacturing these vehicles are identified as the “mining or extraction of raw materials, processing those raw materials into usable refined materials, fabricating refined materials into individual parts, and finally, assembling the parts into a vehicle” (Cherry, *et al.*, 2009). From Table 3.5, the lead material contributes to 26.1% of the total weight of the component material of e-bikes, which forms the main concerns attributed to lead pollution. The main reason for this is that e-bikes equipped with lead-acid battery dominate the market (Mao *et al.*, 2008). For other material usage (*e.g.* plastic, rubber and steel), e-bikes require much less than motorcycles and buses, although they need more than bikes do. Consistent with material consumption, the energy use and emission of production processes have the same tendency. That is,

e-bikes rely on less energy use and emit less pollution than motorcycles and buses, while bike production processes have the lowest energy use and pollution. As a result, compared with motorcycles and buses, the production processes of e-bikes are greener. However, compared with the bike production process, e-bikes appear to be much less sustainable.

E-bike use phase

The use phase comparison studies conducted by Cherry *et al.*, (2009) and Asian Development Bank (2009) showed that e-bikes provide a considerable environmental improvement in terms of the most emissions compared with car use and bus travel in the condition of a per passenger kilometre basis. In addition, Xu *et al.* (2014) analysed the environmental impacts of e-bikes by simulating the levels of energy use and pollutants in two scenarios: with e-bikes and without e-bikes in the Xi'an City. The result indicated that the adoption of e-bikes reduces energy use and CO₂ emission, but increases the emissions of SO₂, PM and lead emission (Xu *et al.*, 2014).

The average electricity consumption of e-bikes is 2.1kWh/100km, including the transmission losses and in-plant losses (China Statistics Bureau, 2007). Because batteries can be removed from e-bikes, users are able to charge the battery at e-bike users' work places. As a result, the electricity demand would be eased by battery charging time, which allows charging batteries in the off-peak time to increase the ratio of electricity usage. However, the electricity consumption from e-bikes is still a problematic issue in China as electricity generation relies heavily on coal-fired power plants (Ji *et al.*, 2012).

Lead-acid battery

E-bikes are restricted because of the level of lead pollution created by lead-acid batteries in 2011 (Rose, 2012). In 2007, 95% of the e-bikes in China used lead acid

batteries (Chen *et al.*, 2009). Although lithium batteries were expected to be a possible substitute, lead acid battery designs still occupied 95% of the e-bike market in China (Liu *et al.*, 2015). So the lead pollution caused by lead acid batteries is still the major concern with regard to using e-bikes.

The lifespan of lead acid batteries is usually one to two years (Cherry *et al.*, 2009). After that, lead acid batteries need to be replaced by new ones in order to maintain their endurance power. As a result, an e-bike could use five to seven batteries in its lifespan (Chen *et al.*, 2009). For e-bikes and hybrid style e-bikes, the lead acid batteries usually use 36V or 48V battery systems with an average weight of 10 kg (Tian *et al.*, 2015). The scooter style e-bikes are typically equipped with 48V or 72V battery systems, with an average weight of 18 kg (Tian *et al.*, 2015). The lead component accounts for 70% of the total battery weight, which means that a bicycle style e-bike or a hybrid style e-bike carries 7kg of lead and a scooter style e-bike loads 14.7 kg of lead (Liu, *et al.*, 2015).

More seriously, only 33% of lead-acid batteries in China are properly recycled by official companies, while 67% are illegally recycled in hazardous and polluting ways (Chun, 2013). The uncontrolled lead recycling process increases the likelihood of a negative impact on human health, such as developmental disorders and a lower IQ (Sanders *et al.*, 2009). Therefore, lead recycling is the key challenge of using e-bikes. One solution is to propose strict regulation for lead acid recycling (Dill and Rose, 2012). In addition, lithium battery technology should be further developed to improve the environmental impact of e-bikes (Rose, 2012; Weinert *et al.*, 2007).

3.3.3 Health effects

Table 3.6 lists the health effects of PM_{2.5} (fine particulate matter) from different pollution sources. From the table, the emission factor of e-bikes is higher than

gasoline cars. The e-cars have the highest emission factor. The reason for this is that the electricity generated by coal increases the emission factor in the use phase of e-bikes and e-cars (Ji *et al.*, 2012). However, the health impacts of emissions from e-bikes and e-cars should be much lower because most of the power plants are far away from where people live (Ji *et al.*, 2012). In this case, e-bikes provide some environmental benefits for China in terms of CO₂ reduction, less energy use, and less emission factors, when e-bikes are used to replace the motorised vehicles (Cherry *et al.*, 2009). However, the e-bikes are the driving force of lead pollution in China (Van der Kuijp *et al.*, 2013).

	Gasoline car	Diesel car	Bus	E-car	E-bike
Emission factor (mg[person-km] ⁻¹) ³	3	30	12	58	9
Kilometres travelled (km y ⁻¹)	10 ¹⁰				
Intake fraction (ppm)	51	51	51	8.2	8.2
Unit dose (g death ⁻¹)	188	188	188	188	188
Total excess deaths per year	9	90	32	26	3

Adapted from: Ji *et al.*, 2012.

Table 3.6 Example calculation: health effects of PM_{2.5} in Shanghai

3.3.4 Safety issues

Safety issues are perhaps the most controversial topic related to e-bikes, and these also influence the direction of e-bike policy and regulation to a great extent. There have been an increasing number of literatures focusing on e-bike safety issues in recent years, especially in China. Here, most research focused on four themes of e-bike safety: 1) the perception of safety using survey questionnaires; 2) crash and injury data analysis from hospital and government crash records; 3) conflict and violation behaviour mainly using camera recorded observation at intersections; and 4) possible solutions to increase safety levels by using comparison studies and simulation.

Perception of safety

Although e-bikes are considered as “dangerous” vehicles to the e-bike users (Tyfield, 2014), some studies gave evidence that e-bike users feel safer using these compared with other two-wheeler vehicles. When e-bike users were asked why they chose to use e-bikes, some of the respondents believed they are safer than motorcycles (Cherry and Cervero, 2007).

Another perception of safety analysis in Shijiazhuang found that female e-bike users feel safer, while both male and female e-bike users feel that fast speed of e-bikes causes some conflicts with ordinary bike users (Weinert *et al.*, 2007). Another study by Lin *et al.* (2008) showed that travellers feel safer when riding e-bikes than when riding bicycles.

Although e-bike users feel safer riding e-bikes, the results showed that the biggest annoyances to e-bike users were other two-wheeler vehicle users and not car drivers and pedestrians (Weinert *et al.*, 2007).

A study analysis investigated user behaviour associated with crash history and found that lower safety attitudes and risk perception was the main cause of the at-fault crashes (Yao and Wu, 2012). In the e-bike studies in China, no study showed a different perception of safety among the two-wheeler vehicles.

E-bike crash data in China

The e-bike crash data used to examine e-bike related injuries are mainly sourced from traffic police and hospital records. Feng *et al.* (2010) provided the earliest study of the relationship between the rapid e-bike development and the increase in injuries by inspecting police crash data between 2004 and 2008. They found that the rates of

mortality and injury increased by 6.5 times in 2004 and 3.7 times in 2008, whilst both injuries and fatalities per 100,000 registered e-bikes slightly decreased between 2004 and 2008. Then, the authors suggested improving current regulations to increase safety levels.

A more recent study examined the non-fatal injury rate and mortality using the police records of crash data from 2004 to 2010 (Zhang *et al.*, 2013). They found that e-bike related non-fatal injuries increased four times, from 0.41 per 100,000 population in 2004, to 1.52 per 100,000 population in 2010, while the mortality rate per 100,000 population was decreasing over the same period. Furthermore, they employed linear regression to predict that the e-bike related casualty rate would significantly increase by 23% per 100,000 population per year. The authors suggested that more efforts were needed to reduce the e-bike related injuries, including mandatory legislation for wearing a helmet, the requirement of a driving license, and mandatory insurance.

The e-bike user injury patterns were studied in a rural hospital in Suzhou over seven months (Du *et al.*, 2013), using data from 500 people who were hospitalized with non-fatal injuries. Findings showed that e-bike related injuries accounted for 25% of all the hospitalised injuries, with 57.2% of injuries from road crashes. In addition, fractures and head injuries were the main injury types. Head injuries in particular were associated with night-time e-bike crashes and collisions with motor vehicles. As a result, the authors advised e-bike users to use helmets to prevent head injuries.

A comparison study between e-bike users and bike users was conducted in Hefei from 2009 to 2011, mainly through hospitalised records (Hu, *et al.*, 2014). This comparison study showed that nearly 33% of e-bike users suffered severe injuries, compared with only 17% of bike users. The injuries were caused by violating traffic rules. In addition, compared with small motor vehicles, the accidents caused by large motor vehicles increased the rate of severe injuries.

Lu *et al.* (2015) focused on examining the characteristics of fatal e-bike crashes on urban roads by analysing the crash reports (2010–2012) of Taixing City in China, which explained the reasons behind these crashes. They revealed the following findings: 1) most of fatal crashes were associated with e-bike users' aberrant behaviours, including driving on the motorway, red light running, and driving against the direction of traffic; 2) fatal e-bike crashes were mainly related to heavy goods vehicles and smaller passenger cars; 3) e-bike users with a lower level of education tended to display more aberrant behaviours; and 4) most night-time fatal crashes occurred due to a lack of street lighting.

E-bike safety behaviour

The e-bike safety behaviour research is mainly studied using video-based observation at signal intersections, because intersections are highly mixed by different vehicle users, which leads to more frequent aberrant behaviours. Most of the studies showed that running red lights is the most commonly found violation behaviour. One of the earliest studies (Wang *et al.*, 2011) that investigated intersection behaviour revealed that typical e-bike violation behaviours included running red lights, riding in the wrong direction, waiting at improper positions, riding in improper lanes and overloading in Shanghai. They further discovered that aberrant e-bike behaviours are very closely linked with the traffic environment (*e.g.* traffic facilities, traffic signal status, and other riders' behaviours), but less associated with users' characteristics (*e.g.* age and gender). They concluded that the violation behaviours of vehicle users did not much differ under the same traffic environment. In addition, e-bike users had more aberrant behaviours than users of other two-wheeler vehicles and tricycles. As a result, they recommended encouraging the construction of traffic facilities to support e-bike use and enhancing e-bike user safety awareness. A similar study (Du *et al.*, 2013) identified the unsafe riding behaviours of e-bike users by observing more than 18,000 e-bike users at intersections in Suzhou. They found that the unsafe behaviours included carrying passengers, riding on motor lanes, running red lights, talking on the

phone, and riding in the opposite direction to traffic.

Another study (Wu *et al.*, 2012) applied a similar approach and found that red light running among bike and e-bike riders in China accounted for 56% of all the violation behaviours, which was associated with both users' demographic and situational factors. In addition, e-bike users have a higher rate of red light running behaviour (63%) than bike users (50%). They explained that the possible reasons could be: 1) a general acceptance of red light running; 2) little general differentiation between e-bikes and bikes; and 3) the sampling sizes were too small to find a statistical difference of red light running behaviour between e-bike users and bike users.

A comparison study (Bai *et al.*, 2013) provided information of aberrant behaviour among all the road users. They used video-based observation data as raw data, which was further distributed by the risk-taking behaviour of e-bikes users and bike users and categorised to 16 types of conflicting movements, and then Poisson Regression was applied to predict models for conflict. They found that 6.53% of e-bike users showed red light running violation behaviours, which was higher than bike users (4.66%). In terms of the 16 types of conflicting movements, they discovered that 75% of the behaviours were displayed by motorised vehicle drivers, while the other 25% of responsibility was evenly shared by bike users and e-bike users. However, e-bike users had higher conflict rates than that of other bike users.

A study (Yang *et al.*, 2015) used a hazard-based duration approach to examine when and why e-bike and bike users run against red lights at signalised intersections. They found that most of the red light running violation behaviour was associated with waiting time: 1) 21% of e-bike and bike users ran against red lights without waiting; 2) more than 50% of riders waited for 49 seconds; 3) 25% of riders waited 97 seconds; 4) e-bike users had a higher violation hazard and waited less time than other bike users; 5) male riders were more likely to display violation behaviours compared with female riders.

Although e-bikes have violation behaviour problems, much evidence shows that e-bike safety outperformed that of motorcycles and cars (Liu and Sun, 2011). 77.7% of conflicts were caused by the risky behaviour of motor vehicle drivers, while only 13.2% of conflicts were caused by e-bike users and bike users (Bai *et al.*, 2013). Four studies examined the speed of e-bikes in the mixed flow of e-bikes and bikes. Three of them found that e-bike speeds were 40% to 50% faster than that of bikes (Cherry & He, 2010; Lin *et al.*, 2008; Yang *et al.*, 2014). One study found that the speed of e-bike and bicycle flows was higher than that of pure bicycle flows due to the higher speed of e-bikes (Zhou *et al.*, 2015). These speed studies did not concentrate on safety issues, but they provided empirical evidence of traffic regulation and control.

Possible solutions to increase the e-bike safety level

Due to the concern about e-bike safety issues, some studies gave possible solutions to increase e-bike safety levels by using regression analysis. An earlier study (Chen *et al.*, 2010) examined the mixed flow of shared-use paths used by pedestrians, e-bike users and bike users. They found that increasing widths of shared-use paths could ease all types of traffic conflicts. As running red light behaviour was a common violation behaviour of e-bike users, a study (Zhang and Wu, 2013) examined whether installing sun shades can decrease red light running behaviours. They found that the probability of running against red lights without sunshields was 1.367 times higher than that with sunshields when other traffic environment factors were controlled, but the effect of sunshields was significantly weaker on cloudy days than on sunny days. They recommended installing sunshields for torrid climate areas to improve the safety performance of e-bike users and bike users. Another study (Dong *et al.*, 2014) investigated the effect of flashing green light on the red light violation behaviour. They found that flashing green lights could give e-bike users more time to decide to stop and go during signal change intervals, which prevented some aggressive behaviours. However, in the literature of e-bike safety in China, more detailed data

are still needed. In addition, there is little knowledge of the cause and fault analysis (Fisherman and Cherry, 2015).

3.3.5 The context in which e-bikes was growing

	Motorcycle	Bicycle	Private car	Moped ^a
1985	NA	152.27	NA	NA
1986	NA	163.45	NA	NA
1987	NA	176.53	NA	NA
1988	NA	177.54	NA	NA
1989	NA	184.68	NA	NA
1990	NA	188.59	NA	NA
1991	NA	185.51	NA	NA
1992	2.8	190.48	NA	NA
1993	3.53	197.16	NA	NA
1994	5.26	192	NA	NA
1995	6.29	194.26	NA	NA
1996	7.94	193.23	NA	NA
1997	11.6	179.1	0.19	NA
1998	13.22	182.05	0.25	NA
1999	15.12	183.03	0.34	NA
2000	18.83	162.72	0.51	NA
2001	20.4	165.42	0.6	NA
2002	22.19	142.71	0.88	2.72
2003	24	143.55	4.25	1.36
2004	24.48	140.21	2.18	6.5
2005	25	120.04	3.37	9.54
2006	25.3	117.57	4.32	12.61
2007	24.81	NA	6.06	17.5
2008	21.39	NA	8.83	23.12
2009	22.4	NA	10.89	25.73
2010	22.51	NA	13.07	28.37
2011	20.13	NA	18.58	32.56
2012	20.27	NA	21.54	34.47

^a Moped refers to e-bike, e-scooter, and gasoline scooter

Adapted from: Nanjing Statistics Bureau (2005-2015)

Table 3.7 Ownership of vehicles per 100 urban households, China 1985-2012

Table 3.7 shows the changes of ownership of various vehicles at a household level in

China. The motorcycle ownership per 100 urban households increased from 1992 to 2006. In 2006, the motorcycle ownership per 100 urban households reached the highest level, 25.3, taking 15 years. After that, the motorcycle ownership per 100 urban households decreased. The bicycle ownership per 100 urban households increased from 1985 to 1993, and afterwards decreased. The highest level of bicycle ownership per 100 urban households was 197.26 in 1993. The ownership of private cars per 100 urban households increased from 1997 to 2012 with highest level of 21.54, taking 15 years. The moped (e-bikes, e-scooters, and gasoline scooters) ownership per 100 urban households has increased since 2002. After seven years of development, the moped ownership per 100 urban households has exceeded private car ownership. After eight years of development, the moped ownership per 100 urban households has exceeded motorcycle ownership. In 2012, the moped ownership per 100 urban households was 34.47.

3.3.6 Reasons for the rapid development of e-bikes in China

As e-bikes rapidly developed in China, some researchers explored the reasons for the e-bike transition phenomenon in China. A main factor is technology, particularly the improvement in batteries and motors which enabled e-bike market growth (Weinert *et al.*, 2007). In the 1990s, the e-bike motors had to be changed every three months, because their durability was very poor with high noise, low efficiency, and poor slope-climbing ability (Huang, 1999). During 2003, brushless motors were developed, which have a low material cost, low noise, higher efficiency and a very long lifespan (10–20 years) (Zhen *et al.*, 2006). In 2005, the sales of e-bikes increased to 15 million (Zhen *et al.*, 2006). In addition, lithium-ion batteries were developed to be lighter in weight and smaller in volume compared with lead acid batteries. The technology development of e-bikes provides a substantial market.

Economic factors included the income level of citizens, low e-bike purchase costs,

low e-bike operation costs, and high fuel costs (Weinert *et al.*, 2007). The income level of citizens increased by 82% from 5,160 CNY in 1997 to 9,422 CNY in 2004 (Weinert *et al.*, 2007). In 2014, the annual disposable income of urban households per capita (CNY) was 28,844, which is 5.6 times more than the income level in 1997 (China Statistical Bureau, 2015). On the other hand, the average e-bike price in 2013 is similar to that in 2004, which ranges from 2,000 CNY to 3,000 CNY (Weinert *et al.*, 2007; Xu *et al.*, 2014). In this case, there is a huge reduction in the price of e-bikes relative to the increase in income. Because of the usage of electricity, the operation cost of e-bikes is much lower than that of gasoline scooters, motorcycles, public transport, and private cars due to the low electricity fare and high fuel cost (Weinert *et al.*, 2007).

Policy factors mainly included one national law which allowed e-bikes to travel on the road and a national e-bike standard; this opened the door to the e-bike market (Weinert *et al.*, 2007). Some local government regulations of e-bikes were also analysed, and divided into pro-e-bike policy (Shanghai and Chengdu), anti-e-bike policy (Guangzhou), and neutral e-bike policy (Shijiazhuang). Another study (Ruan *et al.*, 2014) also found that the government played an important role in its success, such as national safety law and national e-bike standard released from central government, and motorcycle bans from local governments. However, compared to government support for the car and motorcycle industry, the support from government for e-bike development was negligible and unsustainable (Dill and Rose, 2012).

Environment protection is also an important factor for fast e-bike growth. The air pollution is one of the reasons that motorcycles were banned in many areas, which created a market gap for e-bikes. On the other hand, since e-bikes are environmental friendly, the e-bike users emphasised this point to oppose the e-bike ban policy in some cities.

In addition, with the urbanisation and the increase of housing price, many citizens had

to move out of the town, which resulted in the increase of the travel distance (Chen *et al.*, 2011; Wang and Chai, 2009). Meanwhile, the cost of public transport was increasing (Weinert *et al.*, 2007). In this case, e-bikes became a practical vehicle to achieve personal mobility due to low purchase and operation cost.

Later, Weinert *et al.* (2008) further analysed the reasons for e-bike market growth, separating the factors as driving forces and resisting forces. The driving forces were a policy that banned motorcycles, local policy support for e-bikes, the cost and performance improvement of e-bikes, and a poor bus provision and service (Weinert *et al.*, 2008). The resisting forces were an e-bike ban policy, demand for motorcycles, and support for public transport (Weinert *et al.*, 2008). They further proved that the driving forces outweigh the resisting forces. Compared with previous studies, this study provided a more comprehensive research of e-bike rapid growth reasons and the challenges that e-bike transition may face in the future.

3.3.7 The limitation of e-bike studies in China

The previous e-bike studies in China have some restrictions. Firstly, the number of studies in the characteristics of e-bike users is very limited. Many of the studies were conducted in 2006 and 2007. Nevertheless, in the period between 2006 and 2014, e-bike sales in China increased dramatically from 18 million to 32.4 million, so it is necessary to update the information of e-bike user characteristics. Secondly, as criticised by Fishman and Cherry (2016), the studies employing survey questionnaires display self-selection bias, because the survey questionnaire method is greatly dependent on e-bike owners' responses. The bias needs to be minimised by using a sample from the general e-bike user population in future studies (Fishman and Cherry, 2016). Thirdly, the existing studies do not provide information of e-bike use patterns, changing behaviour, the anxiety felt by e-bike users, the feeling associated with using e-bikes, the attitude of e-bike users, and how e-bike users position themselves in the

transport system. Fourthly, the previous literature normally did not adopt a unified theory framework for analysis. To conquer these limitations and explore e-bike user characteristics in a wide range of aspects, our research uses more than 1,000 questionnaires which are designed on the base of semi-structured interviews. Furthermore, the transition theory is used in our work for analysis of e-bike transition in China.

3.4 E-bike research in other countries and areas

E-bike research in other countries and areas are also limited. They mainly focused on its early adoption and niche market. Some studies analysed the characteristics of e-bike users, and some provided safety information regarding e-bike adoption. In addition, e-bikes are considered as a sustainable mobility to benefit health and mitigate climate change.

3.4.1 Characteristics of e-bike users

Demographic information

	Gender (%F)	Age	Education	Income	Other vehicle ownership
North America	15%	Over 44 (71%)	College graduate (37%) Graduate degree (34%)	NA	Bicycle (94%)
Australia	29%	41-60 (57%)	University degree and above (72%)	Over 75,000 AUD (61%)	Car (90.4%)
Austria	41%	Over 60 (61.6%)	Secondary education (57%)	Less than €1,674 (64%)	Car (85%)

Adapted from: Johnson and Rose, 2013; MacArthur *et al.*, 2014; Wolf and Seebauer, 2014.

Table 3.8 Demographic information of different countries and areas

From Table 3.8 we can see that the demographic information of e-bike users in different countries and areas are diverse. The ratio of female e-bike users in North

America is only 15%. 71% of the total participants were over 41 years old, and 94% of them had a bicycle (MacArthur *et al.*, 2014). An online survey conducted in Australia showed that only 29% of e-bike users were female (Johnson and Rose, 2013). The age distribution of e-bike users mainly ranged from 41 to 60 years old (Johnson and Rose, 2013). In addition, 72% of them held university degrees and had higher incomes than average population, and 90.4% of them had a car (Johnson and Rose, 2013). The survey conducted in Australia found that 41% of the e-bike users were female, which is higher than North America and Australia, while the average education of e-bike users was the lowest. 57% of the participants were educated to secondary level and had a lower income (Wolf and Seebauer, 2014). In addition, the majority of the participants were aged 60 years old and above and owned a car (Wolf and Seebauer, 2014). Compared with e-bike users in China, the e-bike users in these countries and areas tend to be older, are mainly male, and own a car.

Trip information

Some evidence showed that e-bikes could increase trip frequency and distance. In North America, e-bikes were found to increase cycling participation (MacArthur *et al.*, 2014). The survey result indicated that 55% of e-bike users travelled by bicycle weekly or daily, while 93% of the participants rode weekly or daily since owning an e-bike (MacArthur *et al.*, 2014). A comparison study in Norway randomly selected 66 individuals who were given an e-bike and compared them with a control group of 160 individuals with bicycles (Fyhri and Fearnley, 2015). The study found that the trips of the e-bike user group increased and trip distances increased, while the control group with bicycles showed no increase (Fyhri and Fearnley, 2015). In addition, the trip distance in the group using a mixed e-bike and bicycle share system is 13% higher than that in the group using purely bicycle share system (Langford, 2013). In addition, the e-bike adoption increased the travel speed (Marchetti, 1994). In China, compared with bicycle adoption, the trip frequency, trip distance and travel speed also increased following e-bike adoption (Cherry and Cervero, 2007; Weinert *et al.*, 2008).

Reasons for e-bike adoption

Similar to the reasons for e-bike adoption in China, the key benefit of e-bikes is identified as being able to “maintain speed with less effort”, and allowing users to travel more comfortably with less exertion (Popovich *et al.*, 2014). E-bikes were viewed as promising vehicles to provide mobility to those who, due to physical limitations, could not ride bicycles (Inagaki *et al.*, 2012; Langford *et al.*, 2013; Rose, 2012). Both MacArthur *et al.* (2014) and Johnson and Rose (2013) found that e-bike adoption helped to conquer some of the commonly cited barriers to bicycle riding, which increased speed and reduced physical exertion. In addition, Heinen *et al.* (2010) identified the barriers of bicycle adoption as “topography, distance, and time limitations”, while e-bike adoption mitigated these negative factors. High temperatures, poor air quality and precipitation also pushed travellers to shift from bicycles to e-bikes (Campbell, 2012). In addition, a study in Austria found that other important reasons for e-bike adoption were social contexts (*e.g.* a positive attitude to e-bikes), the environmental benefits, and more health consideration for leisure use (Wolf and Seebauer, 2014). Last but not the least, the most cited reason for e-bike adoption was its potential as a replacement for motor vehicle use in Australia and North America (Johnson and Rose, 2013; MacArthur *et al.*, 2014; Popovich *et al.*, 2014).

3.4.2 Safety issues

The perception of safety

Similar to the studies in China, e-bike safety perception studied in other countries supported that e-bikes were safer than bicycles. MacArthur *et al.* (2014) found that 60% of e-bike users felt safer using an e-bike and 42% felt that e-bikes had assisted in

avoiding crashes. MacArthur *et al.* (2014) further explained that compared with bicycles e-bikes could accelerate to get out of an intersection quickly, keep up with car traffic, and have a better balance at higher speeds, which enhance the traffic safety.

E-bike safety behaviour

The research regarding the safety of the e-bike users' behaviours in other countries and areas is very limited. A safety study found that the rate of risky behaviour was relatively high on intersections (Johnson *et al.*, 2011). Popovich *et al.* (2014) found that e-bike users were more likely to display traffic violation behaviour compared with bike users in the USA. Weber *et al.* (2014) used police-recorded accident data in Switzerland to analyse the characteristics of e-bike users and found that they were most frequently involved in single accidents related to higher velocities. A more recent study (Dozza *et al.*, 2014) also found that higher velocities were the main reasons behind e-bike accidents. They suggested that increasing e-bike conspicuity would be the easiest and most obvious way to improve safety for e-bike users (Dozza *et al.*, 2014). However, Langford *et al.*, (2015) argued that e-bike and bicycle users behaved very similarly at intersections, violating at about an equal rate to those using GPS equipped e-bikes and bicycles in the USA. In addition, a study on the safety of e-bikes and bicycles found that crashes with e-bikes and bikes were about as equally severe (Schepers *et al.*, 2014).

3.4.3 The promotion of e-bike adoption

As discussed previously, e-bikes entered niche markets in other countries and areas. As a result, some research examined the benefits of e-bike adoption in different aspects, attempting to promote the use of e-bikes and achieve a sustainable form of mobility. There are two main reasons for e-bike adoption promotion. One is the health impact, and the other is the environmental impact.

Health impact

Several studies measured the impact of e-bikes on health, especially on increasing physical activity. An earlier study (Simons *et al.*, 2009) conducted in the Netherlands measured the physiological variables of e-bike use in three different settings (without any power assistance, on eco mode, and on the most electrical assistance). The result showed that all three power settings provided a necessary increase in physical activity to help reduce the likelihood of developing sedentary lifestyle diseases (Simons *et al.*, 2009).

Another study (Gojanovic *et al.*, 2011) tested sedentary subjects in four different trips at a self-selected pace: walking, biking, using e-bikes at a high power setting, and using e-bikes at a lower power setting. This test investigated whether e-bikes in a hilly city allowed sedentary subjects to commute comfortably and make a sufficient effort for health enhancing purposes. They found that e-bikes were comfortable and had ecological transportation modality, making usage easier and needing only mild effort to climb hills. As a result, it is possible to promote e-bikes in a challenging urban environment thanks to their physical and environmental benefits (Gojanovic *et al.*, 2011). Using a similar approach, Sperlich *et al.* (2012) found that the energy expenditure of e-bike users were within the range necessary for health enhancement. In addition, de Geus *et al.* (2013) found a positive physiological change after a six-week period of e-bike adoption.

Environmental impact

E-bikes are widely regarded as an effective approach to mitigate the effects of climate change compared with the usage of gasoline motor vehicles. In the UK, Pierce *et al.* (2013) found that if e-bikes were used to replace all car trips with a travelling distance of less than three miles, 3140 kWh of energy would be saved and 748 kg of CO₂

emissions would be reduced. They also conceived that e-bikes were safe to use for urban commuting or other purposes within a practice area of 5.5 square miles. In the USA, an e-bike sharing project was established to develop a sustainable transportation system at the University of Tennessee campus (Ji *et al.*, 2014). In Sweden, Collado *et al.* (2015) found that 5% of commuting trips using cars could be substituted by e-bikes, and 4% of the trips less than 10km could be replaced by e-bikes.

E-bikes also reduce energy consumption. This point was verified by a case study conducted in Lisbon, Portugal (Baptista *et al.*, 2015). In the analysis of Well to Wheel energy consumption, e-bikes only consumed “11%, 3%, 1%, 2% and 4% of the energy requirement when adopting low powered electric vehicle, standard electric vehicle, conventional gasoline and diesel technologies and bus, respectively” (Baptista *et al.*, 2015). As a result, the Well to Wheel emission of e-bikes was lower than that of five types of vehicles, especially when concerning the CO₂ emission and NO_x emissions (Baptista *et al.*, 2015). In addition, e-bikes increased the average speed by 8%-26 % compared with bicycle riding, especially, for the slope routes (Baptista *et al.*, 2015). As a result, the authors suggested adopting e-bikes for longer distances and hilly paths in the urban areas to achieve a sustainable form of transport, that was faster and more comfortable (Baptista *et al.*, 2015).

3.5 Conclusion

Due to the e-bike inequality sales in China and other countries, the studied e-bike literature themes vary accordingly. In terms of the characteristics of e-bike users, the e-bike users in China tend to be young career-aged commuters, while e-bike users in other countries tend to be elderly people who use them for leisure purposes. In all of the countries, e-bikes increase the travel distance and travel frequency. The main reasons for e-bike adoption are high speed with less effort.

E-bikes face issues with lead-acid pollution and electricity generation in China, while many countries treat e-bikes as a solution for sustainable mobility. In terms of safety studies, running red lights is the main traffic violation behaviour in China, while high speed is the main problem in other countries. The health study in China provides very limited information, while e-bikes are proved to increase physical activities in other countries.

In addition to obtain current knowledge of “e-bikes” from existing e-bike literature, we also compare them with our research result for further analysis and discussion. Moreover, the survey questions in the previous research are a very helpful reference for our questionnaire design in the Nanjing case study to answer RQ3, RQ4 and RQ5.

Although successfully applied to a wide range of transition processes, the transition theory was still not used in previous e-bike research. Our work will fill this research gap by adopting transition theory to analyse the e-bike development in China (RQ1 and RQ2).

Most of the survey questionnaire studies lead to self-selection bias, which could be improved by using larger samples and more even sample distribution. Hence, our study used 1,053 questionnaires in Nanjing City to provide a comprehensive study of e-bike use pattern (RQ3, RQ4 and RQ5).

Also, the surveys in the previous work have a limited question scope, such as e-bike battery technology issues and attitudes to e-bike regulation, the interactions between e-bike users and other model vehicle users, charging use patterns, and so on. These are the important mechanism of the rapid development of e-bike in China (RQ5) and therefore will be included in our survey questions.

Chapter 4

Research Design

4.1 Introduction

The aim of this chapter is to describe and justify how our research is designed and conducted. The research design is referred to as “the overall strategy that the researchers choose to integrate the different components of the study in a coherent and logical way” (Bryman and Bell, 2011). The aim of the research design is to provide a framework for data collection and analysis, which means that a series of choices for collecting the evidence are needed to answer the research questions under investigation (May, 2011).

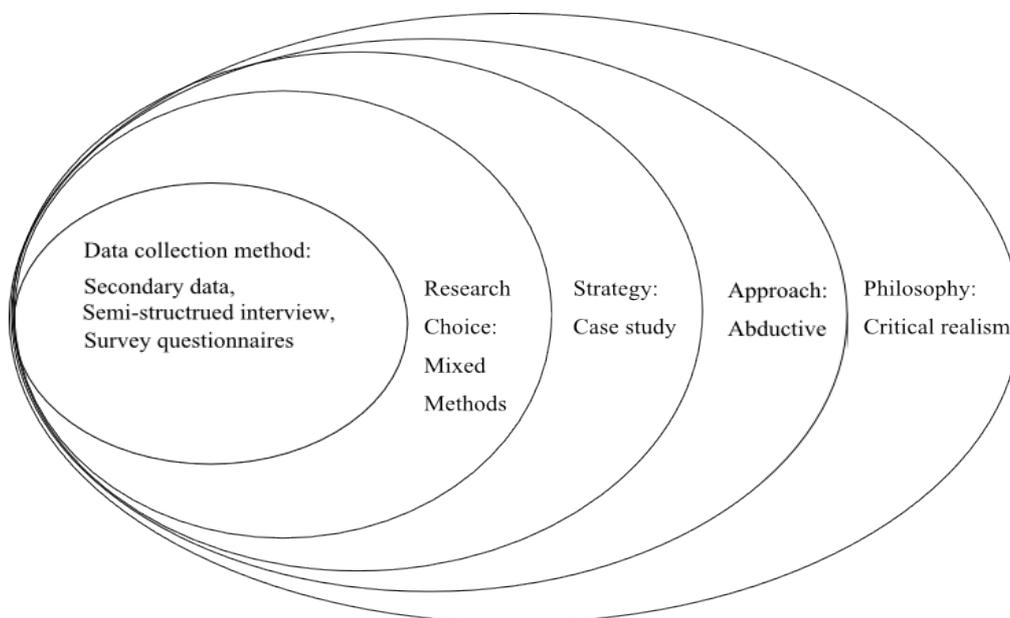


Figure 4.1 The research onion of our research design

The research design can be described by a research “onion” (Saunders *et al.*, 2012)

which consists of many layers: the outer layer is the philosophical stance which underpins the research design, which sequentially determines the inner layers such as research approaches, research strategies, research choices, and data collection and analysis methods. This “onion” sequence of methodological enquiry is widely accepted in academia (Saunders *et al.*, 2012; Kelemen and Rumens, 2008). The research design onion of the thesis is shown in Figure 4.1. As the figure shows, in the research design we adopted critical realism as our philosophy stance, and employed abductive approaches, case study strategies, and mixed methods. In addition, the data collection methods we used were secondary data, semi-structured interviews and survey questionnaires.

To clarify and justify our choices in the research design, the chapter is structured according to the research “onion” of our work (from the outer layer to inner layer). Section 4.2 explains the rationale behind the selection of critical realism. Section 4.3 justifies the choice of case study strategy. Section 4.4 demonstrates why and how the mixed method approach is used. The phases of the research are also clarified in this section. Section 4.5 describes and justifies the data collection method corresponding to each research phase. The forms of data collection include secondary data, semi-structured interviews and survey questionnaires. Section 4.6 provides the criteria to evaluate the quality of the research design. Finally, section 4.7 explains the ethical considerations of the research design, followed by the conclusion section.

4.2 Rationale for the selection of critical realism

Philosophy concerns the basic issues about knowledge, reality and existence (Thomas, 2004). It provides “the version of what exists and therefore how we can go about seeing it”. It also influences researchers’ judgment about good or bad research (Mason 2002, p. 6). In the domain of methodological enquiry, philosophy usually covers ontological and epistemological assumptions. The former issue is in relation to

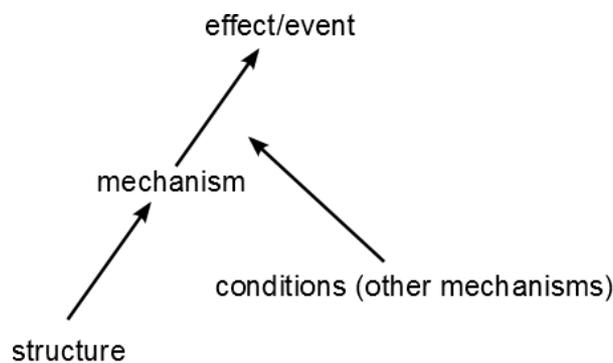
the nature and essence of the nature world, and the latter involves how this social reality can be known and how knowledge can be demonstrated (Bryman and Bell, 2011). Ontological and epistemological assumptions are often intertwined, and have different forms of combinations that further generate the core of various research paradigms.

4.2.1 Critical realism

The philosophy stance of the thesis is critical realism. Saunders (1986) explained critical realism as “unlike empiricist/positivist approaches which see causality in terms of correlation between events (whenever A occurs then so too does B), realist philosophy argues for a conception of causality in terms of generative mechanisms. Theoretical progress thus entails identification of the “necessary” mechanisms that tend to produce given tendencies. The fact that such tendencies may not become manifest in observation is that the operation of contingent factors cannot be theorised obviously but their effects can be examined in given empirical cases.”

As Saunders claimed, critical realism should be distinguished from positivism. Critical realism refutes the positivists’ model of causation. Critical realism points out that “generative mechanisms” are the underlying factors which produce given tendencies, and that the reasons why these tendencies are not observed is due to contingent factors in operation rather than the failure of repeated empirical observations. Bhaskar (1986) further pointed out that believing positivism is an epistemic fallacy, because positivism believes that an event can be understood through repeated empirical observations. This viewpoint is also supported by Sayer (2000) who argued that the number of times researchers empirically observe an event does not help to understand what causes it. In addition, positivism confuses the ontological matter of what exists with the epistemological matter of how we can know it (Archer *et al.*, 1998).

Unlike positivism, critical realism supposes that the world exists independently of our thoughts and perception. Critical realism also believes that the reality is stratification (Bhaskar, 1998). An event can be explained through underlying structures and mechanisms. Structure has causal powers. Mechanism is a force that emerges from the structure (see Figure 4.2). A mechanism will exist whether it is triggered or not. When the mechanism is triggered, it gives rise to an event.



Adapted from: Sayer, 2000.

Figure 4.2 Critical realists’ view of causation

Critical realism divides the dimensions of knowledge into the “empirical world”, the “actual world”, and the “real world” (Bhaskar, 1978). The “empirical” world is what we are observing and experiencing (Bhaskar, 2008). The “actual” world is the causal powers of the empirical world. The “real” world is referred to as the objects and unrealised powers underlying the “actual” and the “empirical” world (Archer, 2002). See Table 4.1.

	Domain of Reality	Domain of Actuality	Domain of Factuality
Mechanisms	√		
Events	√	√	
Empirical Experience	√	√	√

Adapted from: Bhaskar, 2008.

Table 4.1 Three ontological domains for scientific investigation

From the perspective of critical realism, the proper role of science is to understand the

real domain. As the reality cannot be fully understood through perception (the empirical domain), practical and theoretical work can help reveal what is not directly observable (generative mechanisms) (Bhaskar, 2002). In terms of social science studies, critical realism agrees that social phenomenon can be studied scientifically with an epistemological caution with regard to considering scientific knowledge instead of a fundamental rejection of it. This differs from positivism. As social constructionism, critical realism acknowledges that social phenomena such as actions, texts and institutions are concept dependent (Sayer, 1992; Bijker *et al.*, 1987). Also, it does not deny subjective influences or standpoints and the researcher's social context, but unlike most subjective epistemologies that deny an "object truth", critical realism understands that a mind-independent reality exists (Lopez and Potter, 2001). In addition, critical realists suggest that researchers should examine those subjective influences and standpoints in order to guard against forms of projection and selection that misrepresent our objects (Sayer, 2000). From critical realists' perspectives, the realist social science requires reflexivity (Hammersley and Atkinson, 1995).

In practice, critical realism allows the use of both qualitative and quantitative methods to deal with and make sense of complex, evolving problems (Sayer, 2010). This is because extensive research and intensive research are successfully combined by critical realism. Extensive research identifies the phenomenon, while intensive explores the mechanisms and structures of the event. As a result, critical realism enables in-depth research.

4.2.2 Transition theory and critical realism

The theory base of our work is the transition theory, whose main framework is the Multi-Level Perspective (MLP) and provides a tool to interpret and understand the nature of socio-technical transitions to sustainability. There are some crossovers between the MLP and the critical realism. This point can be clarified via Geels'

responses to others' criticisms on the MLP.

Smith *et al.* (2005) criticised the MLP and suggested that it should pay more attention to agency of actors. Genus and Coles (2008) argued that the MLP does not combine well with constructivist approaches, such as actor-network theory, constructive technology assessment, and the social construction of technology.

	Causal agent	Causal mechanism
Rational Choice	Individual, self-interested actors	Decentralised choice by instrumental rationality
Evolution	Agents in population	Variation (search), selection, retention
Structuralism	Taken for granted deep structures (belief system)	Deep structures operate “behind the backs” of actors, influencing their views and preferences
Interpretivism/ Constructivism	Individual actors with varying ideas and interpretations	Social interaction, construction of shared meaning, sense-making, learning, debates
Functionalism (systems theory)	Social system	Actors fulfil system needs, enacting roles, tasks and norms
Conflict and power struggle	Collective actors (groups, classes) with conflicting interests	Conflict and power struggle between different collective actors
Relationism	Networks and ongoing relations	Interaction, co-construction, translation, alignment

Adapted from: Geels, 2010.

Table 4.2 Foundational assumptions in different ontologies

In response to the criticisms of transition theory, Geels (2010) reflected the transition theory on the seven social science ontologies: Rational Choice, Evolution, Structuralism, Interpretivism/Constructivism, Functionalism, Systems Theory, Conflict and Power Struggle, and Relationalism (Table 4.2). Geels (2010) discussed the similarities and differences amongst the seven social science ontologies. He argued that there exists a crossover between the MLP and evolution theory because of the concepts of niches, regimes and trajectories. The MLP also shares some similarities with interpretivism and constructivism as these commonly contain the following factors: 1) regimes as “rules”; 2) creative actors; 3) multi-actor process:

interactions between social groups; 4) emphasis on learning and networks. In terms of research agenda, there exist crossovers connecting the MLP with Conflict and Power Struggle and Structuralism. Compared with conflict and power, the crossovers appear in social movement theory and strategic games between niche and regime actors. The MLP and Structuralism share similar elements such as culture ideology, repertoire at landscape level, cultural sociology and discourse theory, and the importance of legitimacy and performance on the public stage. Inspired by the comparison of the MLP and seven social science ontologies, there are crossovers between the MLP and critical realism in the aspects of interpretivism and structuralism, detailed as interactions between social groups, networks, and discourse theory. Because the MLP is based on these crossovers, agency in the form of bounded rationality (routines, trial-and-error learning, search activities) and interpretive activities has always been considered in the MLP (Geels, 2011).

The response to the criticisms of transition theory explains the ontology of the MLP and its position amongst the main general ontologies in social science. In doing so, it helps to better understand the similarities and differences between the MLP and other general ontologies, which provides a comprehensive understanding of the MLP, for example, how the MLP considers the role of agency, how the MLP deals with the interactions between social groups, networks, and discourse theory, and how the MLP proceeds and forms a model from the observation and data collection in the physical and social world. In this case, when the MLP is applied to e-bike transition study, it inspires to explore the e-bike transition in a wider range of dimensions, including how e-bikes are interacting with other actors, how e-bikes are embedded in the transport system, and what is the mechanism of e-bike transition. Consequently, the MLP helps to shape the research method and analyses e-bike transition in the network of socio-technical system, including culture, policy, infrastructure, users practice, market, industry, science, and technology.

Finally, Geels (2010, p. 495) considered the MLP, not so much as a “grand unifying

theory”, but as a “middle range theory” which is identified as “theories intermediate to the minor working hypotheses evolved in abundance during the day-by-day routine of research, and the all-inclusive speculations comprising a master conceptual scheme” (Merton, 1968, p. 5). Later, the “middle range theory” is refined by Boudon (1991) who states that “it explains, consolidates and federates in empirical data that would otherwise be unconnected without attempting to identify some overarching independent variable or some essential feature of the social structures under examination”. In other words, the MLP transition theory is a “middle theory” that starts with an observation in the physical and social world, and then proceeds to explore the underlying mechanisms and structure of the social-technical transition from this reality which can be seen to be helpful through collected data (Geels, 2010). Hence, the MLP shares the same lens of critical realism to explore the underlying mechanisms and structure of the event.

4.3 An abductive case study strategy

After the philosophy stance choice justification, this section further follows the “onion” procedure for research design and addresses the rationale of the research approach and research strategy choice.

4.3.1 Research approaches

The deductive approach, inductive approach and abductive approach are three common research approaches in the field of social science study (Bryman and Bell 2011; Saunders *et al.* 2012). The details are presented in Table 4.3.

The deductive approach is the dominating research approach in natural science and presents a positivist’s way of knowing (Saunders *et al.*, 2012). The research process is

based on the thinking of positivism. The deductive approach verifies or falsifies a theory by testing hypotheses from theory to observations/findings (Blaikie, 2010).

Features	Deductive	Inductive	Abductive
Closely related philosophies	Positivism	Constructionism	Critical realism
Objective	To test theories, to corroborate true ones and get rid of false ones	To build descriptions of characteristics and patterns	To understand social reality with reference to social actors' meanings and motives
Generalisability	Generalising from the general to the specific	Generalising from the specific to the general	Generalising from the interactions between the general and the specific
Contributions to theory	Theory verification or falsification	Theory building and generation	Theory building or modification
General process	Theory ↓ Hypothesis ↓ Data collection ↓ Findings ↓ Hypotheses confirmed or rejected ↓ Revision of theory	Observations ↓ Produce descriptions ↓ Relate these to research questions ↓ Theory building	Theory ↔ Observations ↓ Generate or modify an existing theory ↓ Observations/data collection ↓ Relate these to research questions/Data analysis ↓ Iterative theory development

Adapted from: Bryman and Bell, 2011; Saunders *et al.*, 2012.

Table 4.3 Characteristics of research approaches

The inductive approach reflects an antithetical process of “knowing” (Bryman, 2008). Philosophically, it is anti-positivism. The inductive approach begins with the observations of characteristics and patterns of social reality, producing descriptions to the theory (Kovács and Spens, 2005). Then the descriptions are analysed with proposed research questions, which further contribute to theory building. The inductive research is philosophically rooted in constructionism (Blaikie, 2010).

The abductive approach accepts both the deductive and inductive approach to test the plausible theory, which shares the basic thinking of critical realism (Alvesson and Deetz, 2000). The abductive approach not only contributes to theory testing, but also contributes to theory building (Dubois and Gadde, 2002; Saunders *et al.* 2000). The abductive research starts with observations or theory. Then, these observation data are utilised to generate or modify a plausible theory. After that, a new round of observation and data collection begins. Through data analysis, the plausible theory will be revised or further developed. The abductive approach accepts both the deductive and inductive approach to test the plausible theory, which shares the basic thinking of critical realism (Robson, 2002).

As these three research approaches are based on different philosophy perspectives, they are used for different research purposes. The deductive approach is only used for description. Inductive and abductive approaches can be used for both exploration and description. The thesis uses the abductive approach to explore and describe the phenomenon of e-bike transitions, because 1) the abductive research process best fits the research purposes which are theory building and theory testing, 2) it is consistent with the philosophy perspective of critical realism, 3) unlike the inductive approach, the abductive approach is concerned with understanding (Blaikie, 2010), and 4) the abductive approach accepts the existing theory and a less theory-driven research (Järvensivu, and Törnroos, 2010).

The abductive approach is conducted in the research as follows. Firstly, the e-bike transition phenomenon is observed. Secondly, the MLP is taken into account to explore and explain the phenomenon. Thirdly, Multi-scalar Transition Theory is proposed. Last but not least, through empirical data collection and analysis, the MLP and the Multi-scalar Transition Theory are further developed.

4.3.2 Case study

The advantages of the case study

Consistent with the selection of critical realism as the research rationale, we adopted a case study method in the thesis. There are various definitions of case study. In this research, case study strategy is defined as “a research method that involves investigating one or a small number of social entities or situations about which data are collected using multiple sources of data and developing a holistic description through an iterative process” (Easton, 2010: 119). Case study strategy is widely used in many disciplines, such as sociology, politics, psychology, business and economics (Yin, 2003). A merit of the case study is that it can be used by both qualitative and quantitative researchers. The concept of case study is justified by both qualitative and quantitative researchers, varying according to their versions of case study design on respective philosophical perspectives (Piekkari *et al.*, 2009; Järvensivu and Törnroos, 2010). Especially, case study strategy is preferred when investigating a contemporary phenomenon within its real-life context (Yin, 2003), as is the case for the e-bike transition.

From the aspect of research philosophy, a case study tolerates continuous interactions between an empirical world and a model world (Dubois and Gadde, 2002; Gibbert *et al.*, 2008). The case study research process is integrated with theory generation and modification, which provides in-depth insights to the research (Yin, 1989). Hence, case study strategy has advantages in answering “what”, “how” and “why” research questions (Yin, 2003; Saunders *et al.* 2012).

Case studies in the MLP

Case studies are predominantly applied in the MLP research as the main analytical

tool in the description and exploration of structures and dynamics within the MLP framework (Geels, 2002; Wells and Nieuwenhuis, 2012). Case studies in the MLP are in the form of a single case (Geels, 2005; Lauridsen and Jørgensen, 2010) and multiple cases (Geels and Kemp, 2007; Jørgensen, 2012), both of which can offer insight into the nature of the phenomena with large data (Easton, 2010).

The format of the MLP (Geels, 2002) is designed to analyse the transition process that a radical innovation is introduced on the niche level and with the landscape pressure and regime structure change, the radical innovation breaks out of niche level and then enters the regime. This is closely relevant to the e-bike transition process. Hence, the intention of this thesis was to develop the MLP case study format (Geels, 2002). However, the MLP approach is under the assumption that radical innovations enter the regime because of technology development, network benefits and government intervention. Individual behaviour and social factors have been neglected in the theoretical framework and in the case study format.

Attitudinal and behavioural data from individuals in case studies

The attitudinal and behavioural data from individuals, especially the data from e-bike users and non-e-bike users, are intensively involved in this thesis. One of the reasons is because of the difficulty to get access to other actors, such as policy makers, e-bike manufacturers, and Non-Government Organisations (NGOs). But a more important reason is that e-bike users and non-e-bike users played a key role in the rapid growth of e-bikes in China.

Firstly, the e-bikes users in China have their own distinctive use characteristics which are worthy to explore. For example, e-bikes are usually adopted for utility use (commuting, and access to services) in China (Weinert *et al.*, 2007a; Cherry and Cervero, 2007; Wang *et al.*, 2013; Rose, 2012; Ye *et al.*, 2014; Zhang *et al.*, 2014), whereas e-bikes are mainly adopted for leisure use in other countries (Pierce *et al.*,

2013; Johnson and Rose, 2013; Héran, 2014). In addition, many questions remained to be answered, such as why e-bikes are chosen, how e-bikes set in the daily life, the advantages of e-bike adoption, the disadvantages of e-bike adoption, the feelings associated with e-bike adoption, and the impression of e-bike users.

Secondly, the e-bike transition process in China has its own characteristic which is different from other main socio-technical transition studies. Many transition studies in other countries stated that positive policy intervention was a crucial factor in promoting sustainable technologies, production systems and consumption patterns, while the e-bike phenomenon in China occurred without the national government's strong support. The attitudinal and behavioural data from individuals provide more comprehensive information about e-bike transition.

Thirdly, very few e-bike research studied the attitudinal and behavioural data from e-bike users, and these are the underlying reasons for e-bike transition. Some studies attempted to explore the reasons for the rapid growth of e-bikes in China on a macro-level, through studying the factors of environmental implications, economic growth (Weinert *et al.*, 2008; Rose, 2012), and the trip purposes of using e-bikes (commuting and access to services) (Weinert *et al.*, 2007; Cherry and Cervero, 2007; Wang *et al.*, 2013; Ye *et al.*, 2014; Zhang *et al.*, 2014). However, these factors alone are still not sufficient to understand why e-bikes achieved such a rapid growth. Many questions remain unclear, such as why e-bikes are chosen, how e-bikes are used in daily life, the advantages/disadvantages of e-bike adoption, the feelings related to using e-bikes, and the public perception of e-bike users. These questions can be answered through the collection and analysis of attitudinal and behavioural data from e-bike users.

In this case, this thesis explores the individual attitudes and travel behaviour in China within the theoretical context of the Multi-Level Perspective and Multi-scalar Multi-Level Perspective. It is different from the previous individual mode choice

studies in the social-psychology and geography literature in the following aspects: 1) The thesis investigated a wider range of influencing factors of e-bike transition. The majority of previous individual mode choice studies examined the influencing factors of travel behaviour, such as urban form, social-demographic variables, psycho-social variables, and pricing, whereas our work further includes policy, industry, market, user practice, more social-demographic variables, and more psycho-social variables, to embed the e-bike users within a socio-technical transition framework; 2) The thesis does not only study the e-bike users' attitudes, but also takes into account the attitudes of other vehicle user groups (car drivers, bicycle users and pedestrians) and traffic police. In doing so, the results of the Nanjing case study provide a more comprehensive view and large quantity data to understand the embeddedness of e-bikes in the transport regime in China.

4.3.3 Scope and Unit of Analysis for the case study

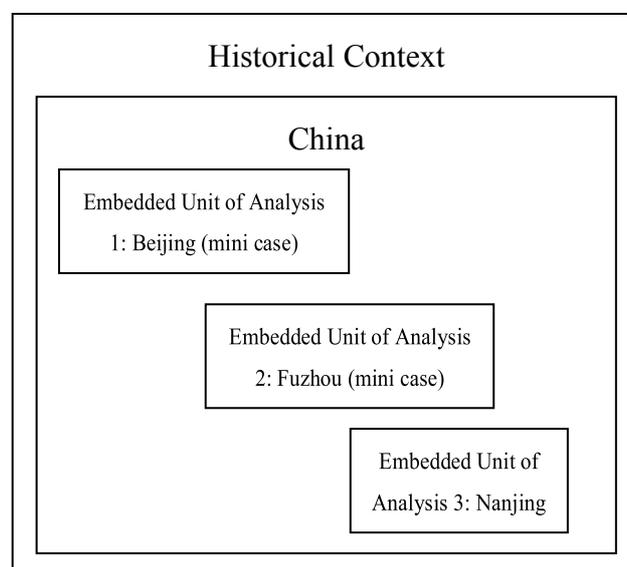


Figure 4.3 An embedded single case study

The case study and unit of analysis should be defined within its context. This project is based on an embedded single case study on the e-bike transition in China (Figure 4.3). The main unit is China as a whole, the smallest units being the several cities

(Nanjing, Beijing, and Fuzhou). At each level of analysis, different data collection techniques are used, ranging from secondary data analysis to survey analysis (see Section 4.4). The main unit of the case study and the three embedded units of analysis concentrate on the policy actors and organisations that engaged in the e-bike transition process.

The main strength of the case study approach is that it allows the use of many different sources of evidence, including semi-structure interviews, questionnaires, observation, and documentary sources (Yin, 2003). This increases the flexibility of the research and enhances the reliability of the results, and converges to a fuller picture of the processes (Dubois and Gadde, 2002; Bryman and Bell, 2003).

Case studies provide a fertile ground for abductive approaches by enhancing the interactions between theory and empirical world (Ritchie and Lewis, 2003). However, the case study strategy must be implemented and combined with the appropriate methods. In practice, the case study is often treated as a method simply by selecting a specific region or organisation and deciding to study it, so it will not provide data directly (Yin, 2003; Bryman and Bell, 2003). Therefore, research methods are needed to collect data when a case has been selected. In this research, mixed methods served for this purpose, by collecting data from semi-structured interviews, questionnaires and documentaries.

4.4 Mixed methods approach

The mixed methods approach is defined as “the research seeking to elaborate on or expand the findings of one method with another method” (Creswell, 2003). The mixed research methods approach is philosophically rooted in critical realism, allowing the use of both quantitative and qualitative methods (Table 4.4) (Creswell, 2003). As a result, the mixed method approach provides a more elaborated

understanding of the phenomenon of interest with greater validation (Creswell and Clark, 2011).

Tend to or Typically	Qualitative approaches	Quantitative Approaches	Mixed Methods Approaches
Philosophical assumption	Constructivist	Post-positivist	Critical realist
Employ strategies of inquiry	Phenomenology, grounded theory, ethnography and narrative	Surveys and experiments	Sequential, concurrent, and transformative
Employ methods	Open-ended questions, emerging approaches, text or image data	Closed-ended questions, predetermined approaches, numeric data	Both open- and closed-ended questions, both emerging and predetermined approaches, and both quantitative and qualitative data and analysis

Adapted from: Creswell, 1997.

Table 4.4 Qualitative, Quantitative and Mixed Methods Approaches

The main challenge of using a mixed methods approach is how to fully integrate the quantitative and qualitative research methods, and how to combine different methods and data to fit the research questions (Bryman, 1988; Denscombe, 2008; Tashakkori and Teddlie, 2010). There are two possible sequential procedures for the mixed methods approach. One starts with a qualitative method for exploratory purpose, followed by a large sample quantitative method (Creswell, 2003). The other begins with a quantitative method to test a theory, followed up with a qualitative method for a detailed exploratory with a few cases or individuals (Creswell, 2003). In our research, the first sequential procedure is applied. That is, the study starts with secondary data and semi-structured interviews, and then undertakes a large sample of surveys. More specifically, we implemented the mixed methods through following stages: 1) Secondary data were synthesised to explore the e-bike transition at the national level (China) and the city level (“mini” case studies of Beijing and Fuzhou); 2) Exploratory Research 1 was undertaken based on semi-structured interviews; 3) Exploratory Research 2 was carried out using semi-structured interviews; and 4)

Nanjing case study used survey to collect data and adopted statistics models for data analysis. See Table 4.5.

Stage	Name	Location	Data Collection	Research Purpose
Stage 1	Case Study 1	China; Beijing, China; Fuzhou, China;	Secondary Data	Address RQ1 and RQ2
Stage 2	Exploratory Research 1	Cardiff, UK	Semi-structured Interview	Help design interview questions in Exploratory Research 2
Stage 3	Exploratory Research 2	Nanjing, China	Semi-structured Interview	Help design questionnaire in Case Study 2
Stage 4	Case Study 2	Nanjing, China	Questionnaire Survey	Address RQ3, RQ4, and RQ5

Table 4.5 Research design of the thesis for the e-bike transition study

The first stage used secondary data to address RQ1 and RQ2, *i.e.* examined whether the development of e-bikes in China was spontaneous and identified the e-bike transition pathways. The research units are China at the national level, and Beijing and Fuzhou at the city level.

The second and the third stages, Exploratory Research 1 and Exploratory Research 2, used semi-structured interviews. They did not really seek to answer the research questions directly. These exploratory phases were intended to test whether our ideas about the topic and the ways in which we might investigate the ideas were indeed valid. More importantly, they helped inform the ultimate design of the questionnaire used in the large sample in Nanjing. For example, the answers of the respondents to the interview questions in Exploratory Research will appear in the response categories of the survey questionnaires in the following step.

There are some differences between Exploratory Research 1 and Exploratory Research 2, particularly in research purposes. Exploratory Research 1 was a preliminary research step, in which Chinese citizens were involved as the main sample group. In addition, in order to gather a wide range of opinions on e-bikes,

non-Chinese people from other countries were also selected. The result of Exploratory Research 1 offered us an overall view of e-bike transition from a global perspective and widened the view of e-bike transition process study in China. The main purpose of Exploratory Research 1 was to design and modify the semi-structured interview questions for Exploratory Research 2. In Exploratory Research 2, we interviewed e-bike users, non-e-bike users and e-bike retailers. The result provided more solid data of understanding e-bike transition in China. They were used to test the assumptions underpinning the survey questionnaire and help design the questions for the questionnaire of Nanjing case study. Since the aim of the stage was to shape the questionnaire design in the Nanjing case study, the interview of Exploratory Research 2 was also undertaken in Nanjing.

The final stage was the key step in our research, Nanjing case study, which collected data with survey and performed quantitative analysis. The reasons why we chose Nanjing for performing surveys included: 1) As the capital of Jiangsu province, Nanjing is an important city in China with developed economics; 2) Nanjing is a base for e-bike industry in China, concentrated with a large number of e-bike manufactures and retailers; 3) E-bikes are widely used in Nanjing; 4) The author has many friends in Nanjing who can help distributing and collecting questionnaires.

The aim of the Nanjing case study was to address the following research questions: a) How are e-bikes embedded in the current transport regime? b) How much longer can e-bikes continue to be embedded in the transport regime? c) What is the mechanism underlying the e-bike's spontaneous emergence? In order to answer the research questions, five groups of interviewees were selected: e-bike users; bicycle users; car drivers; pedestrians; and traffic police. The aim of the questionnaire survey was to test the e-bike transition phenomena by applying MLP transition theory. Therefore, e-bike users were the main targeted participants. In addition, e-bike users' activities frequently interacted with other vehicle users, e-bike manufactures and traffic police, who also have an effect on the e-bike application experience and are essential in MLP

transition framework. In this case, it is necessary that non-e-bike users and traffic police were involved in the survey.

4.5 Data collection method

This section explained the data collection method adopted by each research stage. As mentioned above, the first research stage used secondary data to analyse e-bike transition at the national level and at the City level. The following three research stages, Exploratory Research 1, Exploratory Research 2 and Nanjing Case study, collected first-hand data by undertaking semi-structured interviews and surveys, which are the very important steps and whose information is listed in Table 4.6, including time and location of performing research, sampling methods, sample groups, target sample size, achieved sample size, and research purposes. More details of the data collection methods will be discussed below.

	Exploratory Research 1	Exploratory research 2	Nanjing case study
Data collection method	Semi-structured interview	Semi-structured interview	Survey
Where	Cardiff, UK	Nanjing, China	Nanjing, China
When	March 2012 and April 2012	May 2014 and June 2014	August 2014 to November 2014
Sampling method	Convenience sampling and snowball sampling	Snowball sampling and purposive sampling	Purposive sampling
Target sample population (target sample size)	Chinese students (10), Non-Chinese students (10)	E-bike users (50), Non-e-bike users (50), E-bike retailers (10)	E-bike users (600), Bicycle users (200), Car drivers (200), Pedestrians (200), Traffic police (50)
Achieved sample	Chinese students (13), Non Chinese students (9), Non-Chinese researchers (3)	E-bike users (31), Non-e-bike users (29), E-bike retailers (6)	E-bike users (403), Bicycle users (200), Car drivers (200), Pedestrians (200), Traffic police (50)
Research purpose	Help design the interview questions of Exploratory Research 2	Help design the questions of survey questionnaires in Nanjing.	Address research questions RQ3, RQ4 and RQ5.

Table 4.6 The details of Exploratory Research and Nanjing case study

4.5.1 Case studies of China, Beijing and Fuzhou: Secondary data

Secondary data are “the data which have been already collected by and readily available from other sources, ranging from large statistical studies published by government to the unpublished observations of a knowledgeable observer” (Stewart, 1984). Most studies begin with secondary analysis (Yin, 1989). Through the investigation of secondary data, knowledge of a particular problem is learnt (Huff, 1990). Secondary data can provide an opportunity to obtain insights about the context within which research participants try to operate (Woodrum, 1984). As a result, it provides a comprehensive understanding of a particular topic. In addition, it is possible to arrive at conclusions by combing the information from different sources (Woodrum, 1984). In social science, the secondary data are often used to integrate with the findings of primary studies for theory building purpose (Gephart, 1993).

Secondary data collection is less expensive than primary data collection and more time efficient (Stewart, 1984). In addition, secondary data are a useful comparative tool. By comparing them with new data, differences and trends can be found. For example, the government census provides the demographic characteristics of large population. Comparing it with the e-bike sample information, it may reveal how representative the e-bike sample of the larger population is. Moreover, secondary data have low obtrusiveness and reactivity, so the researchers do not suffer from much bias as the primary data research process (Silverman, 2001).

The secondary data of this study are for exploring e-bike transition pathways in China and two mini case studies in Beijing and Fuzhou. The data are mainly sourced from previously published research, such as statistics data from government-published yearbooks, publicly available policy documents, published journal papers, conference papers, published books, social media sources, e-bike discussions from online forums,

and other online sources. There are two major problems with official published data. One is that it cannot be guaranteed that even the official data are absolutely reliable and consistent. The other problem is that China's official data may conflict with the official data recorded by other countries or areas. For example, the number of official road traffic deaths per annum is about 68,000 in the official report of Ministry of Public Security in 2010 (Meng, 2010), while according to the World Bank, it is estimated to be nearer to 240,000 (China Daily, 2011). Finally, since e-bikes did not gain much government support, the official data about e-bikes are not sufficient and consistent. Therefore, this study integrates a range of sources, such as e-bike industry websites, e-bike industry reports, and e-bike user websites and online forums, as well as journal articles published both in the English and Chinese language.

4.5.2 Exploratory Research 1: Semi-structured interviews

4.5.2.1 The rationale for the selection of semi-structured interviews

When adopting the MLP theories to develop a research model for e-bike transition, the empirical evidence or an exploration study is needed. In our case, this means the research attempted to explore what has taken place in the e-bike transition process, focusing on the interaction between actors and social structure. As Silverman (2005) and Saunders *et al.* (2000) suggested, qualitative interviews are generally considered to be an appropriate method for an exploratory study, because they are not only used to find out what is happening but also to seek new insights.

Semi-structured interviews and unstructured interviews are the two usual forms of qualitative interviews. The selected qualitative method in the thesis is the semi-structured interview. Compared with the unstructured interviews, the interviewers in a semi-structured interview are free to probe beyond the answers

(Mason, 2004). Thus, it allows the researcher to have a dialogue with the interviewees by prompting and seeking clarification on the answers (Saunders *et al.*, 2000). In this case, the researchers can use the dialogue to gain an in-depth understanding of how interviewees generate meanings in social life (Silverman, 2004). This means that with the specified questions, the exploration is guaranteed to be within the scope of research questions and in the meantime the researcher has more flexibility to control the flow of the conversation without constraint.

The semi-structured interviews encourage interviewees to participate in the dialogue and tell more about their experience and opinions (Denzin and Lincoln, 1998). To avoid limiting interviewees, the interview questions are designed to be open, which is beneficial to the exploration purpose (Creswell, 1997). The wording of interview questions should be straightforward and very clear, in order to convey the information accurately (Flick, 2009) and deliver the same meaning for various participants (Seale, 2004).

4.5.2.2 Sampling method in Exploratory Research 1

In qualitative research, two major categories of sampling design are applied: probability sampling and non-probability sampling. Probability sampling includes simple random sampling, systemic sampling, stratified random sampling and multi-stage samplings, while the non-probability sampling mainly consists of convenience sampling, purposive sampling, snowball sampling and quota sampling (Bryman and Bell, 2007).

Two sampling techniques were used in Exploratory Research 1: convenience sampling and snowball sampling. The convenience sampling is referred to as the researcher-selected subjects because of their convenient accessibility and proximity (Saunders *et al.*, 2000). As an initial research activity, the convenience sampling

process was useful because it is fast, inexpensive and easy to use. The snowball sampling is referred to as an iterative way to increase the sample size. That is, a researcher makes initial contact with a small group and then uses them to expand their contact with others who have close relationships with them (Saunders *et al.*, 2000). The snowball sampling helped open more opportunities for gaining access to a wide range of research participants.

4.5.2.3 Samples of the interview in Exploratory Research 1

This research phase was carried out in Cardiff, UK between March and April 2012. The reasons for performing the interview in Cardiff University are: 1) Considering limited research time and expense, it is very efficient to carry out this preliminary research step in Cardiff University; 2) Cardiff University has a large number of students with various backgrounds; 3) The students or researchers at Cardiff University can be easily accessed. The main target sample population was the Chinese students, especially those who had just graduated from universities in China and then begun their study in the UK. Because of the strong connection with China, these students still kept their life setting in the way of the Chinese culture and were familiar with the latest status of e-bike development in China. The non-Chinese students and researchers from other countries were also selected, because their knowledge of e-bikes in their own countries could provide useful information from different perspectives outside of China, which is especially helpful to clarify the research questions with regards to the awareness of background, culture, and life setting difference.

The researcher went to four PhD offices, and invited PhD students to participate in face-to-face interviews. 25 interviewees participated in the interview: 13 Chinese students (five non-e-bike users and eight e-bike users), 9 non-Chinese students, and 3 researchers, including British, French, Spanish, Lithuanian, Brazilian, Iranian, and

Korean. Eleven of the non-Chinese participants were non-e-bike users. One of them tried e-bikes when visiting tourist attractions. For those not familiar with e-bikes, a picture of an e-bike was shown and the way an e-bike works was explained. Twenty interviewees allowed the recording of the interview process. Those interviews were recorded by note-taking and tape-taking. For the interviewees who were not willing to be recorded, note-taking was the main technique for recording the interviews.

4.5.2.4 Interview question design in Exploratory Research 1

For e-bike users:

1. *Tell me your reasons for travelling by e-bikes.*
2. *Would you tell me the positive and negative effects of e-bikes?*

The first question opens the discussion with regard to e-bikes. When participants talked about their own stories of using e-bikes, the information related to e-bikes would be revealed, such as how e-bikes were embedded in their live settings, the use practice, and culture. The second question tries to identify the advantages and disadvantages of e-bike adoption, which may reveal the attitudes of the interviewees towards e-bike development. We can also know how the advantages or disadvantages of e-bikes shaped regime or caused the responses of other regime actors. These questions help to understand the roles of e-bikes in a wide picture of the socio-technical transition system, which provides useful information about e-bike transition reasons and barriers.

For non-e-bike users:

1. What is your opinion on e-bike users?
2. In which situation would you consider trying it?

The first question addresses the image of e-bike users in non-e-bike users' minds,

which would provide different perspectives of viewing e-bike transition and be useful to understand how e-bikes interact with other travel modes in the current transport regime. The second question identifies the factors promoting e-bike transition. In addition, this question reveals the issues surrounding current e-bike transition. For example, the participants may use e-bikes on the condition that bike lanes are widened, the price of e-bikes are cheaper, the battery life of an e-bike is longer, when buses are too crowded, if living and work distance change, or if the government lifts the e-bike bans. In this case, the answers of this question provide an overall picture of e-bike transition in the level of landscape, regime and niche, such as infrastructure, market, technologies, user practice, and policy.

4.5.2.5 Limitations of Exploratory Research 1

The limitation of Exploratory Research 1 is the small sample size, which is not sufficient to generalise a phenomena. In addition, the limited sample is very culturally diverse, which may not be able to explore the e-bike transition in China in-depth. Apart from that, for those who are not familiar with e-bikes or have never heard about e-bikes, it would be difficult for them to answer the questions about e-bikes or express their opinions on e-bike development.

4.5.3 Exploratory Research 2: Semi-structured interviews

The interviews were conducted in Nanjing, during the period between May and June 2014. The requirement was that these participants are Chinese and had spent the majority of their life in China. The requirements ensured that the participants understood the e-bike transition process and its automobility culture in China. The participants were selected carefully to contain the similar number of females and males. In addition, the target sample population should cover a wide range of age

groups from 18 to 70 years old.

The researcher tried to find targeted participants at commercial centre, residential communities, e-bike repair shops and e-bike parking places. Conducting surveys in residential communities, e-bike repair shops, and e-bike parking places is a very efficient way to access e-bike users and usually the participants in these places have time to answer the questions. The advantages of choosing commercial centre are: 1) commercial centre usually have a large flow of visitors with different age groups, education backgrounds, and occupations, which maximises the diversities of the sample; and 2) with the large stream of citizens and the high density of populations, we can find more potential survey participants and also increase the number of accomplished surveys. A possible limitation is that because many participants worked or lived in the city centre, who normally have higher education and income level, so the average education and income level of the sample may be increased.

4.5.3.1 Sampling method in Exploratory Research 2

The sampling techniques used were snowball sampling and purposive sampling. Unlike the convenience sampling technique, the purposive sampling relies on the judgment of the researcher when it comes to selecting the participants that are to be studied, whereas the target sample population of convenience sampling is comprised of participants who are easy to reach (Miles and Huberman, 1994; Denzin and Lincoln, 2005). In this case, e-bike users and non-e-bike users were identified before the interviews. The friends of the researcher who live in China were firstly contacted by phone, email and other communication tools in order to identify whether they were the target interviewees. Then, some of the friends recommended their friends to the researcher. Depending on the backgrounds of the potential participants, the researcher decided whether to invite them to participate.

4.5.3.2 Samples of the interview in Exploratory Research 2

In Exploratory Research 2, three groups of interviewees were selected: e-bike users, non-e-bike users, and e-bike retailers. As the first group interviewees, e-bike users were the main target sample group, and their choices determined the e-bike transition pathways and the e-bike industry development to a great extent. Only with the increase of e-bike users, is it possible for e-bikes to break out of their niche level. Therefore, it is significant to understand why e-bike users spontaneously chose e-bikes as their daily vehicles to achieve the personal mobility and to what extent e-bikes were embedded in their daily life.

The second group consisted of non-e-bike users. As a type of emerging sustainable vehicles, e-bikes provide cheap motorised personal mobility for e-bike users, but the influence of e-bikes on non-e-bike users is still not clear. The viewpoints of non-e-bike users on e-bikes indicate how well e-bikes have embedded into society, and provide a different perspective for understanding e-bike transition. Also, the views and attitudes of non-e-bike users revealed potential policy issues and social issues associated with the rapid development of e-bikes, helping policy makers to make decisions on e-bike policy management. In addition, non-e-bike users are also potential e-bike users, so understanding their attitude towards e-bikes can help explore the future of e-bike transition.

The third group, especially the e-bike retailers, played an important role in e-bike consumption and production. They form a significant position in the e-bike supply chain as the “gatekeepers” between the suppliers and consumers. Firstly, e-bike retailers are the final stop in the consumer’s path to purchasing an e-bike. E-bike retailers are familiar with customer preference, and on the other hand can exert direct influence over consumers’ decision-making when purchasing, and even influence consumers’ purchasing habits and consumption habits. Secondly, e-bike retailers have

direct contact with a large network of suppliers (manufacturers and distributors). In this case, e-bike retailers have opportunities to express their preferences of the products through selecting or deselecting products. Thirdly, with other major actors in the supply chain, e-bike retailers tend to have an impact on the transportation of products and the logistics employed to shape sustainable business models. Fourthly, the size, number, product range and location of e-bike retailers reflect the e-bike development status. Lastly, they are very sensitive to the e-bike policy because policy may influence e-bike sales. Our semi-structured interview helps understand where the e-bike retailers are from, why they enter e-bike market, the range of products they have, usage segments, and the e-bike transition process.

4.5.3.3 Interview question design in Exploratory Research 2

For e-bike users

1. *Tell me your reasons for travelling by e-bikes.*
2. *How does it feel?*
3. *When is it easy to use?*
4. *When is it hard to use?*

The first question is adopted from Exploratory Research 1. The second question asks interviewees to give information about user experiences. This question is closely linked with use practice and culture, which are the essential components of regime in the MLP. The third question and the fourth question help identify the advantages and the disadvantages of using e-bikes. These two questions are closely relevant to participants' daily life experiences with e-bike adoption, which would reveal the issues of e-bike adoption in terms of policy, infrastructure, e-bike technology, the e-bike market, transport system, environment, and e-bike industry. These open questions allow the interviewees to tell us more about their experiences, how e-bikes are embedded in their social life, and their decision making process in relation to

e-bike adoption.

For non-e-bike users

1. *Why not use an e-bike?*
2. *Do you think e-bikes have any benefits? What might these be?*
3. *In which situation would you consider trying it?*
4. *What is your opinion on e-bike users?*

E-bike users interact with non-e-bike users in the urban transport system. Furthermore, they would be potential e-bike users and thus are involved in the transition process. The first question explores the underlying reasons why travellers do not choose e-bikes, identifying the influential factors of mode choice behaviour and the issues associated with e-bike development. The second question prompts travellers to think about the potential advantages of e-bikes. The third and fourth questions are the same as Exploratory Research 1. The third question identifies the factors that have positive effects on e-bike transition. It would reveal various aspects of e-bike adoption, such as policy, technology, user practice, and the market, and these are all associated with the important components of the regime in the MLP. The fourth question seeks to understand the perception of e-bike users from a non-e-bike user's point of view, and explores the current symbolism and social connotations of the e-bike.

For e-bike retailers

1. *Why did you decide to enter e-bike business?*
2. *Why did you choose the particular brand and what is the business model of the brand?*
3. *To what extent does policy influence the e-bike sales?*
4. *What is the major change since you started the e-bike business?*

The e-bike retailers play an important role in e-bike transition process. The first question connects e-bike retailers' previous and recent experience of business, and

highlights the current e-bike development status. The question also explores the underlying mechanisms of choosing e-bike business. The second question gathers the information of e-bike brands and attempts to understand the brand supply chains and business models. The third question is relevant to e-bike policy, for the purpose of understanding the role of policy in e-bike transition and to further explore e-bike retailers' attitudes to current policy. This helps reveal the pressure from landscape in the MLP. The last question asks e-bike retailers to provide a historical narrative of e-bike transition process in his/her experience.

4.5.3.4 Issues and limitations of Exploratory Research 2

There are some issues when applying semi-structured interviews into practice. Firstly, it is difficult to get access to the participants. Forty citizens were invited, but only three of them accepted the interview, on the condition that the interviews would be finished within five minutes. The researcher visited more than twenty e-bike retailers and only six of them accepted the invitation for interview. After an introduction by one of the interviewees, some e-bike retailers agreed to participate in the interview. However, when the researcher started the interview, the retailer said "I am very busy now, when I have time, we can start the interview". Then the researcher tried to make an appointment. The participant responded that "I do not know when I am available" and left the interview.

Secondly, the majority of interviewees are very prudent when answering questions. The majority of the e-bike users and e-bike retailers did not allow the interview to be recorded. In addition, when the researcher described the research purpose and process to the potential interviewees, many of them questioned the researcher's identification, asking many times whether the researcher was a spy or journalist with a hidden camera. The interview process was frequently interrupted by interviewees' questions. This happened frequently when the researcher asked about the sales of e-bikes, and

which products are popular. In response to this, the participants asked “Why do you want to know the sales? Do you want to start your own business? You want to know the business secrets and tell others, don’t you? ”.

Thirdly, there are some biases in the semi-structured interviews. During the interview with the friends of the researcher, they tended to present positive attitude of the e-bike transition process. When the research asked “it seems that you have an optimistic view of e-bike development”, some participants said “Sure, I know your research is to study e-bikes. So I guess that you’d like to listen to some good comments of e-bike development”. The situation was similar when interviewing the recommended participants by researcher’s friends.

For the aforementioned reasons, the researcher did not achieve the initial target of the Exploratory Research 2. The target sample population and sample size were as follows: e-bike users (50); non-e-bike users (50); and e-bike retailers (10). The achieved sample consisted of e-bike users (31), non-e-bike users (29), and e-bike retailers (6). There is a gap between the envisaged sample and the achieved sample, which reduces the quality of the interview results. However, because the results of Exploratory Research 2 were not directly used for e-bike transition analysis, but mainly for helping shape the questionnaires design in the following survey step, this negative effect could be more or less alleviated. Furthermore, to improve the research quality, we used a large sample size for the survey in Nanjing in the following research step.

4.5.3.5 Result analysis of Exploratory Research

Both the Exploratory Research 1 and Exploratory Research 2 used the same data analysis methods. In this research, the interviews will be transcribed and coded using keywords such as effort saving, cost, battery, safety, and e-bike performance. Then,

the data are categorised into four groups: the reasons for the selection of e-bikes, the advantages of e-bike development, the disadvantages of e-bike development, and the issues and barriers against e-bikes transition. The results of Exploratory Research 1 are used to shape the question design of Exploratory Research 2. Then, the results of Exploratory Research 2 are used to shape the survey questionnaires.

4.5.4 Nanjing case study: Survey

4.5.4.1 The rationale for the selection of survey

Research questions and hypotheses are essential in the quantitative studies, because they shape the purpose of the study by using appropriate statistical tools (Crewell, 2003). Hypotheses are the assumption held by the research about the relationship between the variables that are explored by the data collected from samples. Usually, there are four ways of collecting data in quantitative studies (Bryman and Bell, 2007): 1) through official statistics documents; 2) recording individuals' behaviours using a structured observation schedule; 3) asking questions in a self-completion questionnaire or a structured interview; and 4) examining mass media context through content analysis.

This research used “asking questions in a self-completion questionnaire or a structured interview” to collect quantitative data. As a spontaneously developing vehicle, e-bikes have not received enough attention from the government. So the official statistics data are extremely limited and therefore unable to fulfill the requirements of research hypotheses testing. Without government support, the mass media's coverage of e-bike transition are also scarce. In practice, it is very difficult to e-bike users to allow their behavior to be recorded. In this case, a questionnaire is selected as an efficient way to collect quantitative data.

4.5.4.2 Administration of the survey

A questionnaire survey was selected as the main data collection method for this research and the purposive sampling method was used. The administration of the questionnaire survey has two main types: a self-administered survey method and interviewer-administered survey method. The self-administered survey method is cheap and time efficient, while interview-administered survey method is time-consuming and lacks flexibility. In addition, the self-administered survey method provides private space for the respondents who are less likely to be influenced by the characteristics of the interviewers (Bryman and Bell 2007). In this case, the self-administered survey method was selected as the main survey data collection method. However, it is hard to achieve a high response rate using self-administered survey method (Simsek and Veiga, 2000). Therefore, the interviewer-administered questionnaire was also applied as a complement survey method to improve the response rate.

There are several ways of implementing a self-administered questionnaire. The way our work took was the delivery and collection of questionnaires. The reason is that it could protect the participants' privacy and gives them enough time to answer the questions.

The process of delivering and collecting questionnaires is mainly completed by residential community workers, office workers and traffic police. The residential community workers are very familiar with the citizens who live in the communities and have a good relationship with them. Consequently, residential community workers can easily identify those who are e-bike users or non-e-bike users, and communicate with citizens and the government. When the potential participants passed by the neighbourhood committees, the community workers sent them questionnaires and asked them to return them after they were completed. If citizens

refused to participate, the community workers simply asked others. Questionnaires were also sent to office workers and collected and finally, traffic police helped send out the questionnaires during their daily meetings. Once the questionnaires were completed, they were collected and returned to the researcher. The questionnaires were anonymous in order to protect the privacy of participants and minimise bias.

Following the self-administered questionnaire stage, the researcher found that the response rate of the e-bike user group was very low. This is because the e-bike user questionnaire is lengthy (34 questions). In order to increase the response rate, the researcher decided to conduct interview-administered survey method, which mainly were conducted at e-bike repair shops. When the e-bike users were waiting for e-bike maintenance, the researcher asked them to participate in the survey.

Surveys were conducted in Nanjing from late August to early November 2014. The survey targeted e-bike users, non-e-bike users (bicycle users, car drivers, pedestrians) and traffic police. Please refer to Appendix B, C, and D for the survey questionnaires for the three groups, respectively. As the semi-structured interviews in Nanjing, the surveys were also conducted in the city centre area, in commercial office buildings, business centres, e-bike repair shops, and many residential communities.

4.5.4.3 Samples of the survey in Nanjing

In Nanjing City, the mobility system is comprised of e-bikes, bikes, private cars, motorcycles, ferries, buses, the metro, taxis, and walking. The selected sample groups are bike users, private car users and pedestrians, and these are the main actors who intensively interact with e-bikes in the transport system.

Bicycle users were chosen because both e-bikes and bikes are two-wheelers and classified as non-motorised vehicles. Initially, the bike lanes were built for bike users

to increase their comfort and safety levels (Zhang *et al.*, 2014). Since e-bikes have shared the bike lanes, bicycle users have been highly involved in e-bike development (Jin *et al.*, 2015).

Pedestrians are the main regime actors in the transport system. In the literature review, the pedestrians claimed that e-bike users' traffic violation behaviours severely threatened their safety (Cherry, 2008; Li *et al.*, 2009). Therefore, it is worth investigating pedestrians' viewpoints on e-bike development.

The private car drivers were chosen because accidents between private cars and e-bikes are increasing and have become a serious issue (Liu, 2013; Sun *et al.*, 2014). Some of the private car drivers complained that e-bike users often run red lights and ride on the motorways. Both private cars and e-bikes meet citizens' demands for motorised personal mobility. Nonetheless, the ownership of private cars is rapidly increasing with supportive policy, while the ownership of e-bikes has increased spontaneously. Therefore, it is interesting to understand private car drivers' attitudes to e-bike transition in order to know why they do not transfer to using e-bikes.

There are two considerations for why traffic police were chosen. Firstly, as the law enforcement officers, traffic police are directly in touch with all travel mode users. Therefore, they have a comprehensive understanding of traffic issues, such as peak times and the high-incidence time of accidents. Particularly they have a rich knowledge of the traffic violation behaviours, such as which violation traffic behaviours are most commonly found, which violation behaviours cause traffic accidents, and how to deal with traffic accidents. Secondly, The traffic police provide an alternative and indirect way to understand the government's attitudes towards e-bike development. As a result, the traffic police are an essential group in the transport regime, which is useful to further investigate how e-bikes are embedded in the transport regime.

Motorcycle users were not included because the motorcycles have been banned in urban areas in Nanjing since 1998 and so it was difficult to find enough motorcycle users to answer the questionnaires. The ferry is gradually seceding from the mobility regime as the number of bridges built over the river increases, so they were not included in the research either. Taxis tend to provide temporary personal mobility to citizens and therefore taxi users were not considered.

There are two reasons that the public transport users have not been selected as sample targets. The primary reason is that the public transport users were difficult to be accessed in practice. For example, the average waiting time for buses and metro is 3 minutes and 2 minutes in Nanjing, respectively. In this case, it leaves very limited time for public transport users to answer the survey questions during their waiting time. Another reason is that buses and metro have their own lanes, so have fewer opportunities to interact with e-bikes directly.

The target sample population and sample size consisted of: e-bike users (600); bicycle users (200); car drivers (200); pedestrians (200); and traffic police (50). A total of 1,053 responses were collected. The achieved sample consisted of: e-bike users (403); bicycle users (200); car drivers (200); pedestrians (200); and traffic police (50). The achieved sample size is high.

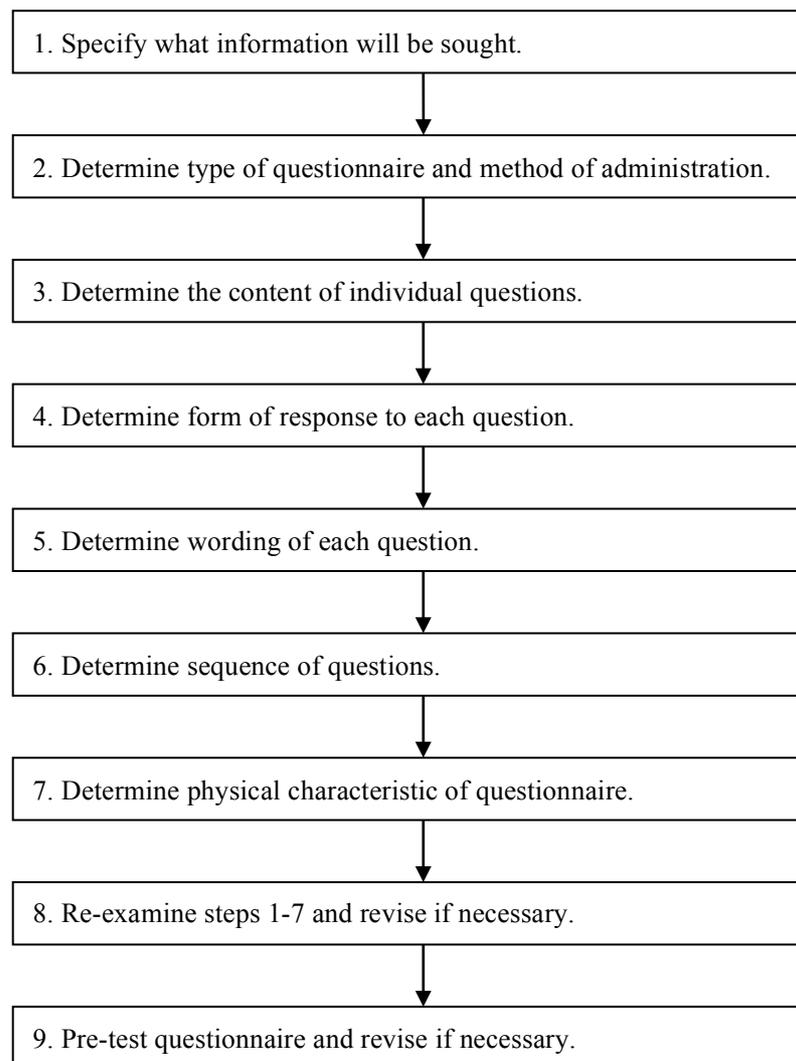
4.5.4.4 Questionnaire design for the survey

The questionnaire was designed using the step-by-step guidelines provided by Churchill and Iacobucci (2002). See Figure 4.4.

Questionnaire design step 1 and step 2:

Step 1 and Step 2 have been completed in preceding sections. The survey was

intended to collect information to seek the answers of how e-bikes are embedded in the current and future transport regime and the underlying reasons for e-bike transition (Step 1). The rationale of the questionnaire selection and the administration of the survey (Step 2) were discussed in Section 4.5.4.1 and 4.5.4.2.



Source: Churchill and Iacobucci, 2002.

Figure 4.4 Procedure for developing a questionnaire

Questionnaire design step 3 (Determine the content of individual questions)

Our questionnaire design borrows several ideas from the previous e-bike studies, in particular, the questionnaire by Cherry and Cervero (2007), which studied e-bike

development in China. The result of Exploratory Research 2 of our work is another important reference in our survey questionnaire design. Moreover, inspired by the literature of the individual mode choice as discussed in Section 2.7, we particularly paid attention to the attitudes and individual behaviours related to e-bike usage. For example, to explore the socio-demographic variables influencing individual behaviours, we collected the information such as age, gender, and income of the participants. In terms of the effect of psycho-social variables, we incorporated the trip purpose, the feeling associated with using e-bikes, and the attitudes towards e-bikes. In addition, considering the value of travel time and travel time reliability, we asked the questions such as which travel mode will be used in an urgent trip and how the trip time accuracy requirement determined the travel mode.

The target sample population was e-bike users, non-e-bike users (bicycle users, car drivers, and pedestrians), and traffic police, and the questionnaires were designed in accordance with the characteristics of different groups. The questions of our questionnaires contained two parts: current e-bike adoption and future e-bike development. The response categories were designed to be as complete as possible, and always included the options of “other” or “other, please specify”, which allowed the participants to provide answers that were not included in the listed specific options and therefore gave participants more opportunities to express their thoughts adequately. The details of the question and response options designed for different groups are discussed below.

Part 1 Questionnaire for e-bike users

To study the e-bike transition by embedding e-bikes in a socio-technical transition system, the questionnaires for e-bike users were divided into eight parts: demographic information, reasons and feelings about e-bike adoption, use anxiety and improvement, batteries, safety, market, the impact of e-bikes on urban transport systems, and future suggestions. These eight parts cover a wide range of aspects, including travel

behaviours, use practices and markets, technologies, culture, infrastructures, and policies, which are the essential components of the MLP. The justification of the design of each question and the corresponding response categories are given below.

(a) Demographic information

As mentioned above, the questionnaire of Cherry and Cervero (2007) was used as the base of our questionnaires. Some parts of their questionnaire inspired the questionnaire design of the Nanjing case study in our work, such as the demographic information, and household vehicle ownership. In this case, the questionnaire included most of the information. The demographic questions in this questionnaire included gender, age, education, occupation, and monthly salary. The response categories of age, education, and monthly salary were determined according to the result of Nanjing Sixth Census (China Population Census of Nanjing, 2011). Incorporating age and occupation into the response categories was inspired by the questionnaire of Cherry and Cervero (2007). Nonetheless, some questions of Cherry and Cervero's (2007) questionnaire were not included in the Nanjing case study; for example, the address of the participants' home and work place, because these questions did not provide much relevant information about the e-bike transition, and some participants were reluctant to answer them due to privacy concerns.

(b) Reasons and feelings related to e-bike adoption

In Exploratory Research 2, e-bike users were asked about their reasons and feelings associated with travelling by e-bikes. According to their responses, the majority of the e-bike users shifted to e-bikes from walking, and using bicycles, buses, the metro, cars or motorcycles, because e-bikes are effort saving, cheap, highly accessible, environmentally friendly, and can be used for multiple purposes such as commuting, picking up children, shopping, and leisure activities. In order to have more complete response categories, the literatures of e-bike studies were also reviewed. Weinert *et al.* (2007) and Xu *et al.* (2014) studied the characteristics of e-bikes in Shijiazhuang and Xi'an, respectively. In their research, some of the e-bike users shifted from using taxis,

but this sort of shifting was not mentioned frequently by the respondents in our Exploratory Research 2. Zhang (2011) and Ye *et al.* (2014) conducted surveys in Fei County and Shanghai, respectively. Both of them asked the trip purpose of e-bike adoption. Their questionnaires' response categories are partly adapted to our case in this questionnaire design. Regarding the feelings about e-bike adoption, this mainly included practical usage, freedom, relaxation, and being a part of the community. The questions and response categories are designed as follows:

- Which vehicles have you replaced with e-bikes?

Response categories: bicycle, walking, bus, metro, car, motorcycle, taxi, coach, tricycle, other.

- For which purpose do you use e-bikes?

Response categories: commuting, picking up children, going to school, going shopping, leisure, visiting friends, travel connections to the metro, business, other.

- Why do you use e-bikes?

Response categories: low purchase cost, low operation cost, effort saving, flexible trip time, saving time in traffic jams, high accessibility, environmentally friendly, health, other.

- Which feelings do you associate with using e-bikes?

Response categories: practical usage, fashion, freedom, relaxation, greener, sense of identity, other.

(c) Use anxiety and improvement

The e-bike users in the semi-structured interviews of Exploratory Research 2 were asked about the shortcomings of using e-bikes and the situations for which e-bikes are not suitable. Their responses were collected as the response categories with a question

“Are you worried or not worried about the following e-bike use anxiety?” Based on this, a series of derivative questions were posed as follows:

- For what reason would you not use e-bikes?

Response categories: bad weather, bad road conditions, long travel distances, safety issues, physical discomfort, and other.

- If e-bikes are not available, what other vehicles would you choose to use?

Response categories: bicycles, buses, the metro, walking, cars, motorcycles, taxis, EVs, coaches, tricycles, other.

- Which aspects of e-bikes should be improved greatly?

Response categories: weight, speed, battery performance, maintenance, diversity models, controller, and other.

(d) Battery

As mentioned above, many participants complained that batteries pose the main concern when using e-bikes. E-bike retailers also explained that the reason they chose a particular brand was normally because the brand offered to “exchange new batteries with old ones” or could repair the batteries. In this case, the batteries were identified as important parts of the questionnaire design. In order to collect more information about batteries, a series of questions related to batteries were designed as follows:

- What type of battery does your e-bike use?

Response categories: lead acid battery, silica gel battery, lithium battery, and other. These three types of batteries are the most popular ones in the current e-bike market in China.

- How often do you renew your battery?

Response categories: never changed, less than once a year, every one to one and half years, every one and half years to two years, less than once every two years.

The e-bike battery renewal time is identified by a previous e-bike battery study (Asian Development Bank, 2009) and the interview results from e-bike users and e-bike retailers.

- At what time do you charge the battery?

Response categories: 0:00 to 5:00, 5:00 to 8:00, 8:00 to 17:00, 17:00 to 20:00, 20:00 to 24:00.

The time interval was determined by the peak and off-peak times of household electricity demand in Nanjing (Nanjing Statistics Bureau, 2014).

- Where do you usually charge the battery?

Response categories: home, working place, parking place, public charging points, business centres, service centres, and other.

The listed places are the most popular charging places according to respondents.

- What are the drawbacks of e-bike batteries?

Response categories: heavy in weight, large size, short life cycle, high price, self-discharge, slow charging, safety issues, and maintenance.

The listed battery drawbacks are from the interview results of this research and the literature of e-bike studies. For example, a report published by Asian Development Bank (2009) and a paper written by Cherry *et al.* (2009) analysed the e-bike lifecycle and revealed the current issues related to the battery industry in China.

(e) Safety

Safety seems to be a serious issue associated with e-bike usage, especially the traffic violation behaviours of e-bike users, which has been discussed in Chapter 3. In the results of Exploratory Research 2, both e-bike users and non-e-bike users complained about the phenomenon of traffic violation behaviours committed by e-bike users. Therefore, we added the questions related to safety issues associated with e-bikes. The questions are as follows: 1) As an e-bike user, what are your main concerns about road safety? 2) As a non-e-bike user, what are your concerns about e-bike users? The choices of response categories were listed according to the participants' complaints, which included speeding, overloading, driving on pedestrian lanes, drink driving, running red lights, and driving the wrong way, and these are frequently mentioned by participants and in e-bike literatures (Wang *et al.*, 2011; Wu *et al.*, 2012; Du *et al.*, 2013; Bai *et al.*, 2013). In order to further investigate safety issues, e-bike users were asked whether they had ever had accidents, and if so, with whom. The response categories included: 1) never 2) yes, with pedestrians 3) yes, with a driver 4) yes, with bicycle users 5) yes, with other e-bike users.

(f) Market

The sales of e-bikes in China have skyrocketed during the last two decades, which is a unique phenomenon in the world (Ruan *et al.*, 2014). The reasons for e-bike growth in China are usually attributed to technology factors, economic factors, and policy factors (Weinert *et al.*, 2007; Ruan *et al.*, 2014). However, few studies explored e-bike user preference, although they are the pillars underpinning e-bike market development. In this study, four questions were designed to explore e-bike user preference and demand. The response categories were determined according to the results of e-bike retailer interviews.

- What is your e-bike type?

Response categories: bicycle style, hybrid style with pedals, hybrid style without pedals, scooter style, tricycle style, mobility scooter, other.

- How long have you had your e-bike ____?
- What brand is your e-bike __?
- What is the price range of your e-bike (CNY)?

Response categories: below 2,000, 2,000–3,000, 3,000–4,000, above 4,000.

- Where did you buy your e-bike?

Response categories: shopping mall, franchised store, online store, other.

- What are the primary factors influencing your e-bike purchase?

Response categories: price, maximum speed, motor power, grade ability, battery life, trip distance per charge, appearance, brand, customer service, weight, anti-theft system, other.

(g) The impact of e-bikes on urban transport system

Both e-bike users and non-e-bike users were asked in Exploratory Research 2 about the advantages and disadvantages of e-bikes. Both of the two groups agreed that e-bikes had a positive impact on urban transport systems, such as being environmentally friendly, relieving traffic jams, and facilitating daily trips. On the other hand, the participants claimed that e-bikes had some negative effects on urban transport systems, such as worsening traffic control, obstructing other vehicles, and increasing accidents. Two questions related to the impact of e-bikes on urban transport systems were designed as follows:

- Does rapid e-bike development have a positive or negative impact on urban transport systems?

Response categories: positive, more positive than negative, same, more negative than positive, negative, no opinion.

- Which effects do you think e-bikes have on urban transport systems?

Response categories: Relieve traffic jams, worsen traffic jams, no noise, facilitate daily trips, environmentally friendly, save road resources, worsen traffic control, obstruct other vehicles, increase accidents, other.

(h) Future suggestions

Suggestions about future e-bike development were also consulted. The response categories are from the previously discussed interview results and the literatures on e-bike studies. For example, some research studying the reasons for the e-bike development in China provide some suggestions for future e-bike development. These are: 1) enhancing the road safety awareness of e-bike users; 2) widening bicycle lanes to reduce collisions between e-bike users and bicycle users; 3) accelerating e-bike technology innovation to promote e-bike development (Weinert, *et al.*, 2007; Weinert, *et al.*, 2008; Yang, 2010; Rose, 2012; Ruan *et al.*, 2014). In this case, “which suggestions are important for e-bike development in the future?” was proposed to study future e-bike development. Response categories were comprised of widening bicycle lanes, building e-bike lanes, building charging points, increasing e-bike parking places, increasing e-bike speed, banning fast speed e-bikes, enhancing road safety awareness, and accelerating e-bike technology innovation.

Part 2 Questionnaire for non-e-bike users

The aim of involving non-e-bike users in this study is to understand the viewpoints of other groups regarding the e-bike transition process and how e-bikes interacted with other transport regime actors in the MLP. The questionnaire of non-e-bike users focuses on the attitudinal questions: 1) what is your main concern about e-bike users?

2) Does the rapid development of e-bikes have a positive or negative impact on urban transport systems? 3) Which effects do e-bikes have on urban transport systems? 4) Which suggestions are important for e-bike development in the future? These four questions and their response categories are almost the same as the questionnaire for e-bike users and are needed to compare the different user groups' views of e-bike transition in the analysis stage. In addition, for the same purpose, the demographic questions of non-e-bike users are the same design as the questionnaire for e-bike users. In addition, in order to discover at which level of the socio-technical transition system e-bikes are, non-e-bike users are asked whether they or their family members have e-bikes.

Part 3 Questionnaire for traffic police

Traffic police are responsible for keeping order of the urban traffic. Their views on e-bike transition are worth exploring. In addition, their responses can give us the clues about policy tendency, which is an important element in landscape level. In this work, the questionnaire for traffic police has the same four attitudinal questions and response categories as that for the e-bike users and non-e-bike users. In addition, they have much more information about the e-bike safety issues compared to other people. The traffic police are asked whether e-bike accidents happened when they were on duty, and if so, with which vehicles and vehicle users. The aim of this question was to investigate e-bike safety issues.

Questionnaire design step 4 (Determining the form of response to each question)

The forms of responses in the questionnaire design are comprised of open-ended and closed-ended questions. Most of the questions are closed-ended questions, because they are more time efficient, can specify the response category to preclude the irrelevant details and are easy to code the responses (May, 2011). The close-ended questions have three types as follows. The first type is the single response, which is

for the questions of gender, age, education, monthly salary, and whether non-e-bike users have e-bikes in the family. The second type is the multiple responses, which are the main form of responses in the questionnaire design. With the multiple responses, respondents are at liberty to tick several choices at their special cases, which would be helpful to collect more information. The questions used in multiple responses include e-bike adoption purpose, previously used transport modes, feelings associated with e-bike adoption, factors influencing e-bike purchase, the drawbacks of e-bike batteries, and so forth. The third form is the rated scale, which is applied to evaluate the use anxiety question of the e-bike user questionnaire, the future e-bike suggestions question of the traffic police questionnaire, and the positive or negative impact of e-bikes on urban transport systems question in all questionnaires. There are five scales of the use anxiety question and the future e-bike suggestions question; these are: strongly agree, agree, neutral, disagree, strongly disagree. There are six scales of the positive or negative impact question: positive, more positive than negative, same, more negative than positive, negative, no opinion.

The open-ended questions are only used for the trip time of e-bike users, the duration of owning an e-bike, and the brand of the e-bike, because the corresponding answers necessitate concrete numbers from a large scale, which cannot be achieved by the close-ended questions. The results of trip time are compared with other research results to examine whether the trip time increases over time. The results of the duration of e-bike ownership are used to investigate the e-bike transition process.

Questionnaire design step 5 (Determining the wording of each question)

The wording of questions should be carefully designed to convey the same meaning to all participants (Floyd and Fowler, 2009). To reach this goal, the question wording should follow the language used by participants. Before choosing the wording of the questions, an overview of e-bike user information was performed via reading and collecting various stories about e-bike users from magazines, newspapers, TV

programmers, academic papers and conducting informal interviews. After these research activities, the first version of question wording was designed. Then, the questionnaires were sent to the main supervisor, three research fellows and five e-bike users in order to receive feedback. Many of them recommended the use of simpler, easier to understand question formats and gave many helpful suggestions. After revision, the question wording was more polite and colloquial.

Questionnaire design step 6 (Determining the sequence of questions)

The questionnaire for e-bike users can be divided into three main parts according to the timeline. Part one investigates the demographic information of the respondents such as gender, age, employment status, income and education. Part two is the main body of the questionnaire, which examines the current e-bike adoption and relevant issues, including reasons and feelings associated with e-bike adoption, use anxiety, market, battery, and safety. Part 3 is relevant to the impact of e-bikes on urban transport systems, and future suggestions for e-bike development. The surveys of non-e-bike user groups consist of two parts: part one asked demographic questions and part two asked questions about e-bike ownership, attitudes and suggestions. The surveys of traffic police asked questions about e-bike traffic violations and their attitudes to e-bike development.

Questionnaire design step 7 to step 9

Step 7 determines the physical characteristics throughout the questionnaires. A booklet style is used and the questionnaires are printed on high quality paper. In addition, the page numbers are inserted. The questions use simple, clear formats.

Step 8 re-examines steps 1-7 and makes revisions if necessary. As discussed previously, the questionnaires were sent to a primary supervisor, three research fellows and five e-bike users. After getting their feedback, the questionnaires were

revised and sent out again until the primary supervisor approved.

Step 9 pre-tests the questionnaire and makes revisions if necessary. The questionnaires were completed by ten people. Depending on their comments, the questionnaires are further revised; for example, the wording of the questions and the format of the questions are made simpler.

4.5.4.5 Data analysis of survey results

The set of quantitative data from the questionnaire surveys are analysed in this thesis. The Chi-squared tests were employed to examine the difference amongst the user segments. Generalised Linear Models (GLM) and Binomial GLM analysis were used to deduce the relationship between e-bike transition and a series of possible influencing factors. The employed statistics software is Microsoft Excel which is used for data input and data visualisation, and the R package is mainly used for data analysis and therefore plays a key role in our work.

R is a computing environment and programming language that allows one to analyse more or less any dataset. R is compatible with all of the common computer operating systems (*e.g.* Windows, Mac, and Linux). Unlike the SPSS software which depends on a Graphical User Interface, R runs by typing in command lines and can also save the commands as scripts, which offers great flexibility for complicated operations and computation. In addition, R is completely free and is open source software, which not only reduces the research cost, but also allows many statisticians and scientists with different backgrounds to contribute new packages or modules. Hence, the community of R is very active and the module packages are comprehensive. It is very easy to find the R tutorials and get help online. For these reasons, R is used as the main dataset analysis tool in this thesis.

Basic statistics concepts

In the questionnaire data set, different statistics tests are determined by the four levels of measurements: nominal data, ordinal data, interval data and ratio data. The nominal scale is discrete data such as gender, employment status, types of e-bikes, types of batteries, and reasons for adopting e-bikes. The ordinal data are ranking-based classification such as e-bike user anxiety on a rating scale from 1 to 5. The interval scale data are referred to as the continuous data such as e-bike prices. The ratio data are interval data with a natural zero point such as the total minutes for which e-bike users use e-bikes daily.

Significance level (α) is the threshold value that “is the proportion of false alarms that we are willing to tolerate in our decision process” (Maindonald and Braun, 2003). Given a hypothesis test, the significance level means that the null hypothesis was rejected. The values of α are normally taken as 0.05 and 0.01 (Stevens, 2012). In this study, the value of α is set to be 0.05. In statistics, p -value is a function of the observed sample results that determines the significance of the test result (Stevens, 2012). A p -value ≤ 0.05 indicates that the null hypothesis is rejected by strong evidence. A p -value > 0.05 indicates a weak evidence against the null hypothesis, so the null hypothesis is not rejected and then the test result is not significant.

Chi-squared test

In this study, one of the aims is to test whether females and males have differences in terms of vehicle choice behaviours, the reasons for selecting e-bike, and trip purpose of using e-bike. Because the information about these perspectives is represented by nominal data, the Chi-squared test is adopted. The Chi-squared test is “applied when there are two or more categorical variables from a single population, which is used to determine whether the two or more variables have a significant association” (Maruscuilo and Levin, 1983). The null hypothesis of the Chi-squared test is that

variables are independent. The formula of the Chi-squared test is given as follows (Marascuilo and Levin, 1983):

$$X^2 = \sum_{i=1}^n \frac{(O_i - E_i)^2}{E_i}$$

Where O denotes the observed frequency, E is the expected frequency. The expected frequency (E_i) equals to ((Column total) \times (Row total)) / Grand total. Degree of freedom (DF) is equal to (the number of categorical variable - 1) \times (the number of other categorical variable - 1) (Marascuilo and Levin, 1983). The test result is calculated using R.

In the study, the respondents were categorised by gender (male or female) and by future mode choice preference for private cars (Yes, or No). Observation values are shown in the contingency table (Table 4.7), in which the data were collected from our survey in Nanjing and corresponded to the question for e-bike users whether they would use private cars in the future.

	Private cars		Total
	Yes	No	
Male	51	164	215
	23.8%	76.2%	100%
Female	63	115	178
	35.4%	64.4%	100%
Total	114	279	393
	29.0%	71.0%	100%
X ² = 6.443, p-value=0.0111			

Table 4.7 The contingency table

The null hypothesis is that gender and future mode choice preference for private cars are independent of each other, whereas the alternative hypothesis is that they are not independent. The independence is conducted through a Chi-squared test with sample data. By applying R with the code as follows (Teetor, 2011):

```
count <- matrix (c(51, 164, 63, 115), nrow = 2,
                chisq.test (count),
```

we obtain the result that $DF=1$, $X^2= 6.443$, $p\text{-value}=0.0111$. For this analysis, the significance level is 0.05. Since the p -value (0.0111) is less than the significance level (0.05), the null hypothesis is rejected. Correspondingly, there is a significant relationship between gender and the future mode choice preference for private cars.

Linear regression

In statistics, linear regression is used as an approach to test the relationship between the dependent variable (y) and one or more independent variables (explanatory variables, x) (Harris, 2014). If we only have one independent variable, the model is called simple linear regression. With more than one independent variables, the model is called multiple linear regression; that is (Zuur *et al.*, 2009):

$$y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \dots + \beta_i X_i + \varepsilon, \quad i = 1, 2, 3, \dots, n$$

where $\beta_i x_i$ is the inner product between vector x_i and β_i (Dalgaard, 2002).

In linear regression, linear predictor functions and the least squared approach are usually used to predict unknown model parameters from the data. In practice, the linear regression is used for two main purposes (Flury, 1988): 1) to predict the value of y by using the fitted model and additional value of x ; 2) to quantify the strength of the relationship between y and x , and identify the relationship between y and a subset of x_i , when y and a number of variables x_1, x_2, \dots, x_i are given. In this study, the linear regression is adopted with the aim of quantifying the strength of the relationship between y and x and identifying which subsets of x have a more obvious linear relationship with y .

After using R to model the linear regression, there are some indicators which are meaningful in statistics, such as p -value, R^2 , Adjusted R^2 , pseudo- R^2 , and Akaike's Information Criterion (AIC) (Crawley, 2005; Everitt and Hothorn, 2011). As discussed previously, p -value is the probability of the null hypothesis being true (e.g. no association between groups). When the p -value is smaller than 0.05, there is a very small probability of the null hypothesis being true, and correspondingly, the alternative hypothesis has a large probability to be true. When p -value is greater than 0.05, there is a large probability of the null hypothesis being true, describing a statistically non-significant pattern. R^2 is the proportion of the variance in the dependent variable that is explained by the model (Field and Miliers, 2012). Adjusted R^2 is a modified version of R^2 , which adjusts for the number of predictors in the model. The adjusted R^2 will only increase if the new variable improves the model more than would be expected by chance (Adler, 2010). However, R^2 and Adjusted R^2 values are not meaningful for binomial regression (logit regression), so they are replaced by pseudo- R^2 value (Crawley, 2007). AIC is another indicator to measure the model efficiency. The lower AIC represents a more efficient model.

Generalised Linear Models and Binomial Generalised Linear Models

The Generalised Linear Model (GLM) is a generalisation of linear regression. In this thesis, the GLM is adopted to examine the potential factors that influence the duration of e-bike future usage. One strength of the GLM is that it allows the combination of multiple independent variables that can be continuous or categorical, or both (Crawley, 2007). In addition, the GLM looks at the relationship between y and each independent variable. Moreover, GLM can yield useful information such as when the residuals from the General Linear Model are not normal, and whether there exist non-linear relationships between dependent and independent variables (Crawley, 2005). In this thesis, the dependent variable of alternative travel mode is categorical data, that is, binomial (yes or no) data. The GLM is widely used in this situation due to its high

flexibility and robustness (Faraway, 2006).

$$y = g(\beta_0 + \beta_1 X_1 + \beta_2 X_2 + \dots + \beta_i X_i) + \varepsilon, \quad i=1, 2, 3, \dots, n$$

where X denotes the independent variables, β the coefficients, ε the error term, g a function (link function) which transforms each value of y in relation to the independent variable within the model. The R code for the future adoption of e-bikes is written as follows (Faraway, 2009):

```
model <- glm (y ~ X1 + X2 + ...Xi,  
             family = gaussian (link =log),  
             data = dframe1, na.action = na.exclude )
```

Before choosing the family function, a frequency distribution histogram is plotted to check whether the data are normally distributed. The histogram represented a symmetrical, bell-shaped curve, which suggested that the data are normally distributed. Therefore, the family function is chosen to be Gaussian.

For alternative mode choice models, the R code is (Faraway, 2009):

```
model <- glm (y ~ X1 + X2 + ...Xi,  
             family = binomial (link =logit),  
             data = dframe1, na.action = na.exclude ).
```

After building the starting model, the link functions can be changed. The indicators used to find the best link functions are residual distribution (looking for normal distribution, except in binomial models), Adjusted R^2 (higher is better), AIC (lower is better). Next is to drop the non-significant variable in the model and further get the fitted model.

4.5.4.6 Challenges and limitations of the survey in Nanjing

One challenge of the Nanjing case study was low response rate, which is similar to what happened in the semi-structured interviews of previous research stages. Many people refused to participate in the survey straightforwardly, and some quitted the survey after answering two or three questions. The low response rate made it time-consuming to achieve a large sample size.

In addition, although the questionnaires were designed carefully, it was inevitable that some participants may misinterpret some parts of the questionnaires. To mitigate this negative effect, before the starting of the survey, we explained the research backgrounds and purposes of the questionnaires to them. Moreover, we reminded the participants that they could ask questions if they are unclear about something in the questionnaire, and we would always clarify it immediately.

Last but not the least, some of the respondents may not be willing to answer the questions involving the private information, such as education background, occupation, and income. They were also cautious to express their opinions on the questions related to policy. To gain their trust, the author showed the student identification card and the research consent form, and let them know that their information would be protected. In addition, we also informed the participants about the purpose of the questionnaire, where the data will be used, and other information related to the survey before the survey started.

4.6 Criteria for quality

The quality criteria are required to determine the status of all forms of research, *i.e.*

distinguishing between “good” and “poor” research. However, unlike pure quantitative research or pure qualitative research, mixed methods do not have definitions of “traditional” criteria, so it is not a simple task to assess the quality of the mixed methods research. In this case, many researchers suggested combining traditional and alternative criteria in mixed methods research or employing different criteria for the quantitative parts and the qualitative components of the mixed methods research (Becker *et al.*, 2006). In practice, most researchers do not favour adopting the same criteria for both quantitative and the qualitative components (Becker *et al.*, 2006).

Therefore, some bespoke criteria for assessing the quality of mixed methods research were suggested. Teddlie and Tashakkori (2009) proposed “inference quality” comprised of “design quality” and “interpretive rigor”. Design quality is comprised of four dimensions: design suitability, design fidelity, within-design consistency, and analytic adequacy (Teddlie and Tashakkori, 2009). “Interpretive rigour” has six dimensions, including interpretive consistency, theoretical consistency, interpretive agreement, interpretive distinctiveness, integrative efficacy, and correspondence” (Teddlie and Tashakkori, 2009). These criteria mainly measure whether the research implements an appropriate method, whether the data analysis is rigorous and appropriate to research questions, and whether inferences are consistent with data, research methods and the theory. O’Cathain *et al.* (2008) stated that a good mixed method study should satisfy the following criteria: “1) the study clearly justifies why the mixed methods approach is appropriate; 2) the study provides a transparent account of the mixed methods design; 3) the study provides appropriate sampling, data collection and analysis of individual components; and 4) the study integrated quantitative and qualitative findings and explains the process of integration.” (O’Cathain *et al.*, 2008).

This criteria adopted in our research for assessing the quality of the mixed methods are generalised based on the work of Becker *et al.* (2006), who conducted the analysis

of 251 internet surveys and 28 telephone interviews, and proposed three criteria for mixed methods research, including relevance to research questions, transparency and the integration of quantitative and qualitative findings. The main reason for selecting this set of quality criteria is that they incorporated some recurring themes of both qualitative and quantitative criteria. (Becker *et al.*, 2006). In the above-mentioned three criteria, “relevance to research questions” means the use of mixed methods to link research questions (Becker *et al.*, 2006). For this research, this criterion is met because the mixed methods research is designed on the pillar of research questions (see Section 4.4). The second criterion is “transparency”, which is the main issue of mix methods research and requires the study to provide a transparent account of the mixed methods design (O’Cathain *et al.*, 2008). This is fully explained by Section 4.4 and Section 4.5, which provides step-by-step documentation of the research process. The third criterion is “integration of quantitative and qualitative findings” (O’Cathain *et al.*, 2008). It can be achieved usually through four research processes, including convergent parallel design, explanatory sequential design (quantitative method to qualitative method), explanatory sequential design (qualitative method to quantitative method), and embedded design. This research fits the explanatory sequential design (qualitative method to quantitative method), which applies the semi-structured interview to explore the e-bike transition which is followed up with a survey questionnaire with a large sample. Therefore, this research fits the mixed methods research quality criteria generalised by Becker *et al.* (2006).

4.7 Ethical considerations in research design

Most of the social research could intervene in some aspects of social life. The process of the interaction with participants could inadvertently harm them in a psychological, financial or social way (Chew, 2000). Therefore, it has become normal practice for the ethical implications of a social research project to evaluate the potential harms and deal with them.

To deal with these issues, Cardiff Business School Research Ethics and Association of Social Anthropologists (ASA, 1999) published guidelines on the ethics of academic practice is released. The contents of the questionnaires and the questions for interviews were approved by the Research Ethics Committee of Cardiff Business School in advance (see Appendix A). It was concluded that the research topics were not personally sensitive and were low risk. Moreover, all the participants in our study were informed about the purpose of the research. For semi-structured interviews, the participants were asked whether the interview process could be recorded at the beginning of the interview. The interview would be recorded only if participants were willing. Participants' information was also confidential. Participants were not offered any payments or other recompenses.

To ensure that no harm occurred to the participants, they were fully informed about the research, what was expected for them, the potential negative consequences which could arise from the participation, how their anonymity would be assured, and how their personal details would be treated in confidence (ASA, 1999; Blaikie, 2010). In addition, data would only be gathered from participants who had consented (ASA, 1999). A clear statement (information sheet) about why the information was collected and how it would be used was given to the participants. Consent was usually gained by using the information sheet and a consent form. It must be noted that the information form gave sufficient details about the research, so that the potential participant could make a decision whether to take part in the research. The information sheet and consent form in this research is provided in Appendix A.

Secondary data greatly contributed to this research, and included documentary data, social media, and publicly available policy documents. Unlike the direct interaction with people, such as interviews, questionnaires, participant observations, there are a few ethical issues arising from the research from documentaries and social media (Wimmer and Dominick, 2013). In this case, the secondary data are freely analysed

and quoted in the research without consent (Chew, 2000).

4.8 Conclusion

This chapter described and justified the choices made regarding the research design of the thesis. The research design described in this chapter can be summarised as an abductive case study rooted in a critical realism philosophy stance. Case studies provide fertile ground for abductive approach development and allow the mixed method approach to be used. The case study strategy applied is a single embedded case study, which includes four case study units (the whole China, Beijing City, Fuzhou City, and Nanjing City). For the whole of China, Beijing City, and Fuzhou City, the data collection method used is secondary data. For the case study in Nanjing, the semi-structured interviews and survey questionnaires are used. The details and the procedures for conducting case study and designing questions for semi-structured interviews and survey questionnaires are also explained. The collected data are analysed using statistics models. Finally, the chapter discussed the criteria for assessing the quality of the mixed method research and introduced the ethical considerations in the research implementation.

Chapter 5

An Overview of E-bike Industry and Transition in China

5.1 Introduction

This chapter aims to address two research questions: 1) Can socio-technical transitions occur without deliberate policy support (RQ1)? 2) How can we explain the rapid emergence and enduring popularity of e-bikes in China (RQ2)? In order to answer the two research questions, the Multi-Level Perspective (MLP) in multi-scalar manner is applied, and the transition pathways in different phases of e-bike transition in China are identified. Under the multi-scalar framework, in addition to exploring the e-bike transition on the whole national level, we also investigated Beijing City and Fuzhou City in the micro-scale, via an original synthesis of secondary sources and materials. The work of this Chapter corresponds to research stage 1 in Table 4.1.

The chapter begins with the definitions of e-bikes. Then, the main e-bike industry regions in China are introduced, and the transition pathways of the e-bike industry cluster are discussed. After that, the multi-scalar perspective is applied to stratify China to a three-tiered structure (macro-level, meso-level, and micro-level) according to China's political system, geographical position, and culture. Under the multi-scalar framework, the e-bike transition pathways on the whole national level are discussed, followed by two “mini” case studies (Beijing and Fuzhou) in city level to explore the transition in micro-scale, based on secondary data.

5.2 The definition of e-bikes

5.2.1 Three styles of e-bikes

The term “electric bicycles” (e-bikes) is generally referred to as a two-wheeler with an electric motor used to power the vehicle, or to assist with pedalling (SBQTS, 1999). E-bikes have three main components, motors, rechargeable batteries, and controllers, which differentiate an e-bike from a traditional bicycle or gasoline scooter. Most e-bikes fall into three categories: bicycle style e-bikes, scooter style e-bikes (e-scooters), and something in-between bicycle styles and scooter styles (hybrid style). The following is a brief introduction to e-bikes from technical perspectives. More technical details can be found in Appendix E.

(1) Bicycle style e-bikes



Figure 5.1 Bicycle style e-bike

This architecture is a human/electric hybrid type that is directly assembled from normal bicycle frames, electric motors, controllers, batteries, and functioning pedals (Figure 5.1). The bicycle style e-bikes have the longest history. The low-end products are usually equipped with a lead acid battery, and have no speed change gears. High-end e-bikes use lithium batteries, and these are usually set up with intelligent controllers and derailleur gears.

(2) Scooter style e-bikes (e-scooters)



Figure 5.2 Scooter style e-bike (e-scooters)

A distinguishing feature of this scooter style e-bikes, or called e-scooters, is that it has no pedals and the maximum speed can reach 50 km/h (Figure 5.2). This model is very similar to normal gasoline scooters in respect to appearance and functions, including horns, headlights, brake lights, turn signals and meters. The main difference is that scooter style e-bikes have large battery packs under the deck or seat.

(3) Hybrid style e-bike



Figure 5.3 Hybrid style e-bike

A hybrid style e-bike is built on the frame of e-bikes and scooters (Figure 5.3). This

e-bike style usually has a more sophisticated integration with batteries, motors, drive systems, rear seats, function pedals, basket, LED lights, and anti-theft locks. Although they are more expensive than bicycle style, hybrid style e-bikes are prevalent in the market because they combine the advantages of both bicycle style and scooter style e-bikes. Firstly, hybrid style e-bikes are lighter than scooter style e-bikes. Secondly, with the deck design, they offer e-bike users an alternative way to place their feet. They also extend the space of the rear seat and add the backrests that satisfy the demand of carrying passengers and enhancing the safety of passengers.

5.2.2 The policy on non-standard e-bikes

According to Electric Bicycles – General Technical Requirements (SBQTS, 1999), in China an e-bike is identified as a special bike with two wheelers, with human powered, electric powered or electric assisted pedal-power functions. In addition, e-bikes must conform to a series of technical requirements. These are: 1) The maximum speed is not more than 20km/h; 2) The maximum weight is not more than 40kg; 3) When the e-bike achieves the maximum speed (20km/h) by electrically assisted cycling, its brake distance must be no more than 4m in dry road surface conditions and 15m in wet road surface conditions; 4) The strength of frame set requirements are the same as the requirements of normal bikes.

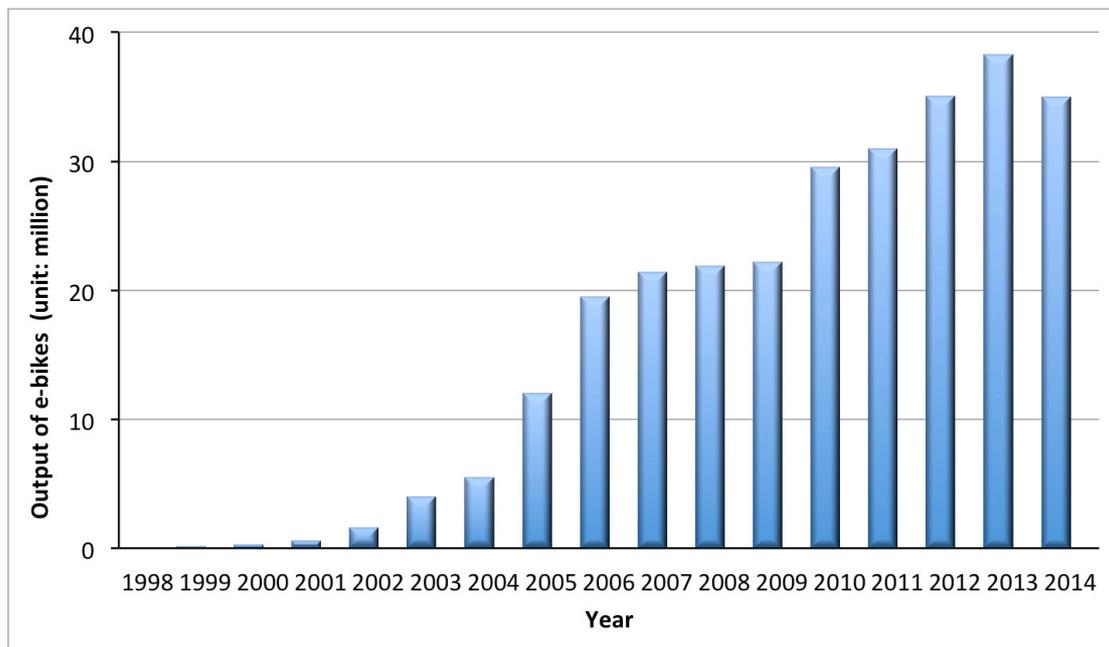
According to the Technical Requirements, scooter style e-bikes (e-scooters) are not viewed as a standard type because they do not have pedals, and more importantly, their maximum speed is beyond what is specified by the Technical Requirement. On the one hand, banning non-standard e-bikes increased the safety level of both e-bike users and non-e-bike users, because many citizens complained that the fast speed e-bikes threatened their travel safety. If e-bikes in the market can be standardised to be safe vehicles, it is possible that e-bikes may attract more people who do not need very fast speed vehicles but have a high requirement on travel safety. On the other

hand, non-standard e-bikes had been widely used, because they satisfied the mobility requirements of a number of e-bike users for their advantages of high speed and driving comfort. If non-standard e-bikes are banned, some e-bike users may not continue to use e-bikes but shift to other travel modes, which may lead to an e-bike sale reduction. Many people argued that the national standard should be updated to legalise e-scooters.

Considering the important role non-standard e-bikes played in e-bike development, the thesis incorporated non-standard styles into the e-bike categories. Hence, the definition of e-bikes in the present article is more general than that specified by the General Technical Requirements.

5.3 The e-bike industry in China

5.3.1 E-bike production

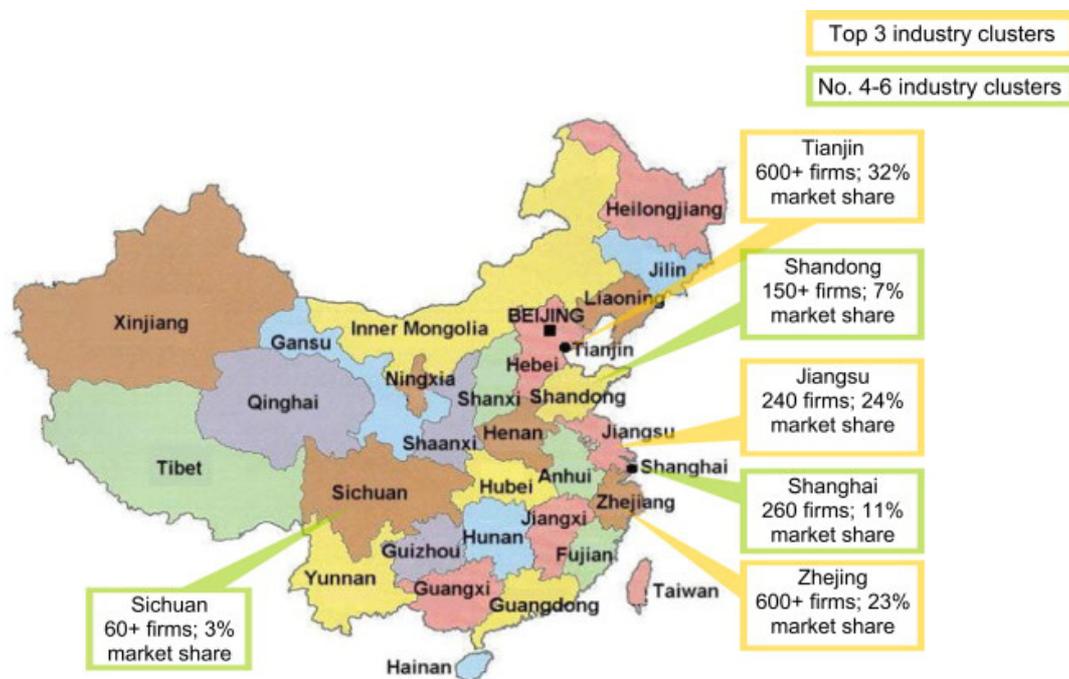


Adapted from: Ruan *et al.*, 2014; Tian, 2015.

Figure 5.4 China's output of e-bikes (2001-2014) (unit: million)

China is the world's largest producer and distributor of electric bicycles (e-bikes) (Figure 5.4). The e-bike industry started in 1998, but has grown dramatically in the past 17 years, with the output increasing from 0.054 million in 1998 to 38.5 million in 2013 (Ruan *et al.*, 2014). Although it experienced a slight decrease in 2014, the output of e-bikes was still at a very high level, around 35 million, in 2014 (Tian, 2015).

5.3.2 Major production regions



Source: Ruan *et al.*, 2014.

Figure 5.5 The top six e-bike production regions

As shown in Figure 5.5, the top three e-bike industry clusters are Tianjin, Jiangsu and Zhejiang, and these dominate e-bike production in China, occupying 79% of e-bike market share (Ruan *et al.*, 2014).

Tianjin

Tianjin is the largest e-bike production region in China. Firstly, Tianjin is originally

the largest production region of traditional bicycles in China. In 2003, more than 24.02 million bicycles were produced in Tianjin, which was 34% of the total bicycle production in China (Jin, 2005). Due to the high demand for e-bikes, many bicycle manufactures transferred their bicycle production lines to e-bike production lines, for example, Giant, a well-known bicycle producer (Guo, 2005). The existing bicycle production lines, skilled labourers and technologies provided fertile ground for e-bike production. In 2003, there were 120 e-bike manufactures based in Tianjin, and the e-bike production in Tianjin was 1 million in 2003 and 1.5 million in 2004, respectively (Gong, 2005). The number of bicycle manufactures entering the e-bike industry continued to increase in the following years. In 2005, Tianjin Fujitec Group, the largest bicycle manufacturer, decided to establish Tianjin Electric Bicycle Company by investing 15 million US dollars (Su, 2005). Because the majority of e-bike manufacturers in Tianjin had transferred from manufacturing bicycles, the types of the e-bikes produced in Tianjin were mainly restricted to bicycle styles, and contributed to 67.2% of total e-bike production in Tianjin (Yuan, 2015).

Secondly, e-bike manufacturers in Tianjin attached an importance to e-bike “Research and Development (R&D)”. For instance, the e-bike manufacturers and Mechanical Engineering Department of Tianjin University jointly established “Tianjin E-bike R&D Centre”, which aimed to overcome the technology barriers, involving the innovations or improvement of lead acid batteries, Li-ion batteries, high efficiency brush motors and brushless motors, controllers (*e.g.* sensor technique), and advanced materials (Jin, 2005). In 2010, Tianjin Bicycle and E-bike Trade Association released a detailed e-bike R&D plan, which included the innovation and development of motors and sensors, batteries and advanced materials (*e.g.* magnesium alloy and carbon fibre composites) (Xin, 2010). In 2011, 38 firms in Tianjin set up e-bike R&D departments and employed 600 researchers, which cost 0.16 billion CNY (Gong, 2011; Liu, 2012).

Year	Bicycle Production (million)	E-bike Production (million)
2002	20.28	0.22
2003	24.02	0.58
2004	16.76	1.52
2005	31.35	3.52
2006	40.19	6.13
2007	40.54	6.50
2008	40.81	6.51
2009	34.74	8.28
2010	35.98	13.42
2011	38.09	14.34
2012	39.53	16.24
2013	40.05	16.46
2014	41.88	16.24

Adapted from: Gong, 2009; Xin, 2010; Gong, 2011; Gong, 2012; Gong, 2013; Yuan, 2015.

Table 5.1 Bicycle and E-bike Production in 2002-2015 (unit: million)

Due to the above-mentioned reasons, the e-bike output in Tianjin rapidly increased (Table 5.1). The e-bike production only accounted for 1% of the total bicycle industry in 2002, but in 2014 the e-bike production equalled 40% of the bicycle production (Yuan, 2015). Recently, more bicycle manufacturers have now become e-bike producers, which accounts for 90% of the e-bike companies in Tianjin, including Tianjin Jianwei, Tianjin Birdie and Tianjin Battle. There are more than ten bicycle and e-bike industry parks in Tianjin. Every year, Tianjin holds the China North International Cycle Show where 600 bicycle and e-bike companies attend and the transaction amount reached 10.69 billion CNY in 2014 (CNIBEE, 2015). In addition, two trading centres were established in Tianjin, with the products including bicycles, e-bikes, components, and accessories. The future plan for the e-bike industry in Tianjin is the “Innovation Priority Plan”, which encourages the e-bike firms to produce high-grade e-bikes (Yuan, 2014).

Jiangsu

Jiangsu is another important base for e-bike production. Many e-bike producers have

established factories in Jiangsu. Firstly, Jiangsu is the birthplace of the e-bike industry in China. For instance, Nanjing Mainland Pigeon Tech Co., LTD. (NMP), which is based in Jiangsu, is the first e-bike manufacturer to obtain an e-bike production licence and to set up e-bike production lines and an e-bike R&D centre. In 1997, the first e-bikes were resembled on NMP's production lines, marking the start of e-bike industrialisation. In addition, NMP participated to set up the National Standard of E-bikes in 1999. From 1997 to 2004, NMP produced six million e-bikes, becoming the biggest e-bike manufacture during that period (Lu, 2005). The success of NMP contributed to attracting new entrants to the e-bike industry.

Secondly, similar to Tianjin, there are a large number of bicycle manufactures in Jiangsu. The bicycle manufactures in Jiangsu accounts for 12% of the total bicycle production in China and many of them, including Giant, Bridgestone, MING Cycle, and Oyama, have a high reputation in the market. A number of bicycle manufacturers spontaneously transferred to e-bike production during the e-bike market expansion. In 2004, of the top 14 bicycle manufactures, three completely converted their bicycle production lines to e-bikes, six produced both bicycles and e-bikes, and five reduced their bicycle production (Su, 2005).

Thirdly, many bicycle component manufacturers such as Nanjing Liming, Senwei Group, Xinhua sprocket wheel, Danyang Spoke, Hannuo rims, and Anteng Hub, are concentrated in Jiangsu, and these provide powerful support to e-bike development. The component manufacturers in Jiangsu focus on the middle and high-grade products in order to enter international markets, and pay attention to component technology innovations. As a consequence, the e-bikes produced in Jiangsu are of a high standard and reputation, and the market orientation is in the middle and high grade, and includes some well-known companies like NMP, Giant, Xiaolinyang, Xinri, and Jincheng.

Finally, the e-bike companies in Jiangsu have developed a distribution network. For

example, Heping adopted the “Business to Customer” model and as such established many customer service points. NMP expanded its direct stores and provided a complete customer service.

In 2014, the number of e-bikes produced in Jiangsu was 9 million (Chu, 2015). The lithium-ion battery e-bike production was 0.28 million, slightly higher than in 2013 (Chu, 2015). The e-bike firms in Jiangsu, which included Jiangsu Xinri, Jiangsu Yadea and Changzhou Supaqi, accentuated their brand image and mainly produced luxury e-bikes as they had previously done with traditional bikes. The China Wuxi International Electric Vehicle Exhibition has been held in Jiangsu every year since 2007 in order to stimulate e-bike development in Jiangsu. In addition, the e-bike industry in Jiangsu has attempted to build e-business to increase its market share.

Zhejiang

Zhejiang is also a large e-bike production region. Firstly, some well-known e-bike brands, such as Lvyuan, Wolong, and Philips, established their manufactories in Zhejiang at the very early stages of e-bike development, and this stimulated the e-bike industry in Zhejiang for a long time. The substantial profits of the e-bike industry attracted many new entrants. Up until 2003, Zhejiang had 300 e-bike manufacturers (Zhang, 2005). The production of e-bikes reached 2.14 million in Zhejiang in 2004, which accounted for 30% of total e-bike production in China (Su, 2005).

Secondly, a large number of battery manufacturers are located in Zhejiang. In 2004, there were 102 battery manufacturers (Zhang, 2005) and the Tianneng battery manufacturers produced 8 million batteries in 2004 (Zhang, 2005). The battery manufactures invested the R&D of new batteries, attempting to break through the bottleneck of battery techniques. Tianneng and Zhejiang University co-founded a postdoctoral centre to improve battery performance (Song, 2005). In 2005, one billion CNY was invested to establish new battery factories in Zhejiang. 0.33 billion CNY

was invested to support the “Ni-MH Battery Production Project” (Song, 2005). In 2010, the Chaowei battery company invested 0.65 billion CNY to establish the “Green Energy R&D Industry Park” to accelerate lithium-ion battery innovations (Fang, 2010).

Thirdly, Zhejiang has numerous manufactures widely spread in a broad range of bicycle component industry segments, including frame factories, pedal factories, tyre factories and so on. Many of them have a high reputation in the market and have mass production lines, for example, the tyre brand “Chaoyang” which holds the “Famous Chinese Trademark” prize. With the e-bike industry development, some new component manufactures have been established. For example, the Wuxing firm concentrates on the e-bike light system development and production.

Fourthly, many e-bike manufactures invested to upgrade the production lines, build new products and establish “R&D centres”. For example, Lvyuan and Wolong upgraded their production lines in 2004 (Zhang, 2005). The Tianneng and Chaowei battery factories and universities jointly established “New energy R&D centres” (Zhang, 2005).

Last but not the least, the e-bike demand in Zhejiang is very high, which has directly promoted the e-bike industry development. E-bike sales in Hangzhou (capital city of Zhejiang province) and Ningbo were 0.14 million and 0.1 million in 2004, respectively (Zhang, 2005). In Suzhou, there were 927,157 registered e-bikes in 2007.

E-bike production in Zhejiang was 8.52 million in 2013, including 0.52 million e-bikes with lithium-ion batteries (DDC, 2015). Many e-bike brands emerged, such as Lvyuan, Lima, Philips, Lanbei and Xinyue. Many new designs for e-bikes are developed in Zhejiang and most of them are scooter styles. What’s more, clustered around the main factories in Zhejiang are about 500 suppliers that provide e-bikes, specialist components, and batteries (DDC, 2015).

5.3.3 Overview of the e-bike industry cluster region

From the above introduction and analysis of the e-bike industry cluster region, the transition pathway of the e-bike industry followed a de-alignment and re-alignment pathway (P2) from the MLP perspective. The e-bike industry was built upon the existing bicycle industry or components industry, which undertook the groundwork for the e-bike industry and hastened its transition process. The e-bike transition process occurs gradually, co-existing with many practises and structures rather than entirely replacing them as theoretical expectations of systemic change (Wells and Nieuwenhuis, 2012).

The e-bike industries in various regions possess different characteristics, which are influenced by the original bicycle industry. For example, the e-bikes produced in Tianjin tend to be bicycle style, while e-bikes produced in Jiangsu have a more luxurious appearance. The three regions also share common features, such as the emphasis on the R&D of e-bike innovations and development. Apart from that, the e-bike industry has spontaneously developed compared with the automobile industry.

5.4 The Multi-scalar Multi-Level Perspective and e-bike policy in

China

5.4.1 The Multi-scalar Multi-Level Perspective

The Multi-Level Perspective (MLP) is the main theoretical framework adopted in the thesis to analyse e-bike transition in China. However, the definitions of landscape, regime and niche in MLP are ambiguous in practice for the transitions process occurring in a country with a large population, vast geographic space, and

complicated political structure (Coenen *et al.*, 2012). For example, a city in China can have millions of people, which is difficult to identify as a landscape or a niche. In these cases, transitions theory should be applied in a multi-scalar manner with regard to transitions pathways as is illustrated in Figure 5.6.

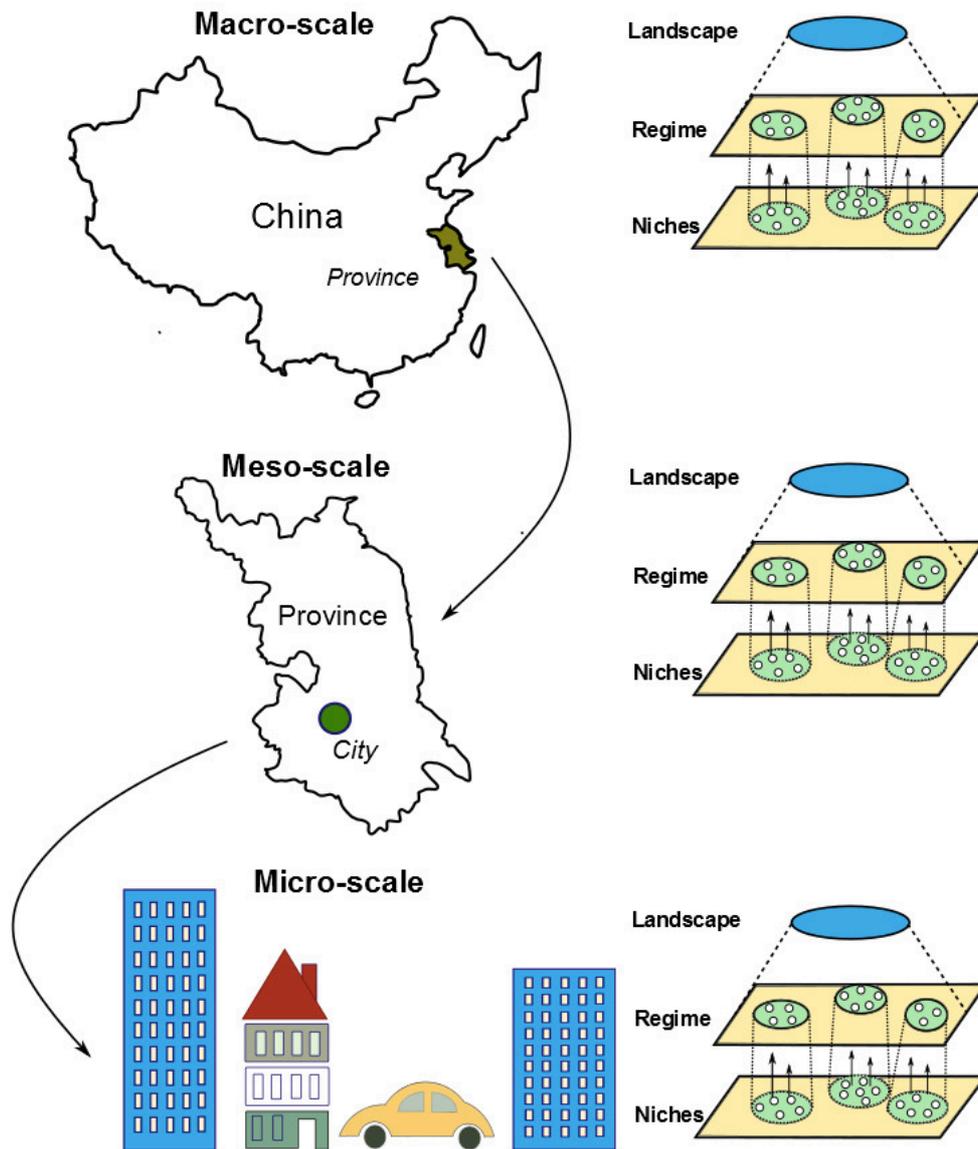


Figure 5.6: Transition theory in a multi-scalar framework

Transition process in which new regimes are embedded often accompany with spatial scale changes (Hodson and Marvin, 2012). Viewing transitions theory using multi-scalar manner, each embedded regime system at the macro-scale contains numerous sub-systems, each of which has its own self-contained multiple perspectives and can be further divided into smaller sub-systems. The interaction between the sub-systems drives the transition process in the higher level. Multi-scalar transition theory is especially suitable for a large and complicated system like China. For example, large cities in China have populations that rival many nation states. Those cities are economically and socially diverse, and city authorities have the discretion to make regulations in certain key areas, notably in this case, transportation. However, from a macro-viewpoint, the cities also serve as constituent elements of China, especially considering the top-bottom political structure of China. The transition process of the mobility regime in China has not been “homogeneous” and “synchronous”, and is a combined effect of different transition processes in various cities. To the best of the author’s knowledge, previous literatures on multi-scalar theory were restricted to a concept without giving guidance about how to apply it into a concrete example. Our research will implement it in practice by analysing e-bike transition in China.

5.4.2 The three-tiered structure of China

To know how the e-bike policy in China is implemented and enforced, we should understand China’s political system. This section provided an introduction and insights into the political structure of China from a multi-scalar perspective. A characteristic of China’s political structure is that the administrative divisions are hierarchical and there are five levels of governments from top to bottom: central government; provinces (34 regions); cities (334 regions); counties (2,853 regions); and towns (47,279 regions). Using the multi-scalar MLP, the political structure of

China can be mainly stratified to a three-tiered structure from top to bottom: macro-level; meso-level; and micro-level, and as such the scalars of the Multi-scalar MLP are specified.

Macro-level

The macro-level is identified as the whole nation of China and determines its policy framework. The National People's Congress (NPC) is the top legislature and highest organ of state power (NPC, 2004). The functions and powers of the NPC are to decide all the important issues in the state, such as legislation, the supervision of other state organs, and the national economic plan (State Council, 2010). The NPC legislates and amends the "basic laws", where the "basic laws" refer to the laws regulating the universal relationship of the nation and its society such as criminal and civil Law. For other laws and national regulations, the Standing Committee of the NPC exercises legislative power, such as the "Road Traffic Safety Law of the People's Republic of China" (State Council, 2004). The State Council is the "highest executive organ of state power and the highest organ of state administration" (NPC, 2004). Another important organisation is the Chinese People's Political Consultative Conference (CPPCC), which is a political advisory body which scrutinises government policy and proposes policy suggestions. The members of the CPPCC are from various political parties and organisations, and this is a very important channel to express people's opinions about policy (State Council, 2005). In addition, the independent members are encouraged to participate. The proportion of representation of the various parties is determined according to established convention and negotiation between the parties (CPPCC, 2015). On the CPPCC, the delegates are encouraged to raise issues and criticise current policy direction and regulation. The CPPCC has two responsibilities: policy proposal and policy supervising (CPPCC, 2004)

The NPC and CPPCC hold their general conventions (also known as "two sessions") every year on 3 and 5 March, respectively (NPC, 2015). During the annual "two

sessions”, all aspects of the national economy and people’s livelihoods are discussed (NPC, 2015). The CPPCC holds its session earlier than that of the NPC session to discuss proposals, laws and other affairs. After getting permits from the CPPCC, the proposals are submitted to the NPC for voting.

It is notable that China’s political system is highly centralised. The central government directly supervises the local provincial governments in addition to the subordinated departments (State Council, 2015). Hence, China is able to enforce abrupt and comprehensive shifts in policy that might not be so readily achievable elsewhere, although putting these into practice may be less straightforward.

The first version of the “Road Traffic Safety Law of People’s Republic of China” (Road Safety Law) was approved on the 5th Standing Committee Meeting of the 10th National People’s Congress in 2003 and went into effect on 1 May, 2004 (State Council, 2005). It was the first time that e-bikes were clearly defined as non-motorised vehicles and therefore should travel in non-motorised vehicle lanes. Following this, the Road Safety Law was amended in 2007 and 2011 (State Council, 2007; State Council, 2011). The latest version still confirmed that e-bikes were non-motorised vehicles.

In order to provide clear administrative implementation guidance for the “Road Safety Law”, the State Council issued “Regulations on the Implementation of Road Traffic Safety Law of People’s Republic of China” (Implementation Regulations of Road Safety Law) on 28 April 2004. These are administrative rules and regulations used for clarifying the provisions on vehicles (State Council, 2004). The provisions on e-bikes are given as follows: 1) e-bikes should travel on non-motorised vehicle lanes, 2) if there are no non-motorised vehicle lanes, e-bike users can use the motorway, 3) e-bike users should not overload, and 4) the age of e-bike users must be over 16 years old. The “Implementation Regulations of PRC” also require local governments to further establish more detailed local regulations and traffic planning to regulate the

road safety issues in their respective administrative areas (State Council, 2004).

Meso-level

The meso-level is identified as the provincial level, which has a similar political organisation as the national structural establishment. It has its own local People's Congresses, governments and local People's Political Consultative Conference, and takes charge of all the lower local authorities in the province. Although provinces are subordinated to the national authorities, they still have large discretion with regard to the economic policy and other affairs within the province (State Council, 2005; Jiangsu Government, 2015). Moreover, the enforcement or translation of policy into action may be different across different areas, and subject to deep cultural variations (Liu *et al*, 2012). For the local People's Congresses and local governments, their legislative and administrative power is limited to corresponding local rules and regulations which are subordinated to legislation issued by the State Council and its subordinate departments. The legislation issued by administrative organs is subordinated to that of state-power organs.

In line with the "Implementation Regulations of PRC", the province governments discuss the details of local road transportation safety law implementing regulations at meetings of NPC's standing committee of provinces. For example, "Road Traffic Safety Regulations of Jiangsu Province" ("Regulations of Jiangsu Province") was approved on 22 October 2004 (JPPCSC, 2012). The "Regulations of Jiangsu Province" was amended in 2009 and 2012 (JPPCSC, 2012). The amendment of the fourth version has already come into the legislative plan of 2015 of Jiangsu NPC 2015 (JPPC, 2013). The "Regulations of Jiangsu Province" clearly stated that the regulation is formulated based on the "Road Safety Law" and "Implementation Regulations of PRC". The provisions for e-bikes are as follows: 1) e-bike users need to apply vehicle registration plates; 2) e-bike users can only carry one passenger under the age of 12 years; 3) e-bike users under the age of 18 should not carry passengers; 4) other

provisions for e-bikes are the same as in the “Implementation Regulations of PRC” (JPPCSC, 2012).

Micro-level

In terms of city level, we identify this as the micro-level. Although city level is not the smallest political unit in China, because a city can take charge with counties which further cover several towns, citizens of the same city share very similar policies and culture, so we identify it as the micro level. The city level government takes charge of local affairs and has spaces to issue regulations in its region but must carry out the laws and regulations issued by provincial-level government and report to the provincial-level government. There are four municipalities (Beijing, Shanghai, Tianjin, and Chongqing) which are categorised to micro-level although they are directly in the charge of central government.

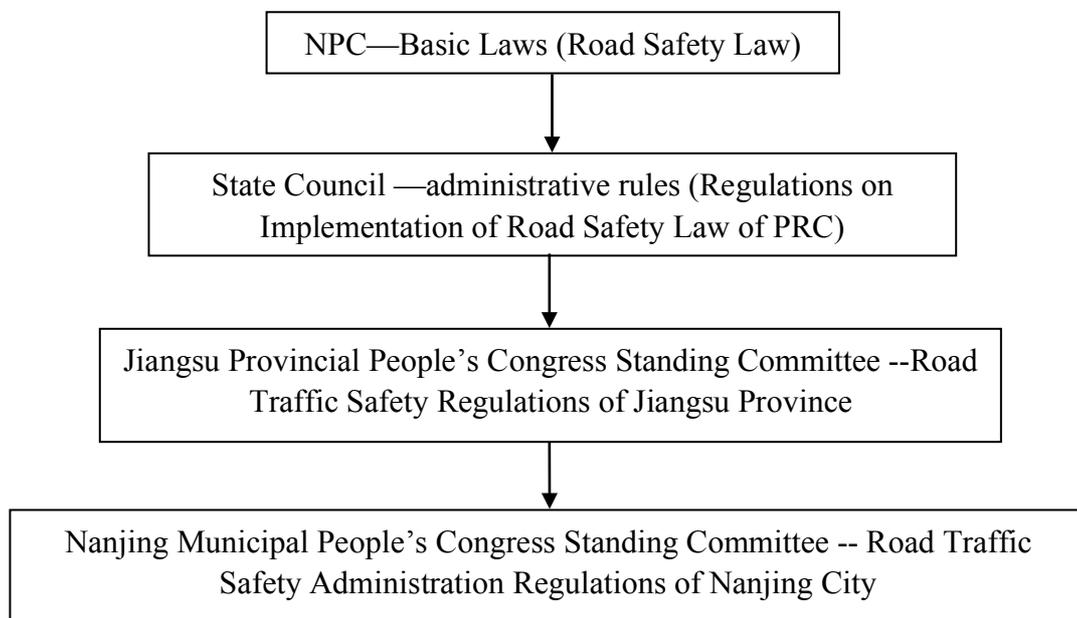


Figure 5.7 A top to bottom regulation process

The “Road Traffic Safety Administration Regulations of Nanjing City” (“Regulations of Nanjing City”) was approved by Nanjing Municipal People’s Congress Standing

Committee in 2009 (NCSC, 2009). The “Regulations of Nanjing City” is formulated in accordance with the “Road Safety Law”, “Implementation Regulations of PRC”, “Regulations of Jiangsu Province” and the concrete conditions of this city. The provisions for e-bikes are: 1) no drink driving by riding e-bikes; 2) the speed of e-bikes should not exceed 15 km/h, 3) other provisions for e-bikes are the same as “Implementation Regulations of PRC” and “Regulations of Jiangsu Province” (NCSC, 2009).

Overall, the administrative policy and the legislative process are implemented in the way of “top to down” in China (Figure 5.7). The local government administrative policies should follow the administrative policy issued by higher level government, but can adapt them depending on their local situations.

5.4.3 E-bike restriction policies in three levels

The above section discussed the three-tiered geo-political system of China. This section introduces how the e-bike restriction policy was implemented from top to bottom.

Macro-level

A specific e-bike regulation, called “Electric Bicycles – General Technical Requirements”, was issued by the State Bureau of Quality and Technical Supervision in 1999 (SBQTS, 1999). The “Electric bicycles – General Technical Requirements” is a national standard for e-bike techniques, production, sales and adoption in China. The policy makers claimed that non-standard e-bikes had a negative impact on the urban transport system. They argued firstly that non-standard e-bikes caused more traffic accidents, because they were of a large size, are heavy, could travel at fast speeds, and did not have robust brake systems, and therefore it was easy for them to

roll forward or sideslip. Secondly, non-standard e-bikes undermined urban road transportation orders and city image due to the traffic violation behaviour of non-standard e-bike users such as running red lights, overloading, and not wearing a helmet. Thirdly, non-standard e-bike users did not hold third party liability insurance. If a serious accident happened, the victims were unlikely to receive full compensation.

To further standardise all types of e-bikes according to the “Electric bicycles – General Technical Requirements (1999)”, the four departments of State Council, Ministry of Public Security, the Ministry of Industry and Information Technology, the State Administration for Industry and Commerce, and the General Administration of Quality Supervision Inspection and Quarantine, issued the “Notice of Strengthening E-bike Regulation”. This clearly required the Provincial Governments or local governments at lower level to propose an effective e-bike administration policy. It was recommended that the policy should include the following five aspects: 1) strengthen e-bike manufacture management; 2) strengthen e-bike market supervision and management; 3) establish requirements for e-bike vehicle registration plates; 4) strengthen e-bike traffic orders and security administration; and 5) enhance e-bike users’ road safety awareness (MIIT, 2011). In addition, the notice emphasises that only e-bikes meeting the “E-bike General Technical Requirements (1999)” can legally travel on roads, and for currently used non-standard e-bikes, local governments must set non-standard e-bikes transition-duration and eliminate those e-bikes in a fixed period (MIIT, 2011). In other words, the primary purpose of the notice is to preclude the non-standard e-bikes from markets.

Meso-level and micro-level

The “Notice of Strengthening E-bike Regulation” neglected the 17 years of vehicle and society development. Many data and evidences have shown that non-standard e-bikes have dominated the e-bike industry and market, and are now permitted by local governments. For example, in Henan province, the ownership rate of

non-standard e-bikes per 100 urban households was 71.61 in 2013 (Henan Statistics Bureau, 2014). In Zhejiang province and Fujian province, the ownership rate of non-standard e-bikes per 100 urban households was 60.21 and 37.58 in 2012, respectively (Zhejiang Statistics Bureau, 2013; Fujian Statistics Bureau, 2013). In Hainan province, the capital city, Haikou, issued e-bike licence plates to both standard e-bikes (blue colour) and non-standard e-bikes (yellow colour) since 2012. Up until 17 March 2014, 0.437880 million licence plates were issued, including 0.123834 million blue ones, and 0.314046 million yellow ones (Ji, 2014). The number of non-standard e-bikes was 2.5 times as large as that of standard e-bikes.

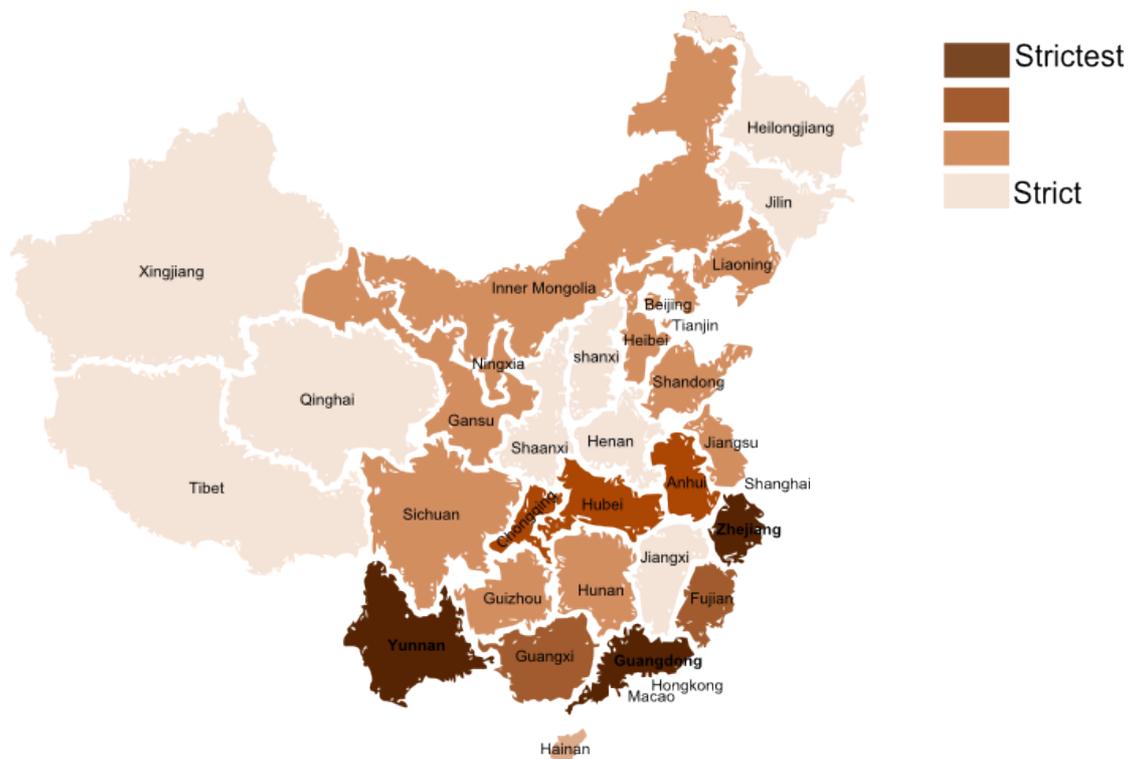


Figure 5.8 E-bike ban policy strength in different areas of China

However, the pressure from central government caused the local government policy to suddenly switch. Many provinces and cities set up a non-standard e-bike transition-duration deadline, including Yunan Province, Beijing, Tianjin, Nanjing, and so on. The deadlines varied from July 2014 to May 2018. Before the deadline, the non-standard e-bike users had to return the old plates to the official e-bike registration

plate handling stations. After that, the non-standard e-bike users could trade their non-standard e-bikes for standard ones or recycle the non-standard e-bikes at recycling points.

Apart from the non-standard e-bike banned policy, some provinces and cities even issued e-bike restriction policies for the standard e-bikes. These policies varied according to local automobility cultures, circumstances, rules and regulation. From the Figure 5.8, we can see the degree to which e-bike ban policies vary in strictness depending on the area.

Cities in Guangdong Province implemented the strictest e-bike rules. Ten cities in Guangdong Province implement harsh e-bike restriction policies. Of these cities, Dongguan is the first city issued e-bike restriction policies and completely ban e-bikes (Dongguan Government, 2007). Other cities enforced regulations as the following e-bike restriction policies: 1) a requirement for vehicle registration plates, 2) enforcing the purchase of motor vehicle road accident responsibility compulsory insurance, 3) the requirement of a driving license, 4) punishing drink drivers and 5) a requirement for users to wear a helmet (Foshan Government, 2013; Jiangmen Government, 2013; Heyuan Government, 2013; Huizhou Government, 2013; Yunfu Government; Zhaoqing Government, 2013; Zhongshan Government, 2013; Zhanjiang Government, 2013).

Yunnan Province has the second strictest e-bike policy among all the provinces. The entire province enforces the following policies in 2013: a requirement for vehicle registration plates, a ban on non-standard e-bike sales, and traffic restrictions for e-bikes (Yunnan Government, 2013). Compared with the above province, two cities issue strict e-bike policies in Zhejiang Province. Hangzhou City, as the provincial capital city, restricts the access of non-local e-bikes into the city (Hangzhou Government, 2009). Ningbo City enforced a tougher penalty for e-bike users' traffic violation behaviours, by implementing penalty standards for motorised vehicles (Jiang

et al., 2013).

All of the four municipalities (Beijing, Tianjin, Shanghai and Chongqing), which are directly under the jurisdiction of central government, have published e-bike restriction policies (Public Security Bureau of Chongqing, 2013; Public Security Bureau of Shanghai, 2014). As the four cities are political, economic and cultural centres, the policies issued by the four cities, Beijing City in particular, usually have an impact on other cities in China. This could be considered as one of the reasons that more and more cities have started to implement e-bike restriction policies. For example, Beijing was the first city to clarify the details of its e-bikes registration plate legislation and traffic restriction in 2002. This was followed by Chongqing City, two provinces (Yunnan and Liaoning), and seven provincial capital cities (Shenyang, Nanjing, Wuhan, Changsha, Guiyang, Fuzhou and Nanning) (Shenyang Government, 2012; Wu and Yuan, 2013; Yunnan Government, 2013; Public Security Bureau of Chongqing, 2013; Changsha Government, 2014; Fang *et al.*, 2015; Legal Affairs Bureau of Guiyang, 2015). These areas and cities only issued e-bike licenses for qualified e-bike models. Later, 11 prefectural-level cities required e-bike users to register their e-bikes (Ye, 2013). These areas and cities clearly specified the qualified e-bike models which had been approved to enter the market and to carry number plates. The traffic restriction policy was also implemented widely in order to control traffic jams in Shanghai and 15 other cities. These policies were mainly separated into two types: restricting access to main roads or the city centre; and restricting access to the city centre during peak times (Ye, 2013). Another example is Tianjin which was the first city to propose the real name registration system in 2010 (Zhao, 2011). This was followed by two provinces (Inner Mongolia and Gansu) and nine cities, including Handan, Zibo, Tai'an, Rizhao, Zaozhuang, Liaocheng and Zhoushan (Feng and Jiang, 2010; Ye, 2013).

With spontaneous development lasting for 17 years, the non-standard e-bikes truly satisfied the personal mobility demand of citizens. However, no laws or regulations

have rendered a clear definition of non-standard e-bikes. As a result, they are neither treated as motorised vehicles on the “Announcements of Road Motor Vehicle Production and Product (2014)” nor as meeting the national general technical requirements of non-motorised vehicles. In this case, non-standard e-bikes cannot obtain registration plates, which is a severe deficiency in management. It is more beneficial for the regime actors to render non-standard e-bikes an appropriate status rather than eradicating them.

5.5 The transition pathway of e-bikes in China

This section provides a historical narrative to analyse the rapid and substantial uptake of the e-bike industry and market in a national level of China from a transition pathway perspective. From the 1980s onwards, the established mobility regime in China was comprised by bicycles, motorcycles, cars and buses. We need to understand the extent to which e-bikes represent an alternative to the existing (less sustainable) mobility regime. In this respect, two pathways in the e-bike transition at the national level over time were identified: P1, the transformation pathway phase (1980–1999); and P2, the de-alignment and re-alignment pathway phase (1999 onwards).

5.5.1 The transformation pathway 1980–1999 (P1)

In transition theory, pathway P1 is referred to as the transformation process; this means that when the landscape pressure is moderate and the niche elements are insufficiently developed, the existing regime will respond with modifications but will not be substituted by the emerging niche innovations. In 1978, the central government prioritised and fostered the motorcycle industry in order to industrialise the transport system as an important part of China’s reform and opening-up policy. Because of

strong support from landscape and regime actors, the output of motorcycles increased sharply from 135,400 in 1981 to 11,534,000 in 2000 (Chen, 2006). At that time, the motorcycle industry dominated the two-wheel mobility regime, and reproduced itself along with reinforcing landscape developments (Li and DaCosta, 2013).

During the 1980s, the e-bike industry emerged as a niche innovation. The new two-wheel mobility modes attracted some users, due to the advantages of reducing user effort and increasing travel distance at a relatively low cost. Several small e-bike manufacturers were established around the Shanghai, Zhejiang and Tianjin areas. In 1988, 40,000 e-bikes were produced in Shanghai (Yang, 2010). In 1995, some manufacturers produced rear-wheel motor e-bikes which were capable of achieving the speed of 20kph (Huang, 1999), which is a significant technology progress. In general, however, the technologies of e-bikes were still at a very early stage. Particularly, the technologies of some critical components were not mature; for example, electric motors impeded e-bike development. In the 1980s, e-bikes simply resembled a bicycle with a chain-driven rear wheel and a motor with 14-18 NM motor output torque (Ruan *et al.*, 2014). These motors were noisy, low in efficiency, and had poor slope-climbing ability. Even worse, the duration of the motor only lasted a few months, which lead to quick wear and tear. The motor had to be replaced every three months in order to maintain the performance of e-bikes (Ruan *et al.*, 2014). This immature motor technology slowed down the e-bike industry development in China. Another example is the dilute lead-acid batteries used in e-bikes, which had the inherent shortcomings of heavy weight, low efficiency and liability to leakage (Huang, 1999). In addition, the high price of e-bikes also restricted their use on a large scale. For these reasons, the market share of e-bikes was restricted to niche level, whilst motorcycles were a main constituent of the regime and reinforced landscape developments.

5.5.2 De-alignment and re-alignment pathway (1999 onwards) (P2)

Transition pathway P2 is the de-alignment and re-alignment pathway. It suggests that the existing regime will experience a de-alignment process in the condition that the landscape change is divergent, large and sudden. In this case, if the niche innovations develop sufficiently, one of them will become dominant regime elements after a period of co-existing and competition with other elements. P2 explains the transition of the two-wheel mobility regime in China after 1999.

Province-level cities	Beijing, Tianjin, Shanghai
Sub-provincial, prefecture-level, and county-level cities	Guangzhou, Zhongshan, Shaoguan, Zhuhai, Dongguan, Shantou, Shenzhen (in Guangdong Province) Shenyang, Dandong, Dalian, Tieling, Benxi, Anshan (in Liaoning Province) Nanjing, Suzhou, Wuxi, Changzhou, Zhenjiang, Nantong, Yangzhou, Yancheng, Huai'an, Xuzhou, Taizhou, Changshu, Zhangjiagang, Jiangyin, Lianyungang, Kunshan (in Jiangsu Province) Fuzhou, Quanzhou, Zhangzhou, Longyan, Xiamen (in Fujian Province) Hangzhou, Wenzhou, Ningbo, Jiaxing, Shaoxing, Yiwu (in Zhejiang Province) Yantai, Qingdao, Jinan (in Shandong Province) Shijiazhuang, Tangshan, Zhangjiakou, Qinhuangdao (in Hebei Province) Luoyang, Zhengzhou, Xinxiang, Nanyang, Linzhou, Jiaozou, Anyang (in Henan Province) Harbin (in Heilongjiang Province) Guiyang, Anshun, Tongren, Duyun, Zunyi (in Guizhou Province) Hefei (in Anhui Province) Nanchang, Jiujiang (in Jiangxi Province) Changsha, Xiangtan, Yueyang, Zhangjiajie, Hengyang (in Hunan Province) Chengdu, Mianyang, Deyang, Yibin (in Sichuan Province) Kunming, Yuxi, Qujing, Mengzi (in Yunnan Province) Haikou (in Hainan Province) Nanning (in Guangxi Zhuang Autonomous Region) Wuhan, Xiangfan, Yichang, Zhongxiang (in Hubei Province) Xian (in Shaanxi Province) Taiyuan (in Shanxi Province) Baotou, Ordos, Dongsheng, Hohhot (in Inner Mongolia Autonomous Region) Changchun (in Jilin Province) Yinchuan (in Ningxia Hui Autonomous Region) Lanzhou (in Gansu Province) Urumqi (in Xinjiang Uyghur Autonomous Region)

Adapted from: Yang, 2010.

Table 5.2 Cities banning or restricting motorcycles

As mentioned in the previous section, e-bike development was on the niche level, while the motorcycle industry were set as a priority by governments and stabilised as a prevailing constituent in the regime. However, the motorcycle development caused some problems such as: 1) motorcycles were the source of many accidents; 2) the emission of millions of motorcycles led to serious air pollution, which is an especially important topic as China became more of an international focus (He *et al.*, 2013); and 3) motorcycles formed obstacles impeding the intensive city construction (Weinert *et al.*, 2007). Out of these concerns, many cities in China have started to partially or even completely ban motorcycles and scooters since 1997 (Table 5.2). Some cities restricted the number of motorcycle licenses or suspended the issuance of new motorcycle licenses. Some cities precluded motorcycles from the city centre or major roads in the city. By 2009, motorcycles and scooters were banned or restricted in over 170 cities (Cao and Fan, 2009). The sudden switch of the central government's attitudes towards the motorcycle industry is one of the "avalanche changes" at the landscape level, which triggered the occurrence of de-alignment process in the existing motorcycle urban transport regime and left an vacuum for the spontaneous emergence of the e-bikes.

After the implementation of motorcycle bans, motorcycle sales experienced a fluctuation. In the country's vast rural areas, the declination was not significant (Ruan *et al.*, 2012), because the negative influence of the ban was alleviated by "The home appliances going to the countryside plan" released by the Ministry of Finance and Ministry of Commerce in 2008. The plan was intended to stimulate the sales of household appliances (including motorbikes) in the country's rural areas at prices 13 per cent lower than those in cities during 2008. In most of the cities, however, the de-alignment process of motorcycles was obvious. The local motorcycle ban created opportunities for multiple niche activities, including the growth of three-wheel vehicles. However, the primary beneficiary was e-bikes, which entered a two-wheel vehicle regime with the fast market expansion and mass production (Ji *et al.*, 2012).

In contrary to the recession of the motorcycle industry, e-bikes have enjoyed a smooth development period since 1999, when an e-bike national standard was released by the central government, which specified the speed, weight and power of e-bikes. In 2004, “Road Traffic Safety Law” was issued by the Department of State Traffic Control Bureau, clearly defining e-bikes as non-motorised vehicles, permitting e-bike users to use e-bikes without a driver’s license, and allowing e-bikes to travel on bicycle lanes. Although e-bikes did not benefit from any direct support policy from central governments, they were given at least a legal status, which laid the groundwork for the spontaneous emergence of e-bikes. Moreover, the bicycle lanes that were already in place, can be shared with e-bikes, and manufacturers of traditional bicycles accumulated some technologies which can be transferred to e-bikes to a certain degree.

	1997	1998	1999	2000
Motorcycles	10,039,362	8,793,443	11,269,136	11,533,848
E-bikes	---	54,500	126,000	276,000
E-bikes/motorcycles	---	0.62%	1.11%	2.39%

Adapted from: Liu, 2008.

Table 5.3 Output of motor bicycles and e-bikes from 1997 to 2000

With the opening of this niche market, the output of e-bikes increased dramatically. As Table 5.3 shows, the output reached 54,500 in 1998, 126,000 in 1999, and 276,000 in 2000. In comparison with motorcycles, e-bike output in 1998 was only 0.62 per cent of motorcycle output, but this proportion increased to 2.39 per cent in 2000. In 2005, the sales of e-bikes for the first time exceeded that of the gasoline motorcycle in China (Ruan *et al.*, 2012). After that, e-bikes further diffused into the market, particularly in urban areas, and the continuous expansion widened the gap with motorcycles.

Attracted by the broad e-bike market prospects, a large number of bicycle and

motorcycle companies flooded into the e-bike industry, including some famous traditional bicycle brands (Yongjiu, Phoenix) and motorcycle brands (Sundiro, Qianjiang). Up to 2003, more than 1,000 companies had entered the e-bike market. This fierce competition accelerated the growth of the e-bike market, and more importantly drove the companies to enhance technology innovation, lower production costs, and improve customer service. With the rapid economic growth and the frequent transport requirements, the consumers had a stronger desire and higher income levels to pursue the e-bikes and were attracted by their appearance, superior performance, and higher degree of comfort and flexibility. During 2003, the first e-scooter model was developed; these are able to carry cargo or a passenger and of greater speed and comfort (Figure 5.2). Thereafter, advanced hybrid e-bike models were produced and won immediate popularity in the market, because of their lighter weight and lower cost (Figure 5.3). By 2010, only 16.1 per cent of e-bikes were of non-advanced hybrid designs based on traditional bicycles, whereas 26.2 per cent were e-scooters, and 57.7 per cent were advanced hybrid models (National Bike Industry Information Centre 2011, cited in Ruan *et al.*, 2012, p.449). The prevalence of e-scooters and advanced hybrid models in the market signified the substantive technology progress and huge commercial success of e-bikes.

As well as adopting different two-wheel architectures, e-bike manufactures also focussed on the technologies of the key components, such as batteries, motors and controllers, in which batteries are particularly critical since they directly determined e-bike performance in multiple aspects. The dilute lead-acid battery initially dominated the e-bike industry, which eventually impeded the market expansion of e-bikes. After that, e-bike models adopted valve-regulated lead-acid (VRLA) batteries with the advantages of lower costs and higher reliability, which met the demand of the lower income class to a certain degree. In 2005, more than 95 per cent of e-bikes used AGM (absorptive glass mat) VRLA in China, with the rest using Li-ion, Ni-MH, or NiCad (Weinert *et al.*, 2007). Many e-bike manufacturers started to apply Gel (gelified electrolyte) VRLA batteries. An increasing number of manufacturers

invested more in e-bike technology, especially lithium battery deployment. For example, the estimated output of lithium-powered e-bikes grew from 461,540 in 2010 to 750,000 in 2011 (Wei, 2013). E-bike retailers also improved the battery service. Some retailers also provided a battery repair and recycling service. In order to achieve customisation, some e-bike retailers sold frames and batteries separately, allowing customers to combine the battery with the frame according to their preferences and facilitating the battery repair or update. Therefore, the trend of e-bike manufactures was to develop and produce higher performance and higher value products with good customer service. From 2000 to 2004, the brushless motors, usually called brushless direct current motors, were developed (Zhen *et al.*, 2006). Compared with the previous motor types, for example the coil motors, the brushless motors have a low material cost, low noise, higher efficiency and a very long lifespan (10–20 years). In addition, the brushless motors do not cause electric shock from batteries. This significant improvement stimulated the e-bike market. In 2005, sales of e-bikes reached 15 million (Zhen *et al.*, 2006). More recently, most of e-bikes have been equipped with a rear wheel brushless hub motor.

As suggested above, the e-bike transition has followed pathway P2 (de-alignment and re-alignment pathway) at national level from about 1999 onwards. The example shows de-alignment of the motorcycle transport component of the established mobility regime, because of many landscape developments and regime actor views. In parallel, multiple niche markets emerged and co-existed after the motorcycle bans were imposed. However, e-bikes rapidly became dominant, potentially forming the core for the re-alignment of a new regime in a process that is currently ongoing. From around 2010 onwards the cumulative penetration of e-bikes contributed to the displacement of other modes in urban areas (Xu *et al.*, 2014). From the perspective of the multi-scalar transition theory, the development of e-bikes is inhomogeneous across the various areas of China. In some cities in south China, e-bikes and cars appears to have dominated the market. For example, the household ownership rates of e-bikes and private cars are 34.56% and 37.97% in Nanjing, respectively (Nan, 2013).

By contrast, in a view of the national level, the e-bike has no clear substitution for motorcycles or other modes, but has become additional to them.

The shifting of the mobility regime mainstream from motorcycles to e-bikes does not necessarily mean that motorcycle technologies are completely obsolete and have therefore failed in the competition. The failure of motorcycles can be mainly attributed to the policy intervention. The bans from governments simply precluded them from the market in relation to administrative means. It is possible that e-bikes have encountered the same problem. As discussion on the Section 5.4.3, some cities started to issue e-bike restriction polices. These regime actions make the future for e-bikes uncertain.

On the other hand, the technology development of e-bikes are not negligible, which possessed some advantages over motorcycles to better satisfy some customers' demand for personal mobility, and enabled e-bikes to capture the opportunity created by "motorcycle bans". Therefore, the technology accumulation of e-bikes and motorcycle ban policies combined to motivate the rapid growth of e-bikes.

5.6 Two examples at the municipal level: Beijing and Fuzhou

City	Initial e-bike policy		Second e-bike policy	
Beijing	08/2002:	Complete ban of e-bikes on 1 January 2006.	01/2006	Issue licenses for e-bikes and permit licensed e-bikes to travel in the city.
Fuzhou	06/2003	Ban the sale of e-bikes.	04/2010	Issue licenses for e-bikes and permit licensed e-bikes to travel in the city.

Table 5.4 City-level policy on e-bikes, Beijing and Fuzhou 2002 to 2010

Now we use the secondary data to study the transition pathways with respect to e-bikes (RQ2) at the micro-scale, *i.e.* the cities. In the cities we studied, Beijing and

Fuzhou, we will find that the e-bike transition also followed P1 and P2 pathways, although the main landscape pressure is from e-bike bans rather than motorcycle bans. An example is that of the enactment of the local policy on banning e-bikes and then subsequently accepting them. In this process, the crucial regime actors are local government and local transport management departments. Table 5.4 shows the treatment of e-bikes in Beijing and Fuzhou, which will be detailed below.

5.6.1 Beijing

With the urbanisation and industrialisation of China, a large number of people from rural areas flooded into the cities like Beijing for new employment opportunities. These newcomers normally had low income level, and thus could not afford the high living costs in central areas of Beijing. Majority of them had to rent accommodation in the suburban districts with the long commuting distance to the working place (Zhang *et al.*, 2013). However, the routes of public transport system were very limited to cover their living places, and the motorcycle bans in 1985 further exacerbated the transport issues. Fortunately, e-bikes emerged with the advantages of low cost, fast speed, personal mobility and convenient accessibility, which could meet the citizens' travel demands to a large degree (Cherry and Cervero, 2007).

However, the Beijing government reacted negatively to the adoption of e-bikes and banned e-bikes completely in August 2002. The government declared that the e-bike ban policy would facilitate traffic management and release more urban road space for automobile development. This change in landscape caused citizen personal mobility problems and was subjected to the criticism from media. Some journalists criticised that the city authorities neglected the desires and travel requirements of the people. They showed the evidence that the penetration of e-bikes in Beijing was 60,000 at the end of 2001, followed by 36,000 sales in 2002 (Gao, 2002; Fan, 2004; Zhang, 2004), in order to justify the argument that e-bikes had been embedded well in the life setting

of many e-bike users. Moreover, Beijing News conducted a poll on purchase intentions with respect to e-bikes, and the results revealed that 2.117 million people had strong intention to purchase an e-bike in the future (Zhang, 2006). However, the city authorities insisted on eliminating e-bikes from the transport system and paid most attention to the automobile industry, for example, by hosting the Beijing International Auto Show, involving the automobile industry in its tenth five-year plan, and by constructing a new 128km highway (Bai, 2002).

E-bike ban was also opposed strongly by e-bike users and manufacturers, energy companies, and the battery industry (Zhang, 2006). Academics from social science research, city planning and law published many papers to argue against the inappropriate e-bike ban policy (Zong, 2002; She, 2002). In response to increased public pressures, local government and the standing committee of Beijing Municipal People's Congress held a public legislative hearing to discuss the e-bike issue on 3 September, 2004 (Beijing People's Congress, 2004). However, the government still did not lift the e-bike ban after the legislative hearing.

However, the situation was altered in 2006. During the fourth session of the tenth Beijing People's Political Consultative Conference (14–18 January 2006), some delegates proposed “the suggestion of advocating resource saving and environmentally friendly transportation tools — e-bikes”. The delegates argued that e-bikes made a great contribution to personal mobility with distinguishing features among the available transport vehicles, such as affordable prices, flexibility, being environmentally friendly, performance, and labour-saving convenience (Guo, 2006). In the proposal, four main suggestions were posed: 1) lift the e-bike bans; 2) issue an e-bike license; 3) establish clear battery recycling rules; and 4) forbid e-bikes to travel on the motorway. This proposal was subsequently adopted by the Beijing government.

Before Beijing government lifted the e-bike ban policy in 2006, e-bikes were

restricted to a niche level and had not yet been sufficiently developed in Beijing. The penetration of e-bikes in Beijing was estimated at 180,000 at the end of 2005(Liu, 2008). Although this number was three times more than that in 2001, but it is still trivial considering that the penetration of private cars in Beijing was 1.54 million in 2005 (Rong, 2006). However, after Beijing lifted the e-bike ban policy, e-bikes grew dramatically and the penetration of e-bikes reached 700,000 in Beijing in 2012 (Zhen, 2012). A citizen said “I bought an e-bike before. Now that the government has lifted the e-bike ban, I am going to buy another one for my child. His working place is very far away from home. In the past, when I was riding the e-bikes, I was always worried about the traffic policeman asking me to pull over. I am happy to ride my e-bike now” (quoted in Ma, 2006). Also, the manager of the E-bike World Shopping Mall stated that e-bike sales increased by 50% after the e-bike ban was lifted (Ma, 2006). Hence, the e-bike market was stimulated as a whole because the city government altered the strategies on e-bike ban policy.

5.6.2 Fuzhou

Fuzhou is the capital of Fujian provinces and has developed economy. The Fuzhou government initially acquiesced to e-bike use, but then banned e-bikes, eventually accepting them again in 2010. The transition of e-bike policy in Fuzhou (the capital of Fujian province) reflects the interaction between the public and the government on policy-making.

Due to the vacuum caused by the motorcycle ban policy, e-bikes developed with remarkable rapidity. However, the explosive increase of e-bikes was beyond the expectation of the government. Faced with some safety and transport management problems caused by e-bikes, and lacking the experience in managing the new transport form, the Bureau of Public Security of Fuzhou government issued a ban on e-bikes (Jue, 2001). This ban ignored the practical transport needs behind the e-bike

growth and irritated the e-bike users, whose representatives sued the Bureau of Public Security for the infringement of public legal rights and interest in July 2001 (Cai, 2003). The case ended in success for e-bike users. After that, the sales of e-bikes increased rapidly, arriving at 100,000, and the number of e-bike retailers rose to more than 100. In the ninth Fujian People's Congress Conference (January, 2002), the deputies proposed to issue e-bike licenses in order to further legalise e-bikes. Moreover, a consultation of e-bike issues comprising of People's Congress deputies, traffic police, officers of Municipal Transportation, journalists, and communities, required the city authority to respect public opinions (September, 2002).

However, the Fuzhou government still held a negative attitude towards e-bikes and found another way to hamper their development. On 1 June 2003, the government held a news conference to announce that the sales of e-bikes would be banned. The government argued that the e-bike ban policy was out of the concern of limited road resources, safety issues, and battery recycling issues (Wang, 2003). The e-bike companies strongly opposed this policy and claimed that the administrative actions to forbid e-bike sales are illegal. The opponents obtained wide support from the Standing Committee of the Fujian Provincial Consultative, the Committee for Social and Legal Affairs, e-bike user representatives, and the Complaint and Supervision Department of Customer Committee. Finally, some e-bike companies sued the Fuzhou Industrial and Commercial Bureau for its e-bike sale ban regulations at a local court (Ruan, 2003).

This case gained wide attention from the public. The majority of the mass media, scholars, and e-bike users stood on the side of e-bike companies. Journalists conducted intensive reports by interviewing officers from Fuzhou government, e-bike retailers and e-bike users (Liu, 2003). One academic fellow of the Chinese Academy of Engineering declared that "I am unequivocal to support the e-bike industry to enforce the Fuzhou city authority to correct their inappropriate method through administrative appeal" (China Bicycle, 2003). The prosecutors received a generous

donation from 106 e-bike companies (Jia, 2003). Unfortunately, the court rejected prosecutors' requirements (Da, 2003) and e-bike sales were forbidden in Fuzhou.

On 28 October 2003 the State Council issued "The Road Safety Law of People's Republic of China", which treated e-bikes as non-motorised vehicles, legalising e-bikes in the range of the whole nation. However, this did not become a turning point for e-bike development in Fuzhou. The law left some space for local government to operate on restrictive regulations: e-bikes should be registered at the local Public Security Bureau in order to travel on roads (State Council, 2005). Hence, the sales of e-bikes still stopped, and most of the shops only offered customer service (Lin, 2005).

The situation was altered in 2006. At this time, Beijing lifted e-bike bans and issued e-bike licenses, so the topic of lifting the e-bike ban again came back into public debate in Fuzhou. At the ninth Fujian Province People's Political Consultative Conference (24 January 2007) and the following Fuzhou People's Congress Conference (10 February 2007), some deputies advocated to lift the e-bike ban, on the ground that e-bikes mainly satisfy people with lower incomes, and the public authorities must consider and respect their demands for personal mobility. In addition, e-bikes served as "green" products by reducing congestion and contributing to improving air quality. The provincial government were expected to take concrete measures to facilitate a battery recycling system and establish the standards of e-bike speed, weight and models, instead of banning them.

After the congress conferences, the Fuzhou government started to gradually loosen the restriction on e-bikes (Chen, 2007). On 1 June 2007, e-bikes were granted the permission to travel on two main roads in Fuzhou city centre, and then extended to two more main roads on 1 June 2008. To further safeguard rights and interests, e-bike users expressed their opinions on TV, and in newspapers, magazines, e-bike user forums, and an online "e-bike bans" seminar (Yi, 2009; Dongnan Site, 2010).

Subject to the continuous pressure from public, the Fuzhou government published a consultation version of “Fuzhou E-bike Administrative Measures” on 29 March 2010 and held a news conference to explain the law terms and the details of the feedback system (Fuzhou Legislative Affairs Office, 2010). Shortly afterwards, the “Fuzhou E-bike Administrative Measures” were approved. The government clearly specified permitted e-bike models, and the places for registration and obtaining a license. The government established a special website to facilitate people to get access to the related information (Fuzhou Government, 2010).

5.7 Conclusion

The chapter provided an overview of the e-bike industry in China and an analysis of the transition of e-bikes. There are three e-bike industry clusters, namely, Tianjin, Zhejiang, and Jiangsu. The main reasons that these three regions dominate the e-bike industry is that it is built upon the existing bicycle or components industry, and these three regions emphasised the R&D of e-bike innovations and development. The formation of the e-bike industry clusters followed a de-alignment and re-alignment transition pathway (P2).

To investigate the transition process of e-bikes, we applied the Multi-Level Perspective with a multi-scalar manner, which is suitable for a country like China with its large population, vast geographic space, and complicated political structure. We divide China to three scalars or levels: macro-level (China), meso-level (Province), and micro-level (city).

Through a historical narrative on the emergence of the e-bike market in China from a transitions pathway perspective, it is revealed that the rapid e-bike emergence in China is spontaneous, which is a distinctive feature compared with other historical cases of transitions discussed in the majority of the literature. This also answers the

research question RQ1 posed in the introduction chapter of the thesis.

It is worth noting that the spontaneous emergence of e-bikes does not deny the effect of state intervention or other favourable conditions. Admittedly, the Road Safety Law by central government classified standard e-bikes as non-motorised vehicles, which means that e-bike users do not need a license and can ride e-bikes on bicycle lanes. The ban of traditional gasoline motorcycles also created an opportunistic space for e-bikes emerging in the two-wheel mobility regime. In addition, the e-bikes also benefited from the cumulative technology and the developed infrastructure of traditional bicycles.

By spontaneous emergence, we mean that the rapid development of e-bikes did not enjoy direct support from positive and purposive policy of central or local governments. The central government did not sponsor R&D programmes for the e-bike and did not implement any stimulus policies to encourage consumers to adopt these vehicles. Some local governments even restricted or banned them. But the technology development of e-bikes made themselves adapted to the new trend of personal mobility requirement, and capture the opportunities which are not intentionally created to benefit e-bikes.

Using multi-scalar MLP, we identified two sequential transition pathways of e-bike development in the national level of China (macro-scale): the transformation pathway during 1980–1999 (P1) and the de-alignment and re-alignment pathway during 1980–1999 (P1). In addition, in the micro-scale, we revealed that the transition pathways in Beijing and Fuzhou are also P1 and P2. The difference is that in the national level the landscape pressure was from motorcycle bans, but in the cite level (Beijing and Fuzhou) the landscape pressure arose from e-bike ban policies. The analysis of the transition pathways explained the rapid emergence and enduring popularity of e-bikes in China (RQ1 and RQ2).

Chapter 6

A Case Study of Electric Bicycles in Nanjing: Sustainable Transport Consumption Behaviour and Socio-technical Transition Part 1

6.1 Introduction

In this chapter, the Multi-Level Perspective (MLP) is applied to investigate e-bike development in China. The Multi-Level Perspective has been widely used to analyse topics such as transport and mobility (Wells and Nieuwenhuis 2012, Geels 2012, Wells and Beynon, 2011), domestic energy (Nye *et al.*, 2010), and water management (Van der Brugge *et al.*, 2005). However, most of these studies focused on the interactions and functions of institutions and organisations in socio-technical transitions. Research on individual choice and sustainable consumption behaviour related to the MLP is still lacking. In addition, from a theoretical perspective, the MLP does not clearly elucidate how behavioural-institutional change might occur (Whitmarsh, 2012). To fill the aforementioned research gaps, a survey was performed in Nanjing to explore the e-bike transition process by asking a wide range of questions related to travel behaviours, consumption behaviours, culture, markets, user practices, technology innovation, infrastructure, and policy. The survey would answer the following research questions: 1) how e-bikes are “embedded” in the current transport regime (RQ3); and 2) the mechanisms underlying the rapid development of e-bikes (RQ5).

The remainder of this chapter is organised as follows. Section 6.2 briefly introduces

how the survey was implemented. Section 6.3 presents the survey data and the related results from statistics models. Section 6.4 provides a further analysis. Finally, Section 6.5 summarises the chapter.

6.2 Survey implementation

Surveys were conducted in Nanjing City in the period from late August 2014 to early November 2014. The surveys targeted e-bike users, non-e-bike users (bicycle users, car drivers, pedestrians) and traffic police.

The survey of e-bike users consists of three parts: 1) demographic questions; 2) the previous travel modes, travel time, future choice, alternative modes, users' anxiety, feelings and use preference and 3) attitudinal questions to e-bikes and future suggestions. The surveys of bicycle users, car drivers and pedestrians comprise three parts: 1) demographic questions; 2) e-bike ownership information; and 3) attitudinal questions to e-bikes. The surveys of traffic police asked about e-bike traffic violations and attitudinal questions.

The survey locations were chosen to be commercial centres, residential communities, e-bike repair shops and e-bike parking places throughout the urban areas. Because commercial centres are concentrated with a large number of people with a variety of backgrounds, so we expected that the sample could be representative to a great extent. However, it could be detrimental to the sample diversity by choosing the people living in the residential communities in the city centre, because they may have higher education and income level than average. Residential community workers, e-bike maintenance technicians and office workers helped conduct the intercept surveys. In total 1,053 responses were collected. The number of responses for each group is: e-bike users (403), bicycle users (200), car drivers (200), pedestrians (200) and traffic

police (50). The figures and tables in the next section illustrate the data based on usable responses for each category and question.

6.3 Survey results

This section presents and analyses the survey results. It starts with descriptive statistics on e-bike usage and user characteristics. After that, a Generalised Linear Model is built to predict future e-bike adoption. To further analyse the influencing factors of travel mode choices and understand the transport system transition, a Binomial Generalised Linear Model is established.

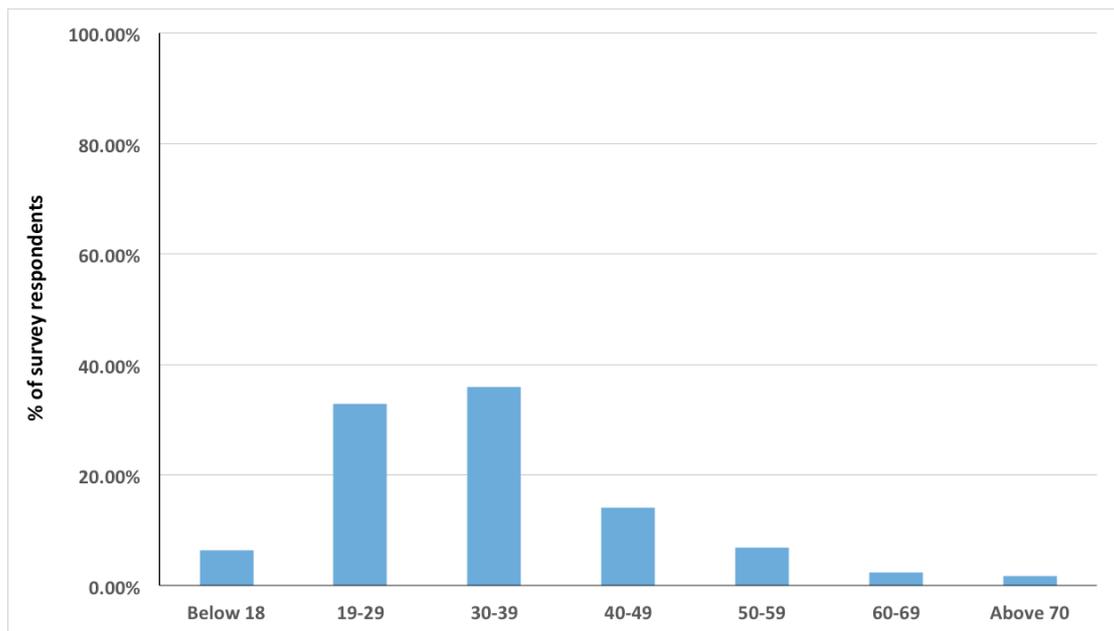
6.3.1 Demographics of e-bike users

According to our survey, the characteristics of e-bike users in Nanjing, China, have significant differences compared with other countries, which will be illustrated in detail from the following perspectives:

Age

From Figure 6.1, we can see that the age groups of the participants tend to be positively skewed. The ages of e-bike users in the study predominantly range from 19 to 39 years old. A survey conducted by Cherry and Cervero (2007) showed similar results in that the average age of e-bike users was 36.4 years old in Shanghai and 33.1 years old in Kunming. Another survey carried out in Shijiazhuang also presented that more than 70% of e-bike users ranged from 24 to 40 years old (Weinert et al, 2008). The result is also consistent with the e-bike survey conducted in Chengdu, which showed that 86% of e-bike users were between 20 and 39 years old (Wang, 2010).

The low age characteristic of e-bike users in China is distinct from other countries. In countries such as the UK, the Netherlands, and Denmark, elderly cyclists are the main group to adopt e-bikes (Parker, 2006; Roijen, 2010; Schepers *et al.*, 2014). E-bike user studies conducted in the United States reported that the average age of e-bike users was 48 years old (Dill and Rose, 2012). In Australia, only 20% of e-bike users are below 39 years old (Johnson and Rose, 2013). A survey among early adopters (Wolf and Seebauer, 2014) conducted in Austria presented that the early e-bike users were mainly comprised of persons aged 60 years or older. The reason is that with the assistance of electric motors, e-bikes are viewed as a solution to overcoming hilly terrain and for long distances for elderly cyclists.



(Sample size, 399 e-bike users)

Figure 6.1 Age group of e-bike users: Nanjing survey

Gender

Table 6.1 shows that the portion of female e-bike users (44.95%) is close to male e-bike users (54.55%). In addition, this gender distribution of e-bike users is also consistent with the overall gender distribution of Nanjing City (49% female) (Nanjing

Statistics Bureau, 2014). In other survey results of e-bike users in China, the gender distribution of e-bike users has a similar tendency (Weinert *et al.*, 2007; Xu *et al.*, 2014). In comparison, the majority of e-bike users in western countries are male: 71% in Australia, 60% in Austria and 63% in USA, respectively (Johnson and Rose, 2013; Wolf and Seebauer, 2014; Popovich *et al.*, 2014).

Demographics	Categories	Percentage in the sample %
Gender	Male	54.55
	Female	44.95
Education	Secondary school and below	16.83
	High school	19.35
	College degree	18.34
	University degree	35.93
	Master degree and above	9.30
Income (CNY/month)	1,500 and below	13.15
	1,500-3,000	27.79
	3,000-4,500	36.97
	4,500-6,000	13.15
	6,000 and above	8.93
Cars	Households without a car	57.57
	Households with one car	37.72
	Households with two cars	3.47
	Households with three cars	1.24
Motorcycles	Households without a motorcycle	77.17
	Households with one motorcycle	22.33
	Households with two motorcycles	0.5
Bicycles	Households without a bicycle	50.13
	Households with a bicycle	40.69
	Households with two bicycles	7.69
	Households with three bicycles	1.49

(Sample size: 399 e-bike users)

Table 6.1 Demographics of e-bike users: Nanjing survey

Education

Table 6.1 shows that the education level of e-bike users in Nanjing, China is rather high. 63.57% of e-bike users have obtained a college degree or above, and 45.23% of e-bike users have completed a university degree. This finding is contrasts with the

media portrayal and some previous literatures which declared that e-bike users normally had a poor education. For example, the study of e-bike users in Shanghai and Kunming showed that the average education level of e-bike users was high school level (Cherry and Cervero, 2007). In addition, many reports appeared to be biased against e-bike users and suppose that the lower education level of e-bike users was the main reason for a large number of traffic rule violation incidents (Bai *et al.*, 2012). The difference between our findings and the previous literature could indicate that members of the e-bike user group have gradually changed and that higher education citizens progressively adopted e-bikes, or may be a feature of this particular survey in Nanjing. It is possible that the city centre location resulted in more educated (and better paid) individuals being captured by the survey.

Income

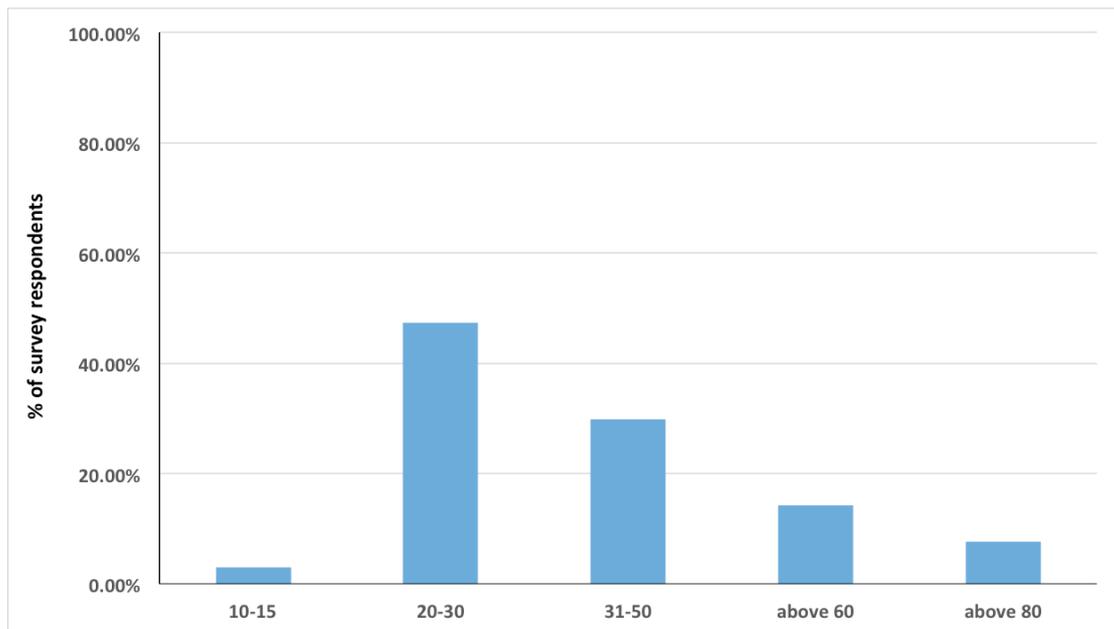
Approximately 59% of participants earn more than CNY 3,000 per month. Taking into account that the range of equivalent household income of Nanjing City varies between below 1,556 (low level), 1,556 to 3,040 (lower-middle level), 3,040 to 6,200 (higher-middle level), and above 6,200 (high level) (Nanjing Statistics Bureau, 2014), the household income of the e-bike users in our study is rather high, which matches the high level of education backgrounds of e-bike users. This user characteristic complements the study by Johnson and Rose (2013), but is against many studies which stated that the education level and household income of e-bike users were rather low both in China and other countries (Wolf and Seebauer, 2014). Our finding might suggest that an increasing number of highly educated people are adopting e-bikes to achieve their personal mobility.

The ownership of other vehicles

Table 6.1 furthermore illustrates that the average household car ownership rate in

e-bike users is 48.83%, which is much more than the overall average household car ownership rate in Nanjing City (32.5) (Nanjing Statistics Bureau, 2014). The average household motorcycle ownership rate in e-bike users is also far higher than average in Nanjing City (23.83% versus 4.5%) (Nanjing Statistics Bureau, 2014). In contrast, the household bicycle ownership rate of e-bike users is 66.54%, which is much lower than the overall household bicycle ownership rate in Nanjing City (89%) (Nanjing Statistics Bureau, 2014). Among these three vehicles, bicycles are the most widely adopted vehicles. Very few participants possess motorcycles, which might be the consequence of the motorcycle ban policy.

6.3.2 E-bike mode choice behaviour



(Sample size: 309 e-bike users)

Figure 6.2 The maximum trip time (minutes): Nanjing survey

Travel behaviour is likely to be affected by numerous external and internal factors. The survey asked e-bike users to answer the questions regarding trip time, trip purpose, model choice, previously used modes, primary alternative modes, reasons for

e-bike adoption, reasons why not to use e-bikes, the future choice of e-bike adoption, alternative mode choices, and reasons for alternative mode choices.

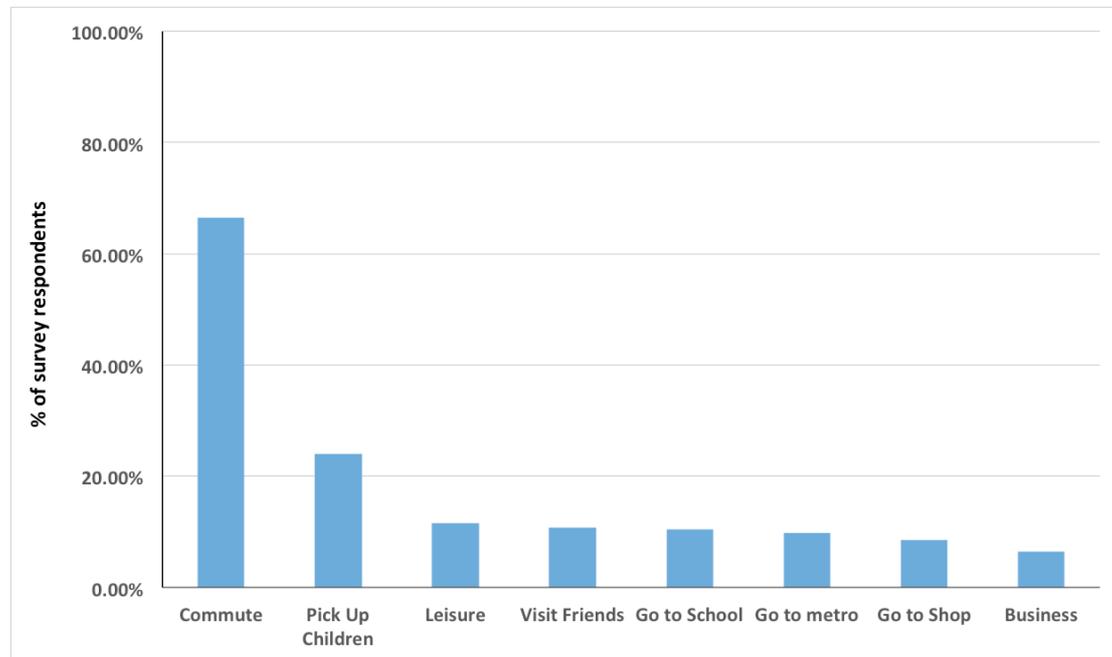
Trip time

Figure 6.2 shows the maximum trip time when travelling with e-bikes. The majority of e-bike users (47 %) stated that 20 to 30 minutes was the maximum trip time, followed by 31 to 50 minutes with 30% of the responses. The average of the e-bikes users' maximum trip time is 41 minutes, which is slightly longer than the survey results in Shanghai (25.26 minutes) and Kunming (20.28 minutes) (Cherry and Cervero, 2007). The survey in other cities, such as Beijing, Tianjin, Handan, Changchun, Jinan, and Huhehot (Wang, 2010), showed the similar average trip time (from 20 to 30 minutes). In the recent survey in Shanghai, the average trip time for e-bikes was 31.82 minutes (Ye *et al.*, 2014). This could suggest that the trip time tends to be longer with the passage of time. There may be two explanations for this phenomenon. One is that the city extensions increased the demand for longer trip times. The other is that the technological progression of e-bikes enabled them to travel for a longer time.

It is noteworthy that the survey did not ask trip length questions. The main reason is that travellers are more sensitive to the travel time rather than the distance according to the time budget theory. But we can still calculate the trip length by multiplying the trip time with e-bike speeds. Given that the average e-bike speed adopted in our study is 18.2 km/h according to the proportions of e-bike types in the market (Wang, 2010), 47.35% of travel distances are from 6.77km to 9.1km, and the average travel distance is 12.19 km. The result is higher than the e-bike travel distance in Kunming, Changchun, Jinan, and Huhehot, which ranges from 3 km to 5.66 km (Cherry and Cervero, 2007; Liu, 2008; Wang, 2010). Also, the trip distance in our sample is higher than that in Beijing and Tianjin which ranges from 6 km to 10 km, respectively

(Wang, 2010). The result could suggest that the e-bike trip distance tends to be longer and the travel demand on motorised personal mobility is increasing.

Trip purpose



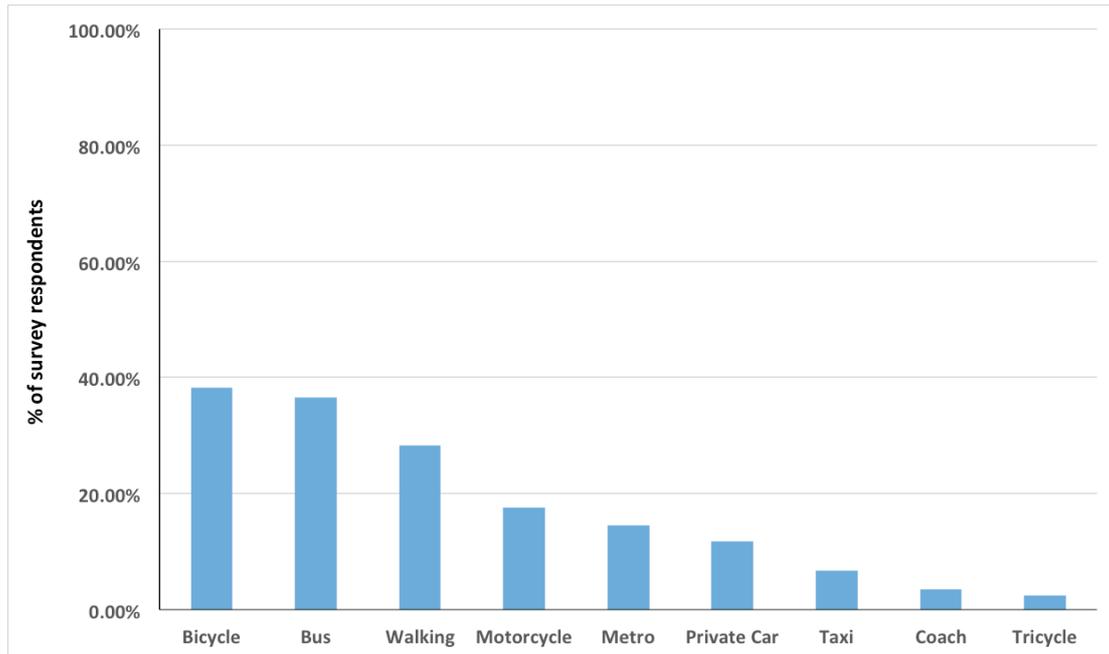
(Sample size: 394 e-bike users)

Figure 6.3 Trip Purpose of e-bike adoption: Nanjing survey

Figure 6.3 illustrates the distribution of e-bike trip purposes. Commuting holds the overwhelming majority for all trip purposes (66.5%), followed by collecting children (24%). The frequencies of leisure, visiting friends, going to school, accessing metro and going shopping are almost the same (10%). The result indicates that e-bikes are mainly adopted for utility use in China, which is a distinctive use characteristic (Weinert *et al.*, 2007; Cherry and Cervero, 2007; Wang, 2010; Rose, 2012; Ye *et al.*, 2014; Zhang *et al.*, 2014). In contrast, in other countries e-bikes are more likely to be used for leisure (Parker, 2006; Roijen, 2010; Dill and Rose 2012; Schepers *et al.*, 2014; Wolf and Seebauer, 2014), so e-bikes are still a niche market, although some efforts have been made to promote the use of e-bikes to replace the use of cars for commuting purposes in the UK, Australia and France (Pierce *et al.*, 2013; Johnson

and Rose, 2013; Héran, 2014).

Previously used travel modes



(Sample size: 403 e-bike users)

Figure 6.4 The mode previously used prior to e-bike acquisition: Nanjing survey

Regarding the previously used transport mode of the e-bike users, the most frequent response was bicycles (39%) (Figure 6.4), followed by buses (37%) and walking (28%). These results indicate that e-bikes are an ideal alternative model to bikes and buses. The survey of Shanghai and Kunming (Cherry and Cervero, 2007) showed that the top three previously used modes were buses, bicycles and walking. Another survey in Xi'an reported the similar results that more than 85% e-bike users transferred from buses, bicycles, and walking (Xu *et al.*, 2014). Therefore, it has been a universal phenomenon that a large number of travellers transfer from bicycles, buses and walking.

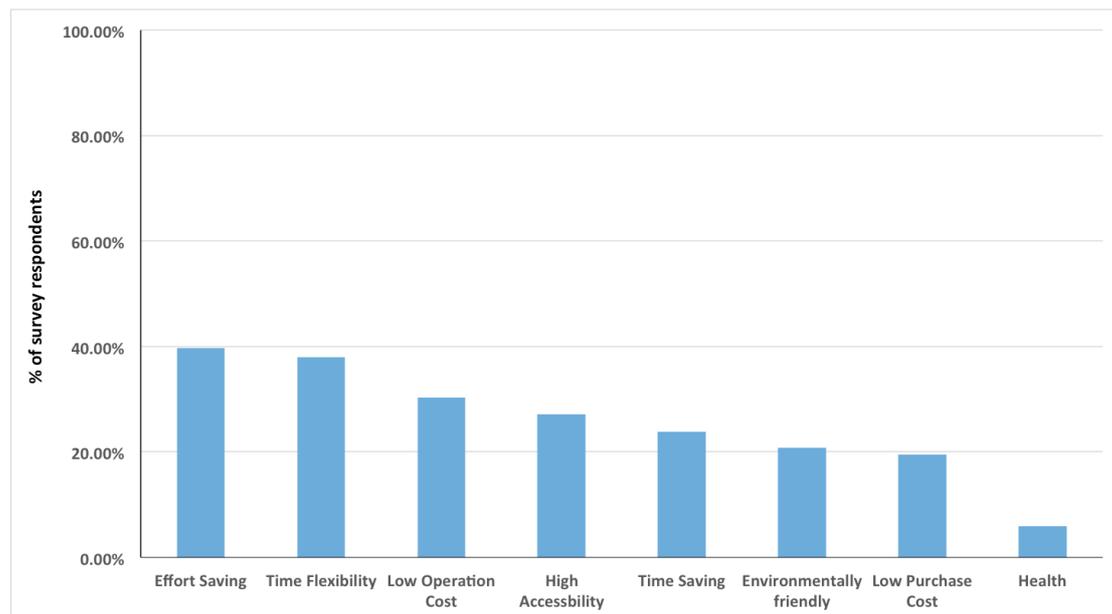
In comparison, less than 17.5% of e-bike users transferred from motorcycles, which implies that the motorcycle ban policy did not cause motorcycle users to shift to

e-bikes; this will be discussed in detail later in the thesis.

Around 29% of e-bike users transferred from the metro, which is much higher than that in Shanghai (10%), and Xi'an (1%) (Cherry and Cervero, 2007; Xu *et al.*, 2014). An explanation may be that only four metro lines operated in Nanjing at the time of the survey, while metro networks in Shanghai and Xi'an were well-developed and robust.

In the survey, 12% of private car users also adopted e-bikes to improve their personal mobility in Nanjing, which is nearly three to six times higher than in Shanghai (2%), Xi'an (2.6%), and Kunming (4%) (Cherry and Cervero, 2007; Xu *et al.*, 2014). A possible reason for this is that the car ownership rate and household income of the Nanjing sample is much higher than in other cities. Another possible reason is that traffic jams and the lack of parking spaces motivate private car users to find an alternative.

Reason for choosing e-bikes



(Sample size: 393 e-bike users)

Figure 6.5 Reasons for e-bike adoption: Nanjing survey

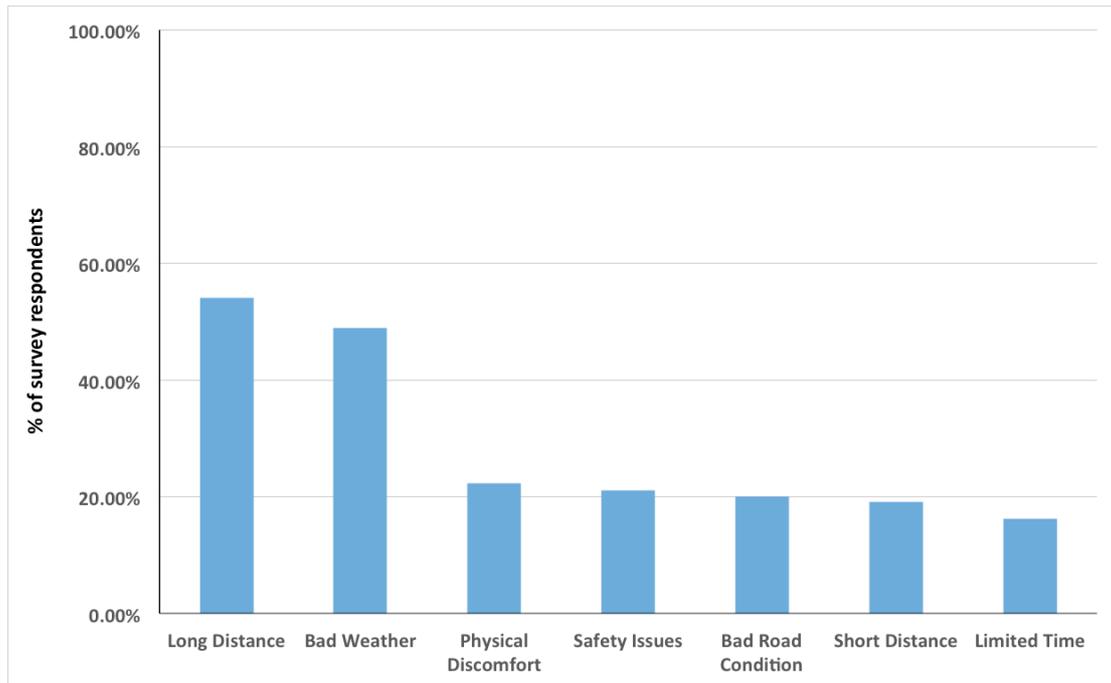
Figure 6.5 shows the reasons for e-bike adoption. Effort saving is the most prevailing reason for e-bike adoption with a 40% response rate, followed by time flexibility and low operation costs. High accessibility, time saving, being environmentally friendly, and low purchase costs have a 30% to 20% response rate. Although e-bikes are verified as a new active transportation mode to benefit health (Gojanovic *et al.*, 2011), only 5% of respondents chose e-bikes as their daily transport vehicles for this reason. Hence, the most important factor of mode choice is practicability, which agrees with the trip purpose research, where we find that people in China use e-bikes for commuting instead of leisure use.

The reasons for e-bike adoption in our study are different from others. The survey results in Shanghai showed that the time saving aspect had the highest response rate (48%), followed by the inconvenience of using the bus, a desire to save money, and convenience (Ye *et al.*, 2014). In the study in Shanghai and Kunming, the high speed of e-bikes was the primary reason and the second most prevalent reason was effort saving (Cherry and Cervero, 2007). In the study of e-bikes in Shijiazhuang, the reasons for e-bike adoptions were ranked as follows: 1) e-bikes were faster than bicycles; 2) e-bikes had more time flexibilities compared with buses; 3) e-bikes were comfortable to use; 4) buses were too crowded; and 5) commuting distances were too long for bicycles (Weinert *et al.*, 2008). The findings may indicate that the e-bike adoption reasons could vary by city due to different situations related to the development of the other transport modes.

Taking into account the previous travel mode of e-bike users and the reasons for choosing e-bikes, we can find that different travel mode users transfer to e-bikes for different reasons. The main reasons for bicycle users to shift to e-bikes are due to effort saving and faster speed. For pedestrians, bus users and bicycle users, the most frequent responses were effort saving and time flexibility. This implies that the travel priorities tend to be time saving, high productivity and personal freedom. Time saving

and high accessibility are the main reasons that bus users and private car users shift to e-bikes in our study.

The situations when not to use e-bikes



(Sample size: 397 e-bike users)

Figure 6.6 The reasons why not to use e-bikes: Nanjing survey

For the situations when not to use e-bikes, the most frequent answers are long distance (54.06%) and bad weather (48.98%). See Figure 6.6. The limitations of e-bikes may have negative effects on e-bike transition in social practice. In addition, many travellers will not use e-bikes when they experience physical discomfort, although e-bikes are thought to have more potential to assist travellers with physical difficulties compared with bicycles. Furthermore, we find that safety issues are not the main concern for travellers when they decide whether to use e-bikes. Bad road conditions, short distances and limited time have little impact on e-bike adoption, and these factors range from 20% to 19% in the results.

6.3.3 E-bike use patterns

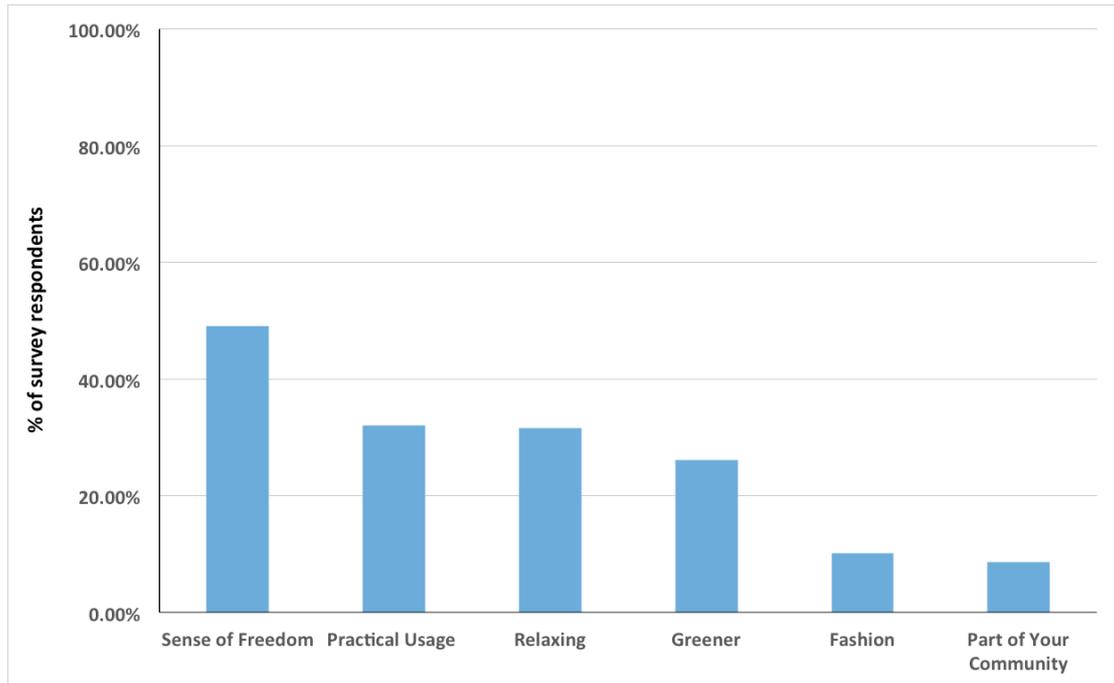
The section investigates e-bike use patterns, such as attitudes to e-bike adoption, consumption behaviours, and battery use patterns. This topic is rarely found in previous studies, but they are essential in understanding how individuals embed technologies as innovations in their consumption in everyday life.

6.3.3.1 Attitudes to e-bike adoption

Some previous studies explored attitude questions to transport modes, but generally these were for cycling and walking (Pooley *et al.*, 2011; Jones *et al.*, 2012). In these studies, it was found that the positive associations of cycling and walking were enjoyment, health, saving money and being environmentally friendly. The negative associations were difficult road junctions, no cycle lanes and exposure to bad weather (Pooley *et al.*, 2011). In addition, they suggested that the positive associations could be jeopardised by the negative associations (Jones *et al.*, 2012). Furthermore, they concluded that positive associations were internal and negative associations are external. This subsection is used to investigate the attitudes to e-bikes.

Positive attitudes to e-bike adoption

E-bike users' attitudes towards e-bike adoption in urban areas are addressed in the study. As shown in Figure 6.7, the majority of e-bike users believed that they would have a feeling of freedom when travelling with e-bikes (45% of responses), followed by practical usage and having a sense of relaxation. Around 25% of e-bike users thought that they had mitigated climate change. Other positive associations with e-bike adoption are the feeling of being fashionable and feeling part of the community. These positive associations imply an intrinsic and personal feeling about e-bikes.



(Sample size: 403 e-bike users)

Figure 6.7 Attitudes for e-bike adoption: Nanjing survey

Negative attitudes to e-bike adoption

There are a series of factors influencing e-bike adoption, including charging difficulty, maintenance difficulty, the weight of e-bikes, narrow bicycle lanes, and exposure to bad weather (Table 6.2). The first three problems, charging difficulty, maintenance difficulty and e-bike weight, mainly derive from batteries, indicating that batteries play a key role in e-bike adoption. In terms of narrow bike lanes, the problem derives from the fact that e-bike users and bicycle users share the same lane, so it is very easy to cause congestion between in these areas. Therefore, many respondents in the survey suggested that e-bike/bicycle lanes should be widened. Finally, e-bike usage is very vulnerable to bad weather conditions, which also poses practical difficulties to e-bike adoption. In contrast to the positive attitudes to e-bikes, the aforementioned negative problems are primarily external to individuals, implying that the transfer between the transport modes is likely to be reversed by an externally built environment (Pooley *et al.*, 2011; Jones *et al.*, 2012), and the negative problems could

be alleviated or removed mainly through engineering technique improvements.

	Mean	Median	Mode
I would be worried about the narrow bicycle lanes	3.41	4	4
It would expose me to wet or windy weather	3.57	4	4
The speed of e-bikes is too fast	3.06	2	3
The e-bikes are too heavy	3.29	4	4
The e-bikes are prone to failure when driving	3.08	2	3
I would be worried about rear seat safety	2.99	4	3
I would be worried about low battery capacity	3.01	2	3
I would be worried about charging difficulty	3.93	4	4
I would be worried about maintenance difficulty	3.58	4	4
It would put my e-bike at risk of being stolen	2.84	2	2

5 = Strongly agree 4 = Agree, 3 = Neutral, 2 = Disagree, 1 = Strongly disagree;
Neutral Scores are in range of 2.8 to 3.2.

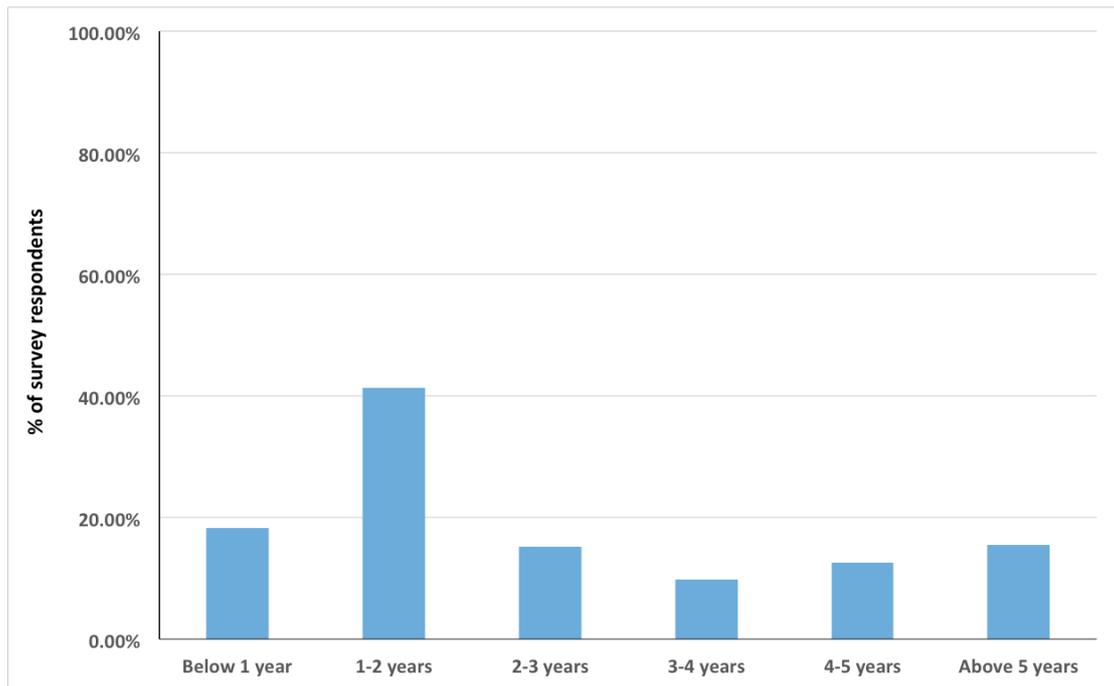
(Sample size: 403 e-bike users)

Table 6.2 Use anxiety for e-bike adoption: Nanjing survey

6.3.3.2 Consumption behaviours

E-bike using years

Figure 6.8 shows the time scales of e-bike adoption. The majority of e-bike users have used e-bikes for one or two years. At that time, e-bike development was at the transition path of de-alignment and re-alignment. The longest time for e-bike adoption is ten years, while the shortest time for e-bike adoption is only 15 days. More than 41% of travelers used e-bikes at least for two years. A possible reason is that the current public transport system could not satisfy their travel demands. Also, it could be because the travel distance is increasing so that using bicycles or walking is no longer appropriate.



(Sample size: 350 e-bike users)

Figure 6.8 E-bike adoption time: Nanjing survey

E-bike brands

Chinese Name	English Name	Ownership number
绿源	Lvyuan	41
小刀	Xiaodao	39
飞鸽	Feige	38
爱玛	Aima	38
新大洲	Palla	33
大陆鸽	Daluge	30
雅迪	Yadi	32
捷安特	Giant Electric Vehicle	21
飞毛腿	Feimaotui	18
富士达	Fushida	18

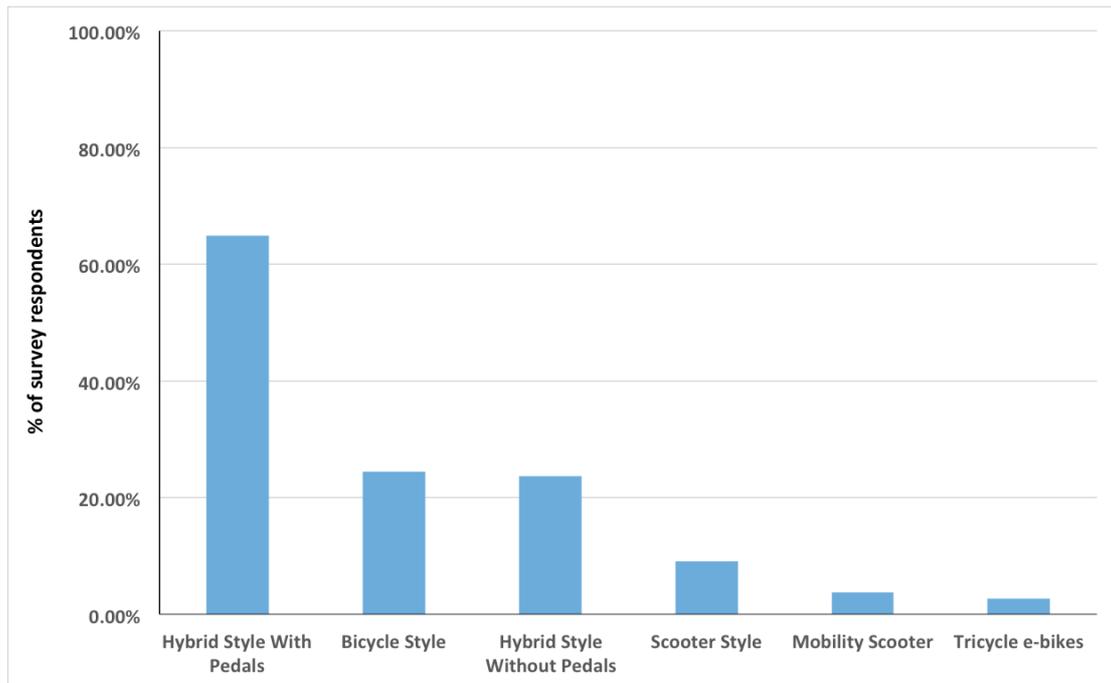
(Sample size: 334 e-bike users)

Table 6.3 The most prevalent brands of e-bikes: Nanjing survey

334 participants supplied answers about their e-bike brands. According to the

responses, more than 55 brands of e-bikes are adopted. The distribution of the e-bike brands is widely scattered. The top ten brands are Lvyuan, Xiaodao, Feige, Aima, Palla, Daluge, Yadi, Giant Electric Vehicle, Feimaotui and Fushida (Table 6.3). Of these brands, Daluge, Yadi, Giant Electric Vehicle, and Feimaotui are based in Jiangsu Province, where Nanjing city is located. Aima and Palla also have e-bike factories in Jiangsu Province. The emergence of a great number of well-established enterprises in the e-bike industry indicates the high expectations of manufactures for the e-bike market.

E-bike type distribution



(Sample size: 379 e-bike users)

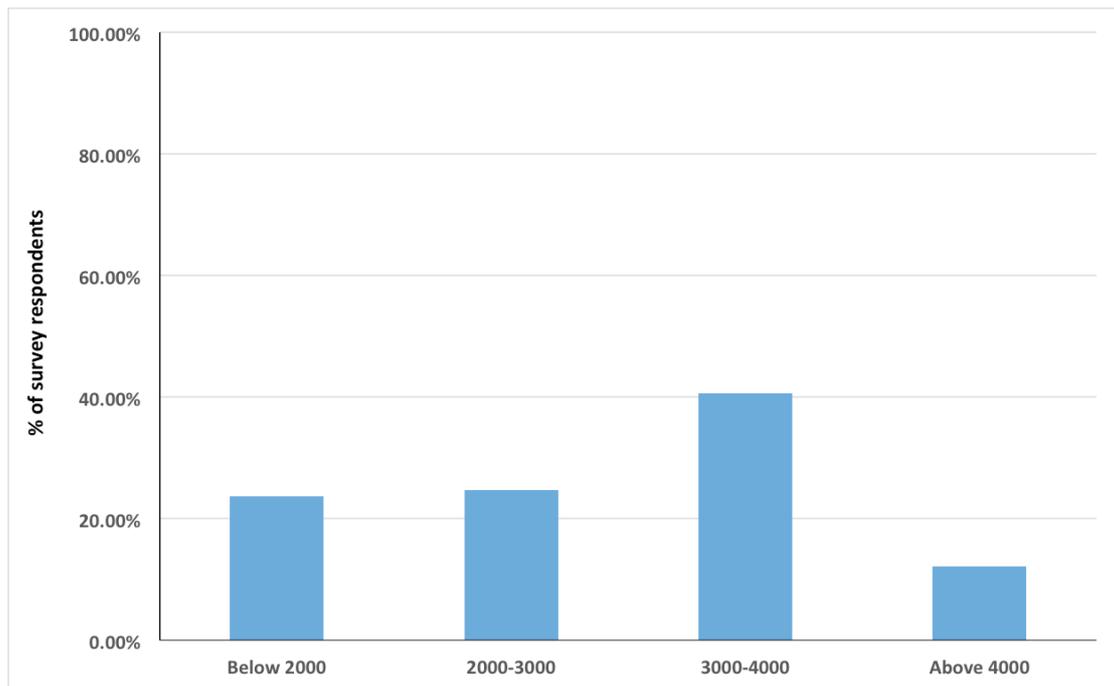
Figure 6.9 The types of e-bikes used by current users: Nanjing survey

In Nanjing, the most prevalent e-bike type is the hybrid style with pedals, which occupies more than 60% of the sample (Figure 6.9). The bicycle style and hybrid style without pedals share the same portion of the sample (more than 20%). The contribution to the market share from scooter style e-bikes, mobility scooters and

tricycle e-bikes is trivial.

Other e-bike market studies conducted in Beijing, Shanghai, Tianjin, Anhui Province, Hebei Province, Henan Province, Jiangsu Province, Jiangxi Province, and Zhejiang Province showed similar results that 57.7% of e-bikes were hybrid style, and 16.1% of e-bikes were bicycle style (Bicycle Industry Information Centre, 2011). However, the scooter style e-bikes in Shanghai or other well-developed cities are much more popular than in Nanjing. This may be an influence of the e-bike policy in Nanjing where a scooter style e-bike needs more complex procedures in order to obtain a license.

E-bike price distribution



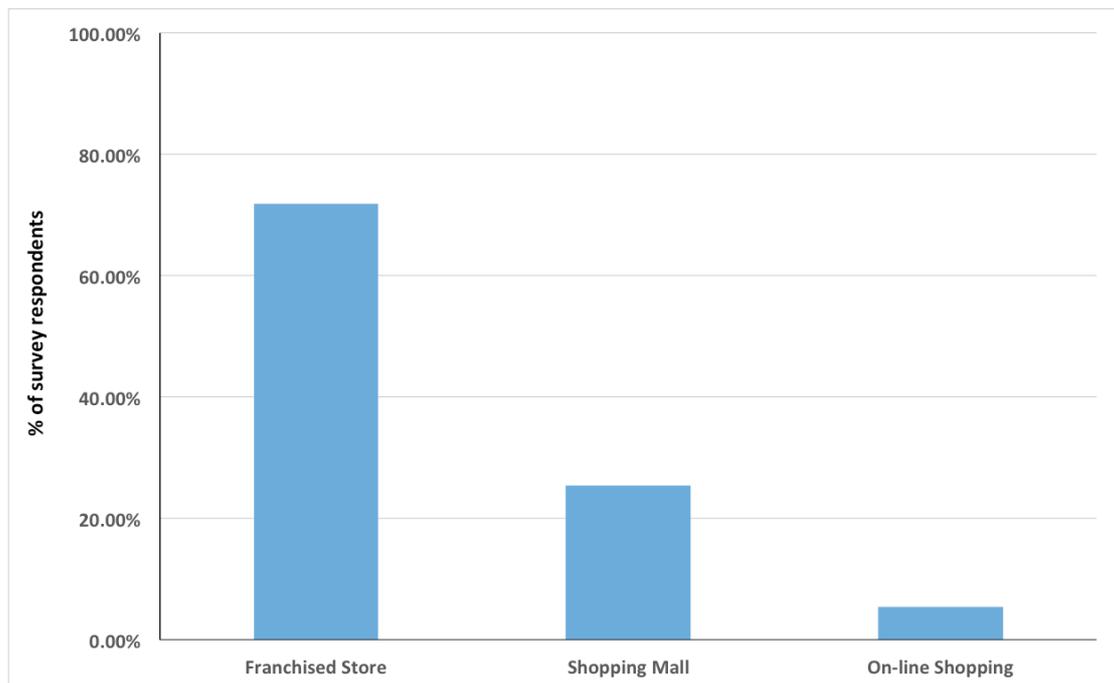
(Sample size: 400 e-bike users)

Figure 6.10 The retail purchase price of e-bikes owned by e-bike users (unit: CNY): Nanjing survey

The prices of e-bikes mainly range from CNY 2,000 (GBP 200) to CNY 4,000 (GBP 400), with more than 60% of the response rate (Figure 6.10). 22% of e-bikes are

below CNY 2,000, while 12% of e-bikes are above CNY 4,000. The prices of e-bikes are closely relevant to e-bike styles. Assuming that e-bikes are equipped with lead acid batteries, the prices of different e-bikes styles are sorted from highest to lowest as follows: mobility scooters or tricycle e-bikes, scooter style, hybrid style, and bicycle style. It is noteworthy that if lead acid batteries are replaced by lithium-ion batteries, the price will further increase by CNY 700 (GBP 70). The result may suggest that the hybrid style e-bikes are at the middle range of e-bike prices. Also, the majority of e-bike users expect to pay CNY 3,000 or below to get an e-bike, which partly explains why the price range of popular e-bike products in China is much lower than that of the European e-bike market.

E-bike purchase channels



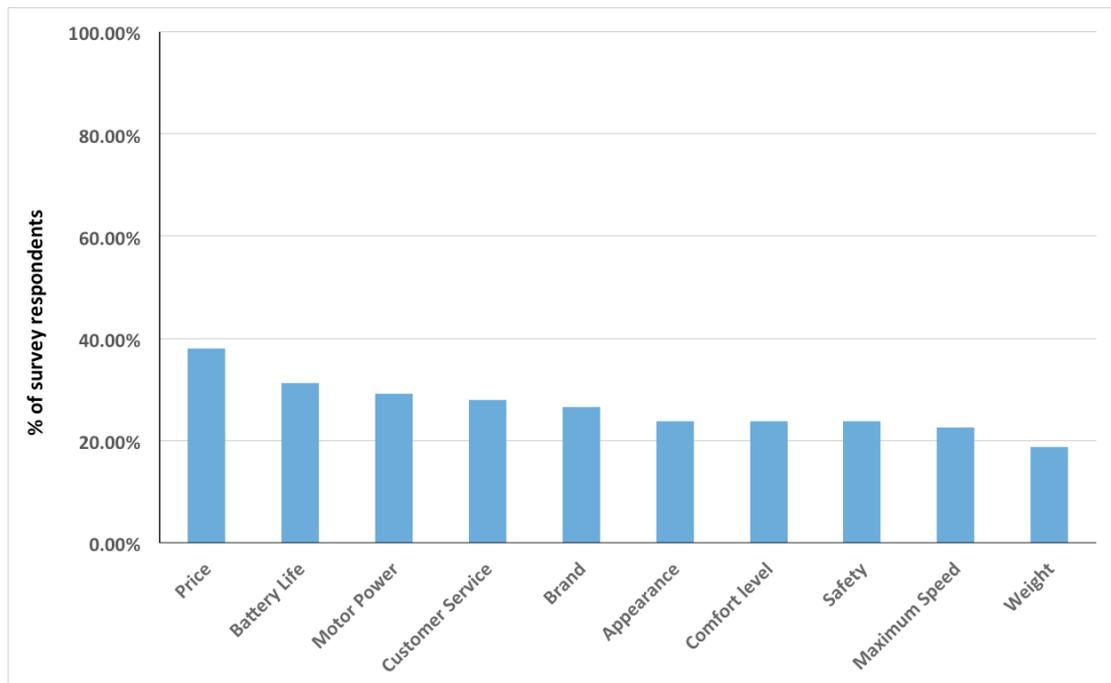
(Sample size: 393 e-bike users)

Figure 6.11 The place to purchase e-bikes: Nanjing survey

Figure 6.11 shows the purchase channel for e-bikes. The majority of e-bikes (78%) are bought from franchised stores. Surprisingly, despite the booming e-commerce

market in China, very few e-bike users bought e-bikes through online shops. Recently, e-commerce in China has been driving a new consumer culture. By the end of 2013, e-commerce transactions reached more than \$360 billion in China (KPMG, 2014). E-commerce is viewed as a fast and convenient way of shopping. In terms of e-bikes, many manufactures have established official online shops and tried to build the regular chain through the business-to-customer model, including Lvyuan, Aima, Feige, and other well-established companies. However, e-bike users prefer purchasing from traditional physical stores rather than online retailers. The reason could be that the consumers purchase e-bikes with great caution due to the importance of e-bikes in their daily life. The local store service can help and support the purchase decision and provide a better sense of security (Sung, 2010).

Factors that influence e-bike purchase



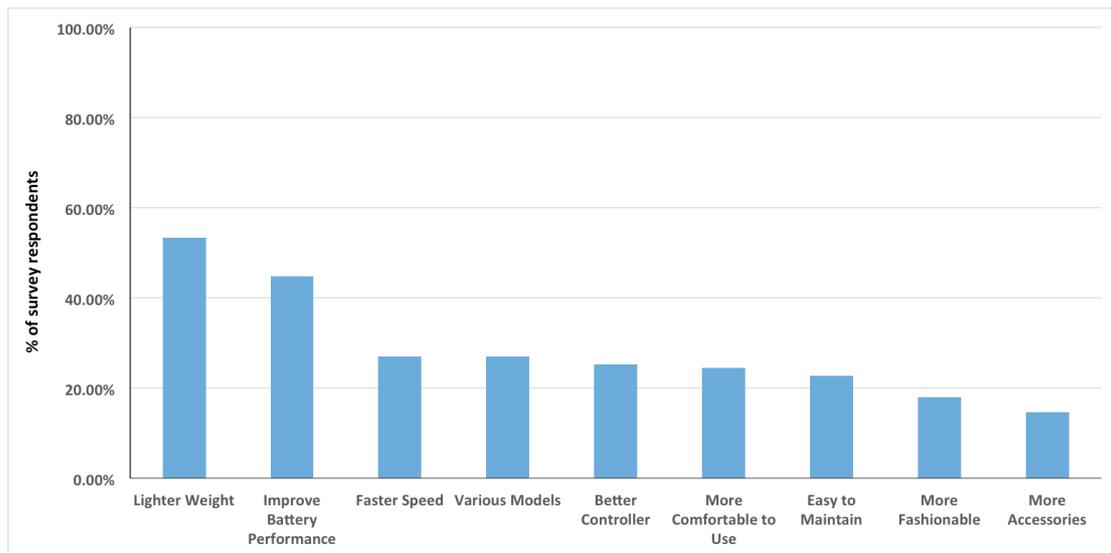
(Sample size: 403 e-bike users)

Figure 6.12 The primary factors influencing e-bike purchase: Nanjing survey

The primary factor influencing e-bike purchase is the price (Figure 6.12). It may

explain the fact that many e-bike users chose lead acid batteries, which are much cheaper than lithium-ion battery. Other highly ranked concerns are battery life, motor power, customer service, and brand. Of those, the battery life and motor power are directly relevant to e-bike performance, and the customer service factor reflects the use anxiety of e-bike users. That is, the customers tend to believe that e-bikes are more likely to be broken during usage or they lack the confidence to repair the e-bikes. On the other hand, the appearance, comfort level, safety, maximum speed, and weight are less important. Hence, the robustness of e-bike performance is the main concern of the consumers.

E-bike performance suggestions



(Sample size: 393 e-bike users)

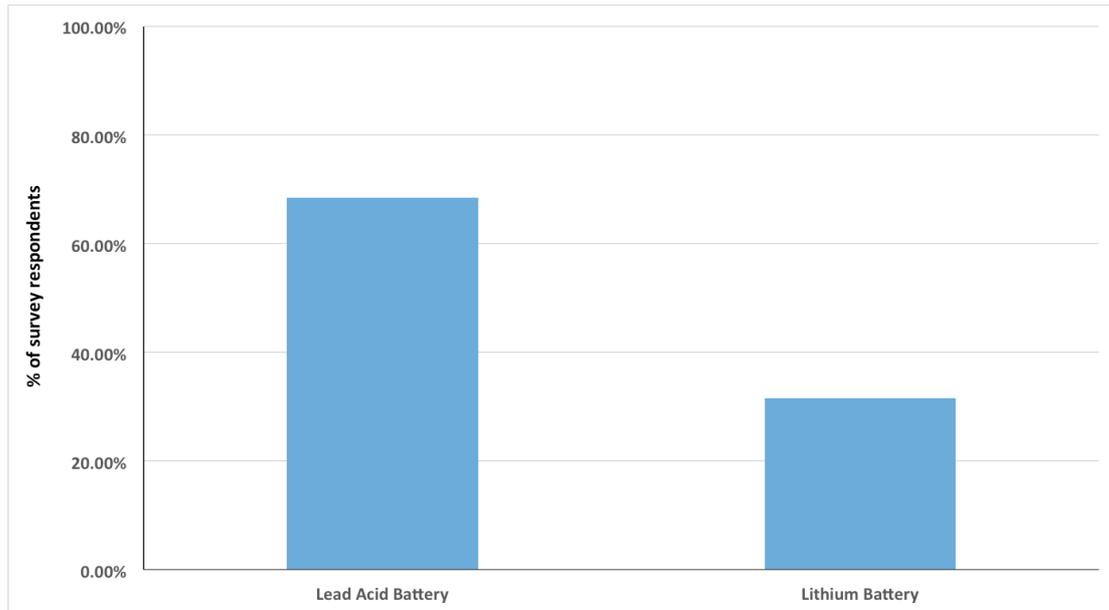
Figure 6.13 Aspects of e-bikes that should be improved greatly: Nanjing survey

Figure 6.13 shows the suggestions to improve e-bike performance. More than 56% of e-bike users suggested that e-bikes should have a lighter weight. The second most prevalent suggestion was to improve battery performance. The result reinforces the aforementioned fact that the battery is the main concern with respect to e-bike adoption. Although e-bikes are criticised as being too fast and become a threat to

other travellers' safety, some e-bike users still hope that e-bike speed can be further increased, reflecting the high demand for fast and convenient transport modes.

6.3.3.3 Battery use patterns

Battery type



(Sample size: 402 e-bike users)

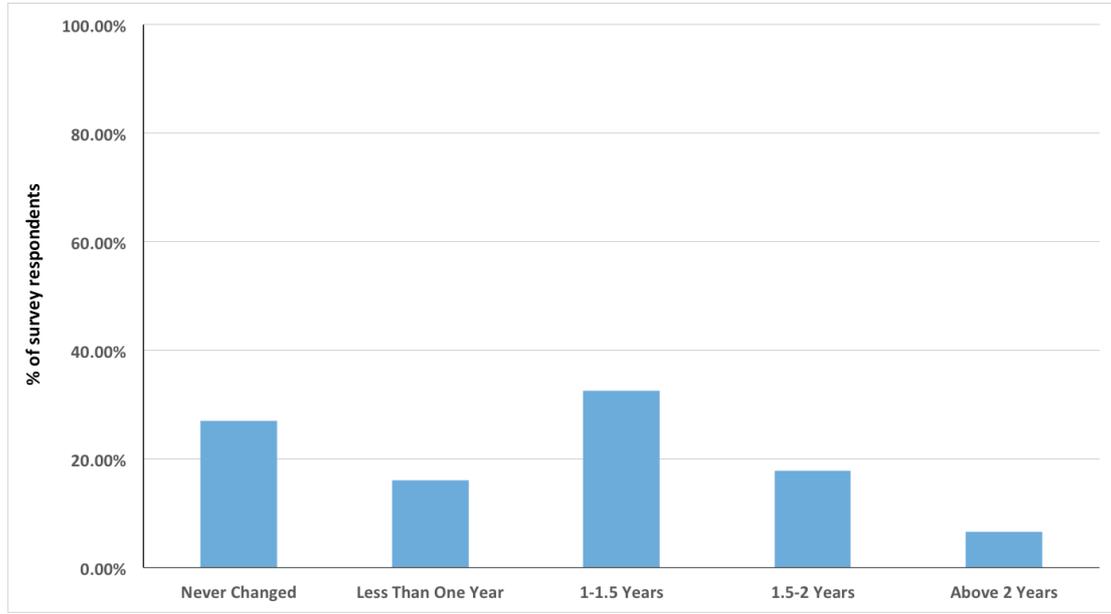
Figure 6.14 Battery Type: Nanjing survey

More than 60% of e-bikes use lead acid batteries, so these still dominate the e-bike market in Nanjing. In the e-bike battery study carried out in Beijing, Shanghai, Tianjin, Anhui Province, Hebei Province, Henan Province, Jiangsu Province, Jiangxi Province, and Zhejiang Province, the lead acid batteries are also used widely with an average capacity of 48V and 12Ah (Bicycle Industry Information Centre, 2011). However, the usage of lithium batteries has increased quickly and has occupied 40% of the market share in our study (Figure 6.14). If e-bike users have more than one e-bike in their household, most of them are willing to update them with a lithium battery.

Also, the study provides the information for battery capacity that 74.64% of batteries

are 48V and that 56.35% of e-bikes are 12Ah by investigating the e-bike battery used by e-bike manufacturers (Bicycle Industry Information Centre, 2011). This information could be helpful to the technical standards.

Battery renewal frequency



(Sample size: 402 e-bike users)

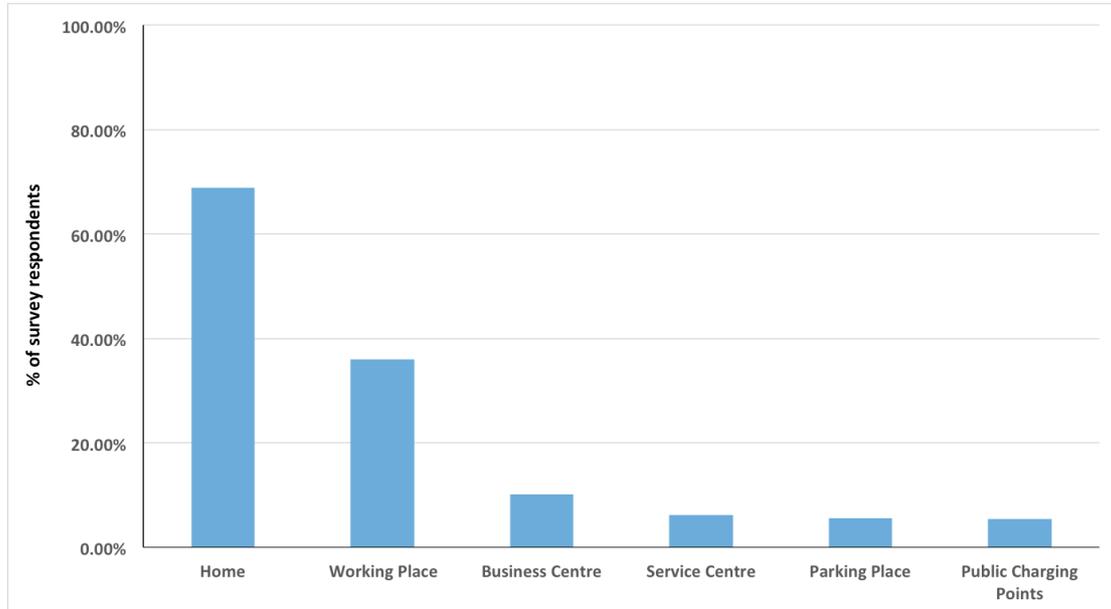
Figure 6.15 Battery renewal time: Nanjing survey

Figure 6.15 shows that 38% of e-bike batteries are replaced every year to eighteen months. Around 20% of e-bikes need to renew the batteries within one year. Nearly 30% of e-bikes never renew the battery. Very few batteries are replaced less frequently than every two years. Although many e-bike companies claim that the lead acid battery can keep up its function for two or three years, the life cycle is actually much shorter in practice.

Charging place

As shown in Figure 6.16, the overwhelming majority of e-bike users charge their e-bikes at home (nearly 70% response rate), followed by the working place. Other charging places are business centres, service centres, parking places, and public

charging points which account for 10% of responses. The result indicates that e-bikes have a certain degree of flexibility in terms of charging because the battery can be pulled out of the frame. However, this result also exposes the problem that public charging services are in short supply.

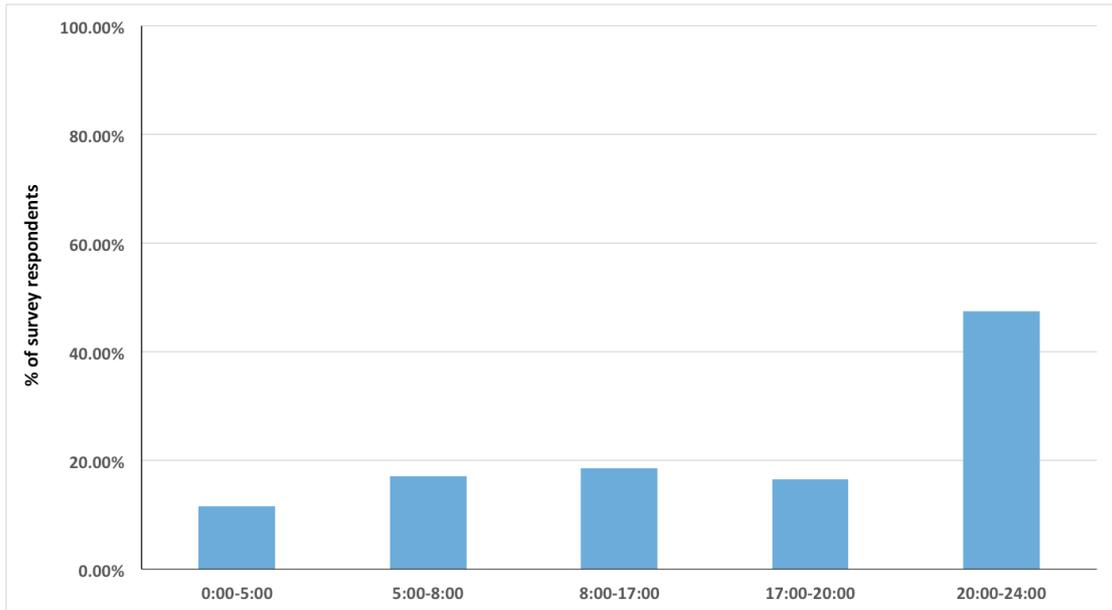


(Sample size: 395 e-bike users)

Figure 6.16 Battery charging place: Nanjing survey

Charging time

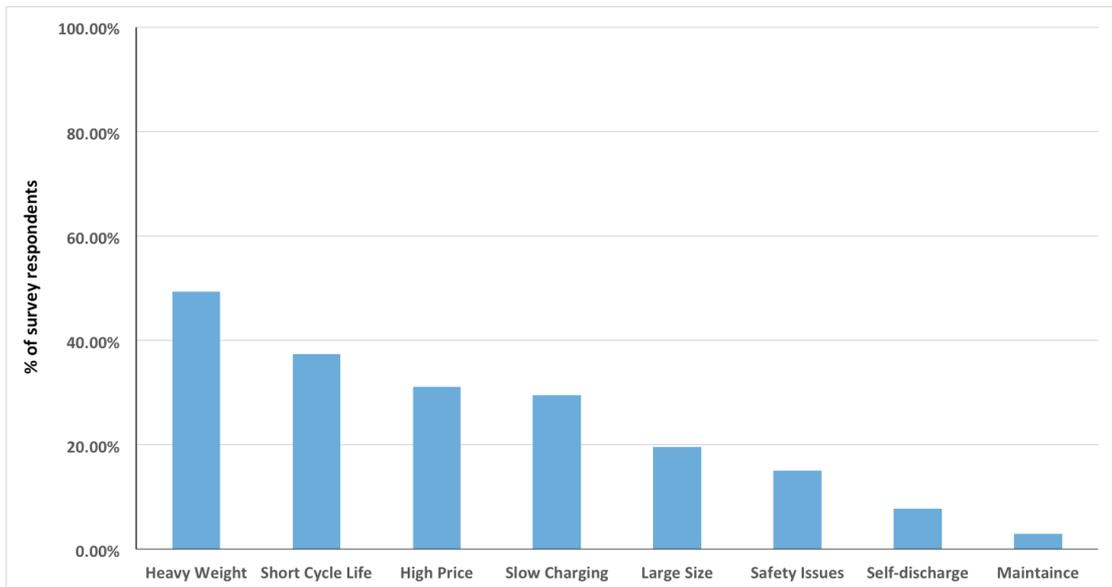
E-bike charging time normally requires at least three to four hours. Figure 6.17 shows that 50% of e-bike users charge the batteries during 20:00 and 24:00, which is the peak time for electricity consumption. Only 15% of e-bike users charge batteries during the off-peak time (0:00–5:00). The charging time scale of e-bikes is in parallel to the home electricity consumption that the peak time is from 17:00 to 24:00 and off peak time is from 0:00 to 6:00. Therefore, e-bikes can be treated as a normal household appliance. Around 20% of respondents charge e-bikes from 8:00 until 17:00, which is slightly higher than those charging between 5:00 to 8:00 and between 17:00 and 20:00. The reason for this is that many e-bike users choose to charge their e-bikes during working hours.



(Sample size: 395 e-bike users)

Figure 6.17 Battery charging time: Nanjing survey

Drawbacks of e-bike batteries



(Sample size: 402 e-bike users)

Figure 6.18 Drawbacks of e-bike batteries: Nanjing survey

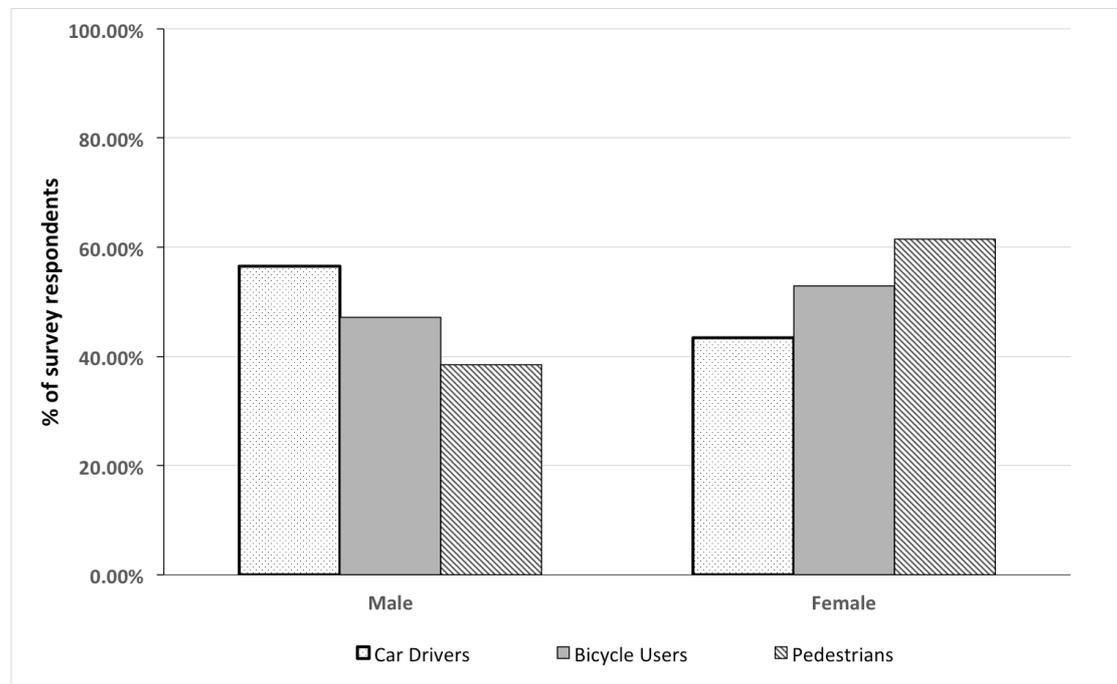
The heavy weight of batteries is the main drawback with 50% of the response rate (Figure 6.18). Another major concern is the short life cycle of batteries (40% of response rate). Other concerns include high costs, slow charging, large size, safety

issues, self-discharge, and maintenance issues. The listed drawbacks are closely related to the use of lead acid batteries, which is the main technology barrier of e-bike development.

6.3.4 Interactions with non-e-bike users

E-bikes influence travellers using other travel modes, whose opinions on e-bikes are very important. This subsection presents the demographics information of non- e-bike users, such as car drivers, bicycle users and pedestrians. For each type of demographic information, the one-way ANOVA tests or Chi-squared tests are conducted to examine whether there were statistically significant differences among subsample groups.

Gender distribution



(Sample size: 184 car drivers; 193 bicycle users; 195 pedestrians)

Figure 6.19 The gender of car drivers, bicycle users and pedestrians: Nanjing survey

Figure 6.19 demonstrates the gender distribution of car drivers, bicycle users and

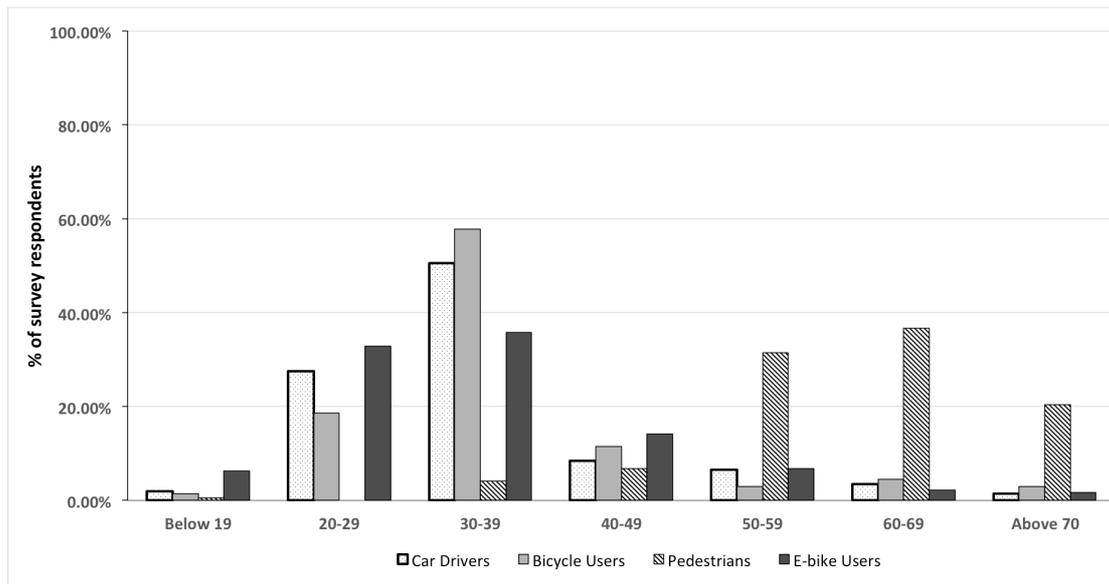
pedestrians in our samples. A Chi-squared test of independence was performed and found that there are statistically significant differences between different vehicle user groups for their genders ($X^2(1, 576)=28.967, p\text{-value}<0.0001$). See Table 6.4. For the car driver group, there are more male than female participants, whereas with bicycle users and pedestrians, the situation is the opposite.

	Male	Female	Total
Car Drivers	104	84	188
	56.52%	43.48%	
Bicycle users	91	102	193
	47.15%	52.85%	
Pedestrians	75	120	195
	38.46%	61.54%	
Total	270	306	576
	46.86%	53.14%	%100

$X^2=28.967, p\text{-value}<0.0001$

Table 6.4 Chi-squared test of gender of car drivers, bicycle users and pedestrians: Nanjing survey

Age distribution



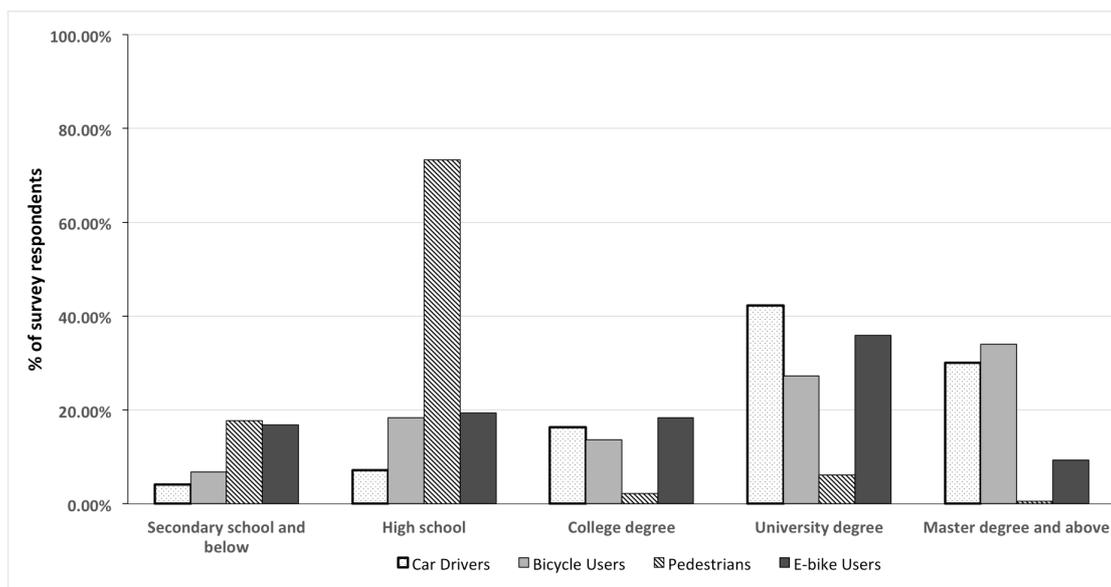
(Sample size: 200 car drivers; 199 bicycle users; 191 pedestrians; 394 e-bike users)

Figure 6.20 The age groups of car drivers, bicycle users, e-bike users and pedestrians: Nanjing Survey

Figure 6.20 shows the age distribution of four groups. A one-way ANOVA was conducted, and the results ($F(3, 984)=249.7, p<0.0001$) reveal that there are statistically significant differences amongst vehicle user groups related to different age groups. More than 80% of car drivers, bicycle users and e-bikes users are younger than 49 years old, and are mainly between 20 and 39 years old. In contrast, more than 80% of pedestrians are older than 50 years old; half of them are between 60 and 69 years old.

Education levels

The one-way ANOVA result reveals statistically significant differences amongst the vehicle user groups in relation to education levels, $F(3, 965) = 93.1, p < 0.0001$. Nearly 80% of pedestrians are at a high school education level or below (Figure 6.21), and these completed their education during the 1970s and 1980s. During that period, only 6.779% of the population graduated from high school, and 0.615% of the population hold a college degree and above (China Statistical Bureau, 2010).

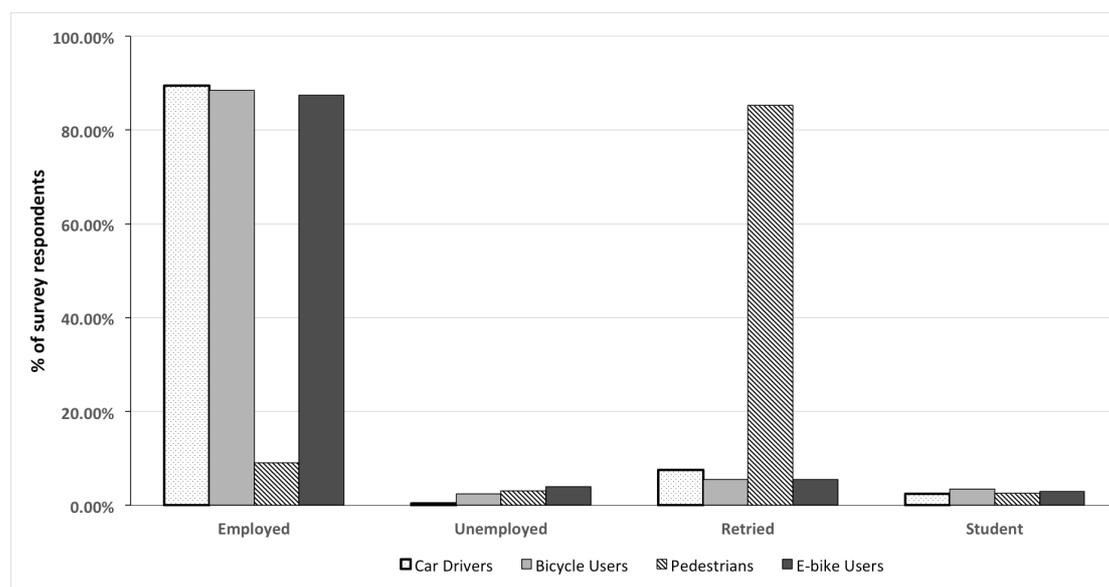


(Sample size: 196 car drivers; 191 bicycle users; 180 pedestrians; 398 e-bike users)

Figure 6.21 The level of education for car drivers, bicycle users, e-bike users and pedestrians: Nanjing survey

In comparison, the other three groups have much higher education levels. More than 70% of car drivers have been awarded a university degree or above, followed by bicycle users (60%) and e-bike users (45%). In particular, over 30% of the car drivers and bicycle users hold postgraduate degrees. Considering that 26.12% of the population has completed a college degree or above, and 20.82% of the population has graduated from high school in Nanjing (China Population Census of Nanjing, 2011), the average education levels of car drivers and bicycle users are much higher than that of Nanjing City as a whole. Our sample shows that compared with car drivers, e-bike users have a relatively lower level of education, but theirs is still higher than the overall average education level in Nanjing.

Employment status



(Sample size: 199 car drivers; 191 bicycle users; 197 pedestrians; 400 e-bike users)

Figure 6.22 The employment status of car drivers, bicycle users, e-bike users and pedestrians: Nanjing survey

Figure 6.22 shows the employment status of various travellers. A Chi-squared test of independence was performed to examine whether there were statistically significant

differences among different traveller groups in relation to their employment status. The statistically significant differences are found when the employment situations are employed and retired (Table 6.5). On the other hand, there are no statistically significant differences when the employment situations are students and unemployed people (Table 6.5). The majority of the car drivers, bicycle users and e-bike users (all above 80%) are employed in our sample, but more than 80% of pedestrians have retired (Figure 6.22). Car drivers have the lowest unemployment rate (0.5%), while e-bike users have the highest unemployment rate (4%), which is around the overall average unemployment rate in Nanjing (2.66% in 2013) (Zhu, 2013). The employment status of different groups reflects their income situation

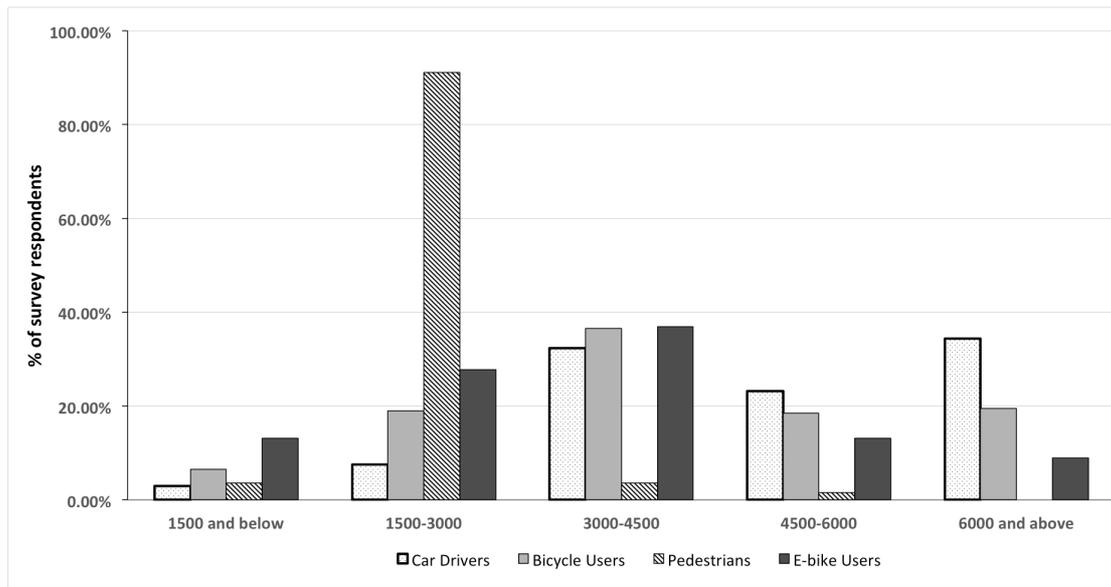
	Employed		Total		Unemployed		Total
	Yes	No			Yes	No	
Car drivers	179	21	200	Car drivers	1	199	200
Bicycle users	176	23	199	Bicycle users	5	194	199
Pedestrians	17	174	191	Pedestrians	6	185	191
E-bike users	345	49	394	E-bike users	16	378	394
Total	717	267	984	Total	28	956	984
$X^2=490.7164, p\text{-value}<0.00001$			$X^2=6.2255, p\text{-value}=0.101139$				
	Retired		Total		Students		Total
	Yes	No			Yes	No	
Car drivers	15	185	200	Car drivers	5	195	200
Bicycle users	11	188	199	Bicycle users	7	192	199
Pedestrians	163	28	191	Pedestrians	5	186	191
E-bike users	22	372	394	E-bike users	12	382	394
Total	211	773	984	Total	29	955	984
$X^2=574.7765, p\text{-value}<0.00001$			$X^2=0.452, p\text{-value}=0.929302$				

Table 6.5 Chi-squared test of the employment status of car drivers, bicycle users, e-bike users and pedestrians: Nanjing survey

Income

The one-way ANOVA result revealed statistically significant differences amongst the vehicle user groups in relation to different income levels, $F(3, 993)=109.07, p <$

0.0001. Consistent with the employment status, the income of most pedestrians is in the range between CNY 1,500 and CNY 3,000. The majority of pedestrians have retired (Figure 6.23), and the average income of retired citizens in Nanjing is CNY 2,659 in 2015 (Huang, 2015).



(Sample size: 198 car drivers, 200 bicycle users, 192 pedestrians, 403 e-bike users)
Figure 6.23 Monthly Income of car drivers, bicycle users, e-bike users and pedestrians: Nanjing survey

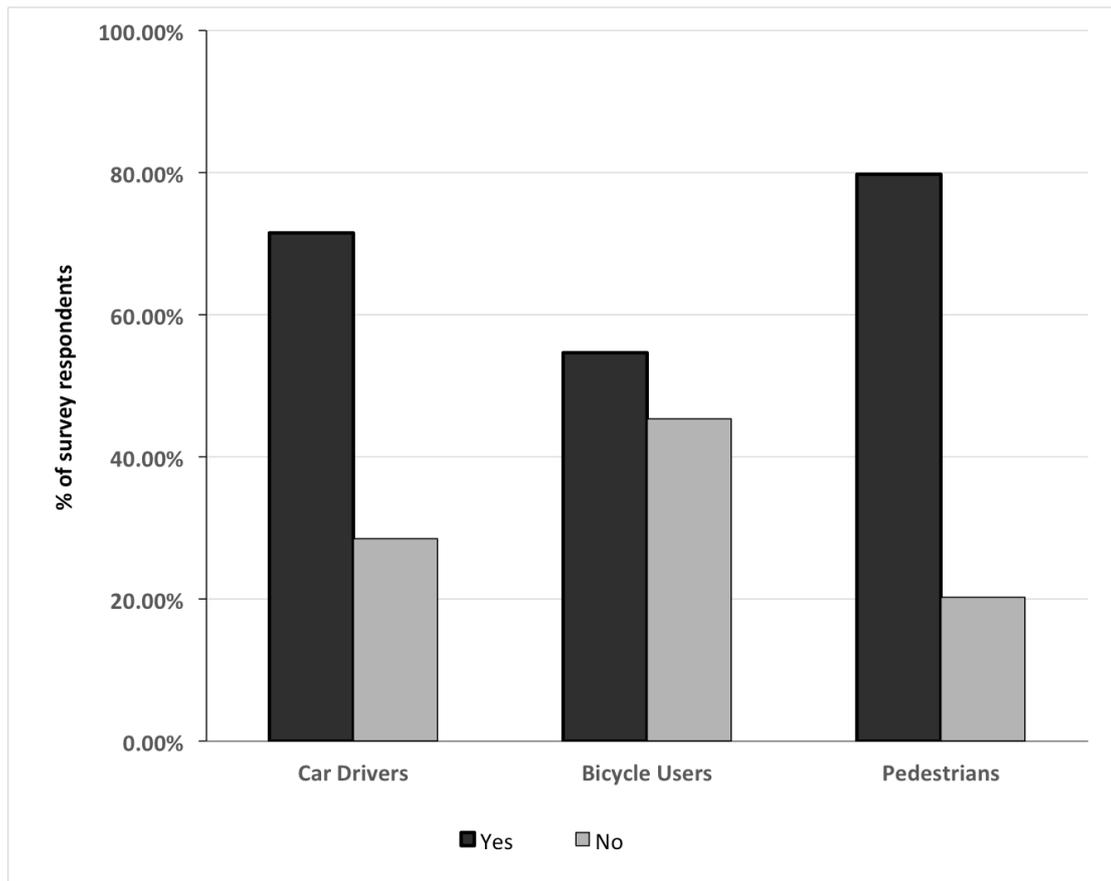
In terms of response rate, the e-bike user group is the second largest group whose income is in the middle range (from CNY 1,500 to CNY 3,000). The income distribution of e-bike users is negatively skewed, which means that the income distribution is concentrated on CNY 4,500 and below.

As expected, the car driver group has the highest income in our sample. They dominate the top two ranges (CNY 4,500-6,000 and CNY 6,000 and above). In terms of bicycle users, more than 50% of them are in the top two ranges of income.

According to the automobility culture of China, the transport vehicle choice usually reflects the wealth of the users. In this case, higher income citizens tend to use private

cars, while lower income citizens are more likely to use e-bikes and bicycles. However, in our sample, the citizens with higher incomes not only presented an inclination to adopt private cars, but also had strong preference of adopting bicycles.

E-bike ownership for the non-e-bike users' households



(Sample size: 200 car drivers; 192 bicycle users; 188 pedestrians)

Figure 6.24 E-bike ownership for the non-e-bike users' households where some other inhabitants use e-bikes

	Yes	No	Total
Bicycle users	105	87	192
Pedestrians	150	38	188
Car Drivers	143	57	200
Total	398	182	580

$X^2 (2, 580) = 28.967, p\text{-value} < 0.0001$

Table 6.6 Chi-squared test: e-bike ownership for the non-e-bike users' households where some other inhabitants use e-bikes

For the non-e-bike users, it is possible that the other inhabitants in the households own and use e-bikes. Figure 6.24 shows the e-bike ownership of non-e-bike users' households. A Chi-squared test of independence was performed to examine the relationship between different vehicle user groups and e-bike household ownership. The relationship between these variables was significant, $X^2(2, 580) = 28.967$, $p\text{-value} < 0.0001$ (Table 6.6). According to our survey, 70% of car drivers, nearly 60% of bicycle users and 80% of pedestrians have e-bikes in their households used by other inhabitants. The result indicates that e-bikes have reached a regime level in Nanjing. In other words, e-bikes have already been widely accepted by the families in Nanjing regardless of their household income or level of education.

The characteristics of different users

Table 6.7 shows the mean value of age, education, and the monthly income of different vehicle user groups (car drivers, bicycle users, pedestrians, and e-bike users). One-way ANOVA tests were performed to reveal that there were statistically significant differences amongst the vehicle user groups in relation to age groups, education levels, and monthly income.

	Car Drivers	Bicycle users	Pedestrians	E-bike users	F value	p-value
Age (years old)	31	32	56	29	249.7	<0.0001
Education Level	3.9	3.6	2.0	3.1	93.1	<0.0001
Average Monthly Income (CNY)	4200	3500	1500	2700	109.07	<0.0001

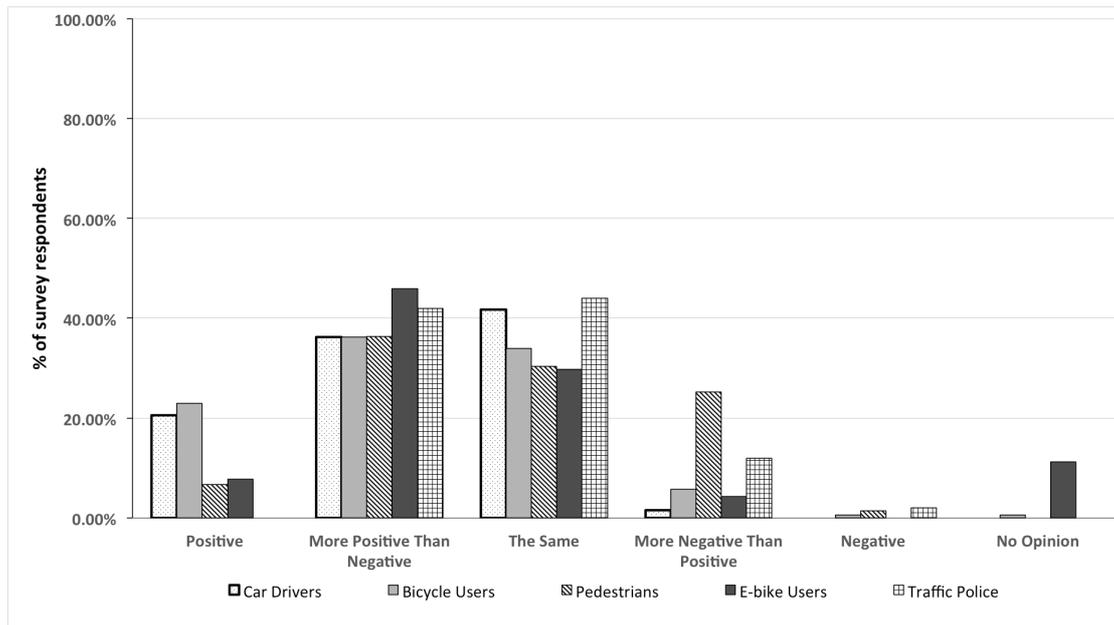
Education level: 2 – high school, 3 – college degree, 4 – university degree

Table 6.7 Mean value of age, education level, monthly income of car drivers, bicycle users, pedestrians, and e-bike users: Nanjing survey

Table 6.7 shows that e-bike users are the youngest group whose average age is nearly

29 years old; this is two years younger than car drivers and 27 years younger than pedestrians. The average education level of e-bike users is college degree, which is higher than pedestrians whose average education level is high school, and lower than bicycle users and car drivers whose average education level is university degree. In terms of average monthly income, car drivers are the highest paid (CNY 4,200), followed by bicycle users (CNY 3,500), while pedestrians have the lowest average monthly income (CNY 1,500). The average monthly income of e-bike users is the third highest (CNY 2,700). In addition, the majority of e-bike users, car drivers, and bicycle users are employed, while most pedestrians have retired (Figure 6.22). Compared to other vehicle users, the e-bike users are young career-aged commuters and are middle class in terms of their income.

Attitudes to e-bike development



(Sample size: 199 car drivers; 174 bicycle users; 135 pedestrians; 398 e-bike users; 50 traffic police)

Figure 6.25 Attitudes to e-bike development: Nanjing survey

The one-way ANOVA result reveals that a statistically significant difference exists amongst the vehicle user groups in relation to their attitudes to e-bike development,

with $F(3, 906)=14.23$, $p < 0.0001$. The opinions of citizens about e-bikes have a significant impact on the transport system and the prospects of e-bike development. In general, the attitudes of various groups of travellers to e-bikes are positive.

As Figure 6.5 shows, the percentage of car drivers and bicycle users agreeing that e-bikes have a positive impact on the transport system or have more of a positive than negative impact reaches 60%. In terms of negative impacts, pedestrians are the highest proportion (more than 20%), followed by traffic police, but very few of the other groups hold negative attitudes.

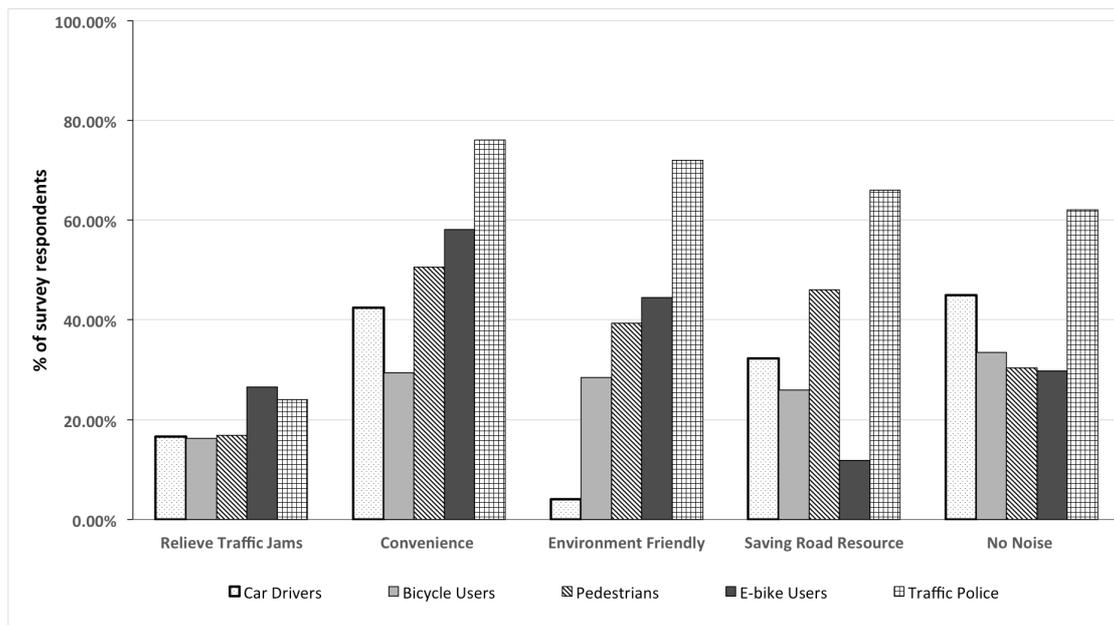
By combining the findings of this subsection and the preceding subsections, we can find that e-bike transition is highly embedded in the current transport system, for the reasons that: 1) The majority of car drivers, bicycle users, pedestrians, traffic police, and e-bike users have positive attitudes towards e-bikes in general; and 2) e-bikes have been adopted as widely in many aspects of daily life settings, including commuting, going shopping, picking up children, as other transport modes in the regime level such as buses, the metro, bicycles and walking.

The impact of e-bikes on the transport system

Figure 6.26 and Figure 6.27 show the detailed positive and negative impact of e-bikes on the transport system. A Chi-squared test verifies that there exist statistically significant differences among subsample groups (car drivers, bicycle users, pedestrians, e-bike users and traffic police) in relation to their opinions on the positive and negative impact of e-bikes on the transport system (Table 6.8 and Table 6.9).

Nearly 70% of traffic police believe that e-bikes exacerbate traffic jams. Moreover, compared with other groups' perceptions, traffic police think that e-bikes are more likely to obstruct other vehicles, increase accidents and worsen traffic control

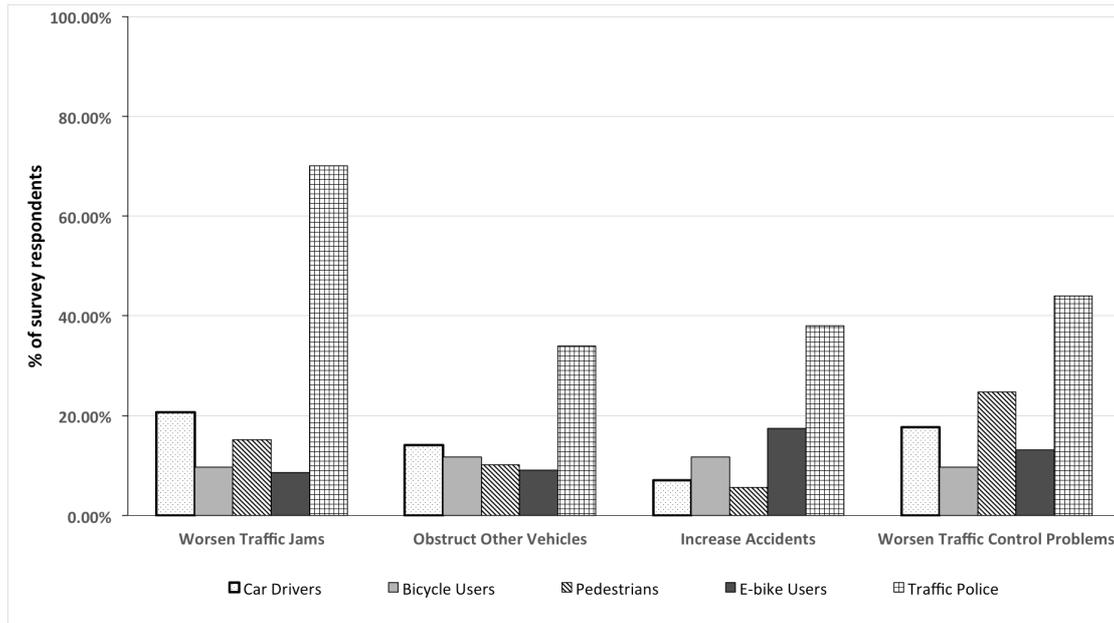
problems. The reason for this could be that the duty of traffic police is to deal with traffic issues, which leads to a more negative impression of e-bikes in the transport system. The response rates of traffic police are also very high on the positive impact of e-bikes. Most traffic police agree that e-bikes are beneficial to achieving personal mobility, saving road resources and making a contribution towards reducing climate change.



(Sample size: 200 car drivers; 198 bicycle users; 200 pedestrians; 399 e-bike users; 50 traffic police)

Figure 6.26 The positive impact of e-bikes on the transport system: Nanjing survey

Similar to the traffic police, more than 40% of car drivers stated that e-bikes provide a more convenient way to access urban areas. Specially, more car drivers responded that e-bikes were very quiet compared with bicycle users, pedestrians, and e-bike users. In terms of worsening traffic issues, car drivers have the second largest response rate claiming that e-bikes are more likely to worsen traffic jams and obstruct other vehicles. Nonetheless, car drivers do not believe that e-bikes are the main factor for causing accidents.



(Sample size: 200 car drivers; 198 bicycle users; 200 pedestrians; 399 e-bike users; 50 traffic police)

Figure 6.27 The negative impact of e-bikes on the transport system: Nanjing Survey

	Relieving traffic jams		Total		Convenience		Total		Environmentally friendly		Total
	Yes	No			Yes	No			Yes	No	
Car drivers	33	167	200	Car drivers	85	115	200	Car drivers	8	192	200
Bicycle users	32	168	200	Bicycle users	59	141	200	Bicycle users	57	143	200
Pedestrians	34	166	200	Pedestrians	101	99	200	Pedestrians	79	121	200
E-bike users	106	294	400	E-bike users	232	168	400	E-bike users	178	222	400
Traffic police	12	38	50	Traffic police	38	12	50	Traffic police	36	14	50
Total	217	833	1050	Total	515	635	1050	Total	358	692	1050
$X^2=15.0549, p\text{-value}=0.004589$			$X^2=61.5414, p\text{-value}<0.00001$				$X^2=137.2431, p\text{-value}<0.00001$				
	Saving road resource		Total		No noise		Total				
	Yes	No			Yes	No					
Car drivers	65	135	200	Car drivers	90	110	200				
Bicycle users	52	148	200	Bicycle users	67	133	200				
Pedestrians	92	108	200	Pedestrians	61	139	200				
E-bike users	47	353	400	E-bike users	119	281	400				
Traffic police	33	17	50	Traffic police	31	19	50				
Total	289	761	1050	Total	368	682	1050				
$X^2=123.9394, p\text{-value}<0.00001$			$X^2=31.6165, p\text{-value}<0.00001$								

Table 6.8 Chi-squared test of the positive impact of e-bikes on the transport system: Nanjing survey

The response rates of bicycle users on positive impacts are much higher than on negative responses. Although bicycle users share bicycle lanes with e-bike users, few of them complain that e-bikes obstruct their way. Only 30% of bicycle users stated that e-bikes provided convenient personal mobility and contributed to a better environment, which is the least enthusiastic response amongst the five groups. The reason for this could be that bicycles share many similar advantages with e-bikes. Although e-bikes are faster and can save effort, bicycles are more environmentally friendly and can also achieve satisfactory personal mobility for short distances.

	Worsen traffic jams		Total		Obstruct other vehicles		Total
	Yes	No			Yes	No	
Car drivers	41	159	200	Car drivers	28	172	200
Bicycle users	19	181	200	Bicycle users	23	177	200
Pedestrians	30	170	200	Pedestrians	20	180	200
E-bike users	34	366	400	E-bike users	36	364	400
Traffic police	35	15	50	Traffic police	17	33	50
Total	159	891	1050	Total	124	926	1050
X ² =140.2579, p-value<0.00001			X ² =28.2403, p-value=0.000011				
	Increase accidents		Total		Worsen traffic control problems		Total
	Yes	No			Yes	No	
Car drivers	14	186	200	Car drivers	35	165	200
Bicycle users	23	177	200	Bicycle users	19	182	200
Pedestrians	11	189	200	Pedestrians	49	151	200
E-bike users	70	330	400	E-bike users	53	347	400
Traffic police	19	31	50	Traffic police	22	28	50
Total	137	913	1050	Total	178	872	1050
X ² =51.3411, p-value<0.00001			X ² =45.9015, p-value<0.00001				

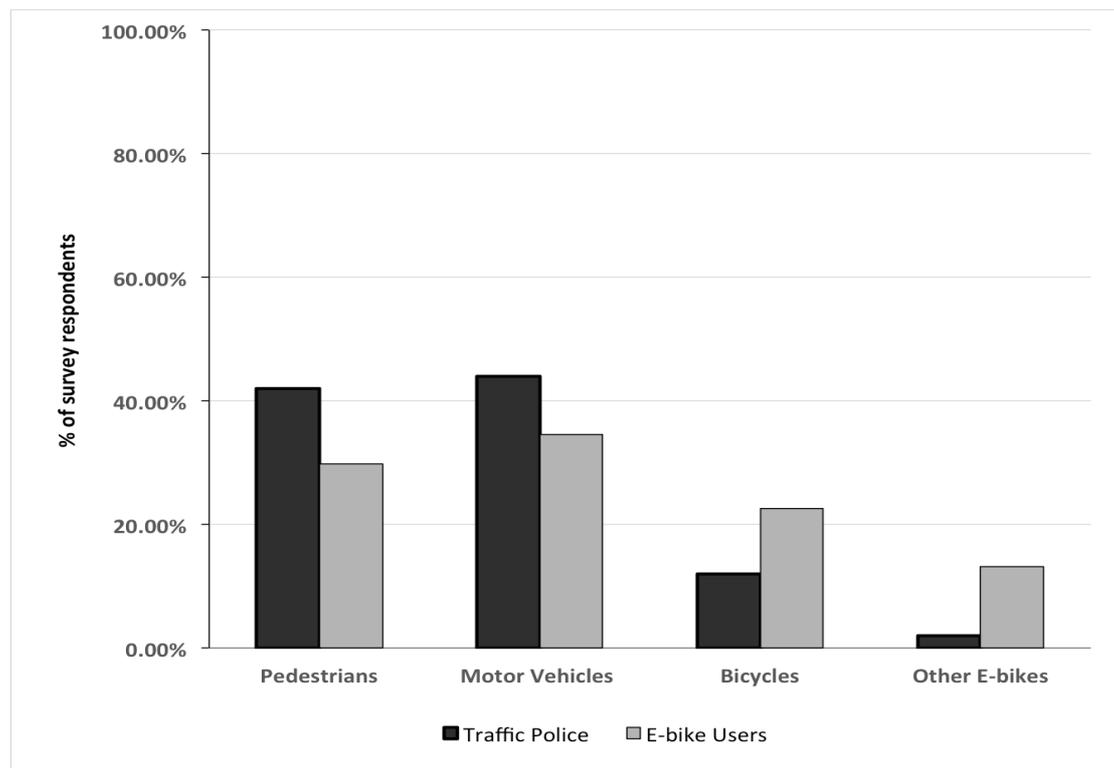
Table 6.9 Chi-squared test of the negative impact of e-bikes on the transport system: Nanjing Survey

25% of e-bike users responded that they contribute to relieving traffic jams, which is the highest in the five groups. Nearly 60% of e-bike users tend to agree that e-bikes are a convenient transport mode. Many e-bike users do not agree that e-bikes will worsen traffic problems or obstruct other vehicles. Interestingly, compared with other groups, most e-bike users disagree that e-bikes can help save road resources. Overall,

the response rates reflect a higher tendency towards the positive impacts in all five groups.

Traffic accidents

Figure 6.28 shows the traffic accident rates of e-bikes for various vehicles in Nanjing. A Chi-squared test was conducted to test whether there were statistically significant differences between traffic police and e-bike users in relation to the traffic accident rates of e-bikes with various vehicles. The results revealed statistically significant differences between the traffic police and e-bike users in terms of traffic accident rate among e-bikes, $X^2(1, 218)=5.023$, $p\text{-value}=0.02965$ (see Table 6.10). There are no other significant differences between other groups.



(Sample size: 50 traffic police; 168 e-bike users)

Figure 6.28 The traffic accident rates of e-bikes with various vehicles (Traffic police and e-bike users): Nanjing survey

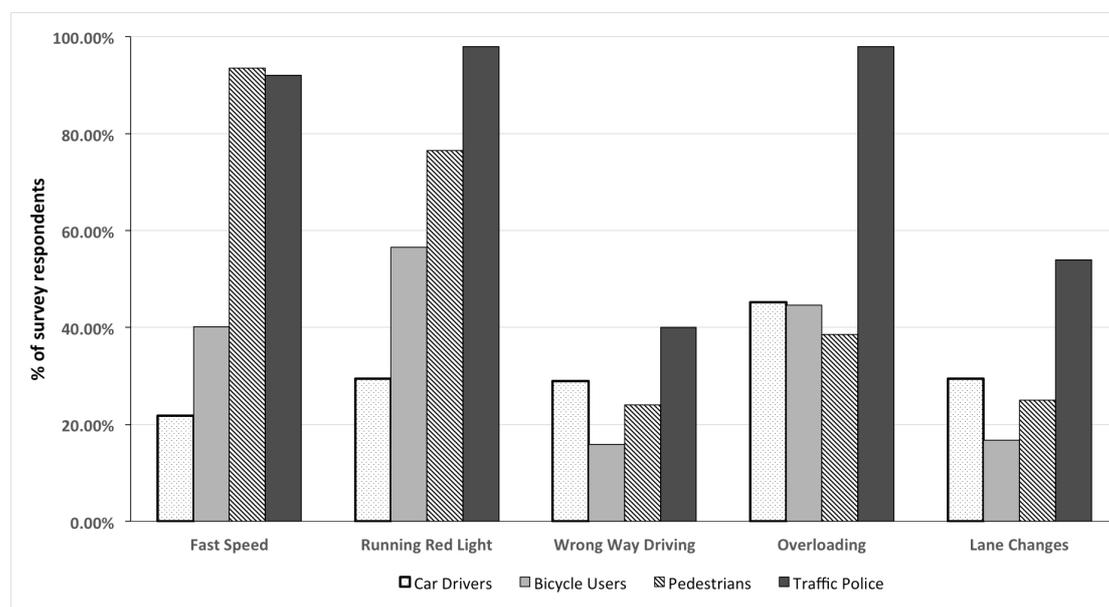
	Pedestrians		Total		Motor vehicles		Total
	Yes	No			Yes	No	
E-bike users	50	118	168	E-bike users	58	110	168
	29.8%	70.2%	100%		34.5%	65.5%	100%
Traffic police	21	29	50	Traffic police	22	28	50
	42%	58%	100%		44%	56%	100%
Total	71	147	218	Total	80	138	218
	32.6%	67.4%	100%		36.7%	63.3%	100%
X ² =2.6278, p-value=0.105009			X ² =1.4895, p-value=0.222297				
	Bicycles		Total		Other e-bikes		Total
	Yes	No			Yes	No	
E-bike users	38	130	168	E-bike users	22	146	168
	22.6%	77.4%	100%		13.1%	86.9%	100%
Traffic police	6	44	50	Traffic police	1	49	50
	12%	88%	100%		2%	98%	100%
Total	44	174	218	Total	23	195	218
	20.2%	79.8%	100%		10.6%	89.4%	100%
X ² =2.6971, p-value=0.10058			X ² =5.023, p-value=0.02965				

Table 6.10 Chi-squared test of the traffic accident rates of e-bikes with various vehicles (Traffic police and e-bike users): Nanjing survey

Safety issues are a main concern in many e-bike studies with a focus on e-bike users' rule violation behaviour and conflicts with other vehicle users (Chen *et al.*, 2010; Liu and Sun, 2011; Jiang *et al.*, 2012; Du *et al.*, 2013; Salmon *et al.*, 2013; Bai *et al.*, 2015; Yang *et al.*, 2015). In our study, however, more than 60% of e-bike users stated that they had never had an accident. For the e-bike users who experienced traffic accidents, nearly 35% of accidents were between them and motor vehicles, followed by 30% of accidents with pedestrians and 22% with bicycles. Only 13% of accidents were with other e-bikes. The frequency of accidents reported by e-bike users is consistent with traffic police reports. Hence, motor vehicle users and pedestrians are the primary groups that have accidents with e-bike users, which implies that e-bike users are using the pavement and vehicle road instead of the bicycle lanes. Also, a combination of bicycles and e-bikes in the bicycle lane is not the main cause of traffic accidents, because it is rare for e-bike users to have accidents with bicycle and other e-bike users.

Unsafe behaviour by e-bike users

Figure 6.29 shows the unsafe behaviour of e-bike users. A Chi-squared test revealed that there were statistically significant differences among subsample groups (car drivers, bicycle users, pedestrians, and traffic police) in relation to different opinions on the unsafe behaviour of e-bike users (Table 6.11). In terms of unsafe behaviour, nearly 90% of traffic police and pedestrians feel that e-bikes are too fast. In contrast, only 40% of bicycle users and 20% of car drivers hold the same opinion (Figure 6.29). So the fast speed of e-bikes is perceived mainly as a threat to pedestrians. The next frequent violation behaviour of e-bike users is running a red light, which is complained about by nearly 100% of traffic police, 80% of pedestrians and 60% of bicycle users.



(Sample size: 200 car drivers; 200 bicycle users; 200 pedestrians; 50 traffic police)

Figure 6.29 Unsafe behaviour by e-bike users: Nanjing survey

An interesting finding is that almost 100% of traffic police complained about the overloading of e-bikes but the other three groups are not sensitive to this. The study of violation behaviour by e-bike users conducted in China further identified the main

sources of traffic accidents as fast driving, running red lights and overloading (Du *et al.*, 2013). However, for car drivers, the main concerns are driving the wrong way and sudden lane changes.

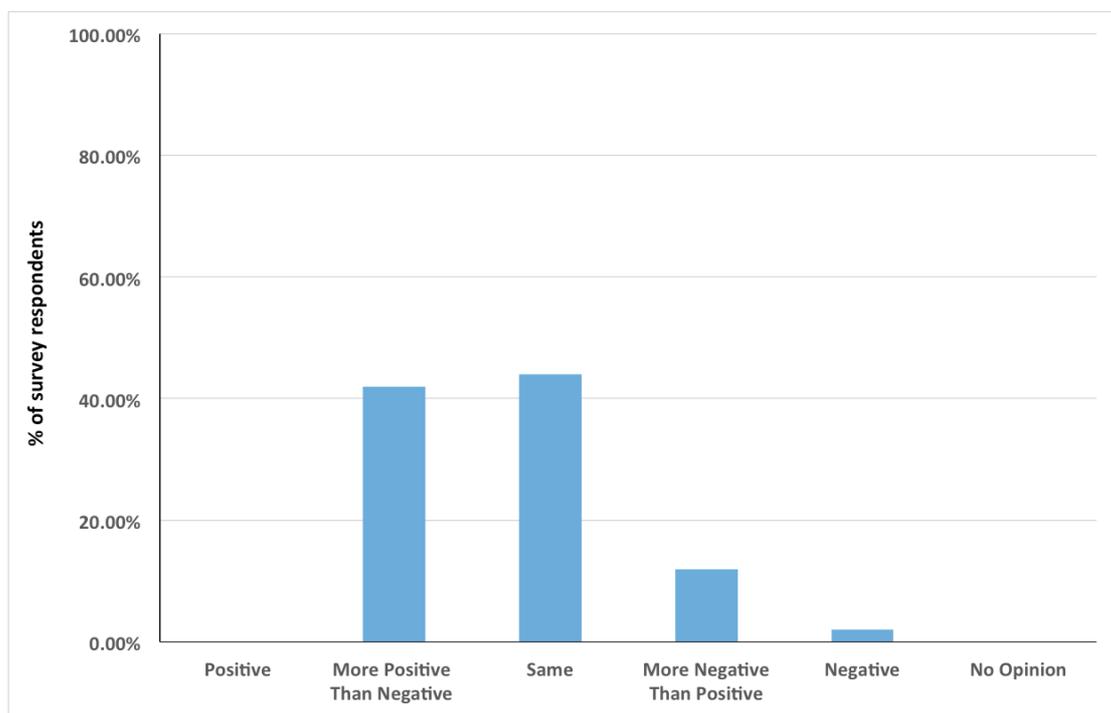
	Speeding		Total		Running red lights		Total		Driving the wrong way		Total
	Yes	No			Yes	No			Yes	No	
Car drivers	44	156	200	Car drivers	59	141	200	Car drivers	58	142	200
Bicycle users	80	120	200	Bicycle users	113	67	200	Bicycle users	32	168	200
Pedestrians	187	13	200	Pedestrians	153	47	200	Pedestrians	48	152	200
Traffic police	46	4	50	Traffic police	49	1	50	Traffic police	20	30	50
Total	357	293	650	Total	374	256	650	Total	158	492	650
$X^2=253.5346, p\text{-value}<0.00001$			$X^2=13.0981, p\text{-value}<0.00001$			$X^2=16.5978, p\text{-value}=0.000855$					
	Overloading		Total		Lane Changes		Total				
	Yes	No			Yes	No					
Car drivers	90	110	200	Car drivers	59	141	200				
Bicycle users	89	111	200	Bicycle users	34	166	200				
Pedestrians	77	123	200	Pedestrians	50	150	200				
Traffic police	49	1	50	Traffic police	27	23	50				
Total	305	345	650	Total	170	480	650				
$X^2=58.8413, p\text{-value}<0.00001$			$X^2=30.0486, p\text{-value}<0.00001$								

Table 6.11 Chi-squared test of unsafe behaviour by e-bike users: Nanjing survey

6.3.5 Traffic Police

Traffic police play a crucial role in the transport system due to their role in undertaking general traffic and road management. In this case, the traffic police have a rich experience of traffic situations and grasp the realities of the various transport modes. Therefore, their responses are crucial to this study. The sample size of traffic police in this study is 50. There are five questions in the survey to understand traffic police attitudes to the e-bike transition process, including the positive impact of e-bikes, the negative impact of e-bikes, e-bike users' violation behaviour, and future recommendations.

When traffic police were asked about their attitudes towards the impact of e-bikes in the transport system, 44% responded that the e-bike transition had a more positive than negative impact, and this was followed by 42% of traffic police who believed that the positive impact was equal to the negative impact (Figure 6.30). 12% of traffic police said that e-bikes had a more negative than positive impact on the transport system. Only 2% of traffic police stated that e-bikes had a negative impact on the transport system.



(Sample size: 50 traffic police)

Figure 6.30 The attitude of traffic police to e-bike transition: Nanjing survey

The main positive impacts include usage convenience, being environmentally friendly, saving road resources, no noise, and relieving traffic jams. For example, more than 70% of traffic police agreed that e-bikes were convenient to use and also very environmentally friendly. More than 60% of traffic police agreed that e-bikes saved certain road resources and abated the traffic noise.

However, 70% of traffic police claimed that e-bikes worsened traffic jams. Other

negative impacts include worsening traffic control problems (44%), increasing accidents (38%), and obstructing other vehicles (24%). In general, the response rates of positive impact options are much higher than negative impact options. These negative impacts are mainly caused by the traffic violation behaviour of e-bike users. Nearly 90% of traffic police stated that the most common traffic violation behaviours of e-bike users were running red lights, overloading, and fast driving. Other violation behaviours include driving the wrong way and lane changes. In this case, the majority of traffic police strongly suggested that e-bike users should enhance their safety awareness (Table 6.12). In addition, the traffic police thought that it might be worth restricting e-bike usage during specific time periods in the city. Other suggestions included the requirement of an e-bike driving license, building e-bike lanes, increasing punishment standards, restricting non-standard e-bikes, and restricting the travel of e-bikes on main roads in the city.

	Mean	Median	Mode
Enhance the safety awareness of e-bike users	4.68	5	5
Increase punishments for law breakers	4.02	4	4
Restrict non-standardised e-bikes	3.92	4	4
Restrict the travel of e-bikes on main roads in the city	3.78	4	4
Restrict the travel of e-bikes during specific times in the city	4.5	5	5
Increase the number of traffic police	3.92	4	4
The requirement of an e-bike driving license	4.14	4	4
Strengthen e-bike registration administration	4.14	4	4
Build e-bike lanes	4.06	4	4
Establish an e-bike commercial insurance system	4.04	4	4

5 = Strongly agree 4 = Agree, 3 = Neutral, 2 = Disagree, 1 = Strongly disagree
Neutral Scores are in range of 2.8 to 3.2

(Sample size: 50 traffic police)

Table 6.12 Future suggestions of e-bike traffic management: Nanjing survey

6.4 Analysis

6.4.1 The difference between female and male respondents in mode choice and e-bike usage experience

	Shifted from bicycle *		Total		Shifted from motorcycle※		Total		Shifted from walking *		Total
	Yes	No			Yes	No			Yes	No	
Male	72 33.8%	141 66.2%	213 100%	Male	53 24.89%	160 75.11%	213 100%	Male	52 24.4%	161 75.6%	213 100%
Female	81 43.55%	105 56.4%	186 100%	Female	17 9.13%	169 90.87%	168 100%	Female	61 32.8%	125 67.2%	186 100%
Total	153 37.84%	246 62.16%	399 100%	Total	70 17.54%	329 82.46%	399 100%	Total	113 28.3%	286 71.7%	399 100%
X ² = 3.9889, p-value= 0.045801			X ² = 15.9505, p-value=6.537e-05			X ² = 3.03, p-value= 0.08142					
	Shifted from bus		Total		Shifted from metro※		Total		Shifted from private cars		Total
	Yes	No			Yes	No			Yes	No	
Male	72 33.8%	141 66.2%	213 100%	Male	21 9.85%	192 90.15%	213 100%	Male	21 9.9%	192 90.1%	213 100%
Female	74 39.8%	112 60.2%	186 100%	Female	37 19.9%	149 80.1%	186 100%	Female	20 10.7%	167 89.3%	186 100%
Total	146 36.6%	253 63.4%	399 100%	Total	58 14.5%	341 85.5%	399 100%	Total	41 10.3%	359 89.7%	399 100%
X ² =1.2845, p-value=0.2571			X ² =7.2585, p-value=0.0071			X ² =0.0164, p-value=0.8982					

※ p-value < 0.05, * p-value < 0.1

Table 6.13 Chi-squared test result of previously used mode: Nanjing survey

In order to understand the difference between genders in terms of transport mode choice, Chi-squared tests were conducted to determine whether male and female e-bike users preferred different travel modes (Table 6.13, Table 6.14 and Table 6.15). The number of male and female participants who shifted from using bicycles, motorcycles, and the metro is significantly different (Shown as Table 6.13).

There are more female than male e-bike users, who previously travelled by bicycle or walked. However, male travellers show a strong preference for motorcycles. In our

sample, 24.89% of male travellers previously used motorcycles, much more than females (9.13%). Therefore, female travellers preferred low speed vehicles compared with males. This finding is also supported by the suggestion of future e-bike development: only 20.1% of female respondents suggested that e-bike speed should be increased, while 31.6 of male respondents expected to have fast speed e-bikes.

	Commute		Total		Pick up children		Total		Go shopping ※		Total
	Yes	No			Yes	No			Yes	No	
Male	139	74	213	Male	47	166	213	Male	12	201	213
	65.3%	34.7%	100%		22.1%	77.9%	100%		5.7%	94.3%	100%
Female	127	60	187	Female	49	138	187	Female	22	165	187
	68%	32%	100%		26.3%	73.7%	100%		11.8%	88.2%	100%
Total	266	134	400	Total	96	304	400	Total	34	366	400
	66.5%	33.5%	100%		24.0%	76.0%	100%		8.5%	91.5%	100%
X ² =0.2074, p-value=0.6488			X ² =0.7215, p-value=0.3957			X ² =4.0565, p-value=0.044					
	Leisure *		Total		Visit friends ※		Total		Access Metro *		Total
	Yes	No			Yes	No			Yes	No	
Male	18	195	213	Male	15	198	213	Male	7	206	213
	8.5%	91.5%	100%		7.1%	92.9%	100%		3.3%	96.7%	100%
Female	28	159	187	Female	28	159	187	Female	28	159	187
	15%	85%	100%		15%	85%	100%		15%	85%	100%
Total	46	354	400	Total	43	357	400	Total	35	365	400
	11.5%	88.5%	100%		10.8%	89.2%	100%		8.8%	91.2%	100%
X ² =4.163, p-value=0.05968			X ² =5.728, p-value=0.016697			X ² =17.034, p-value=0.0000368					

※ p-value < 0.05, * p-value < 0.1

Table 6.14 Chi-squared test result of trip purpose of e-bike adoption: Nanjing survey

Another significant difference between female and male respondents is in the metro usage. 19.9% of female e-bike users used the metro previously, whilst only 9.9% of male respondents travelled by metro before. In terms of the choice of buses and private cars, there is not much difference between female and male respondents, indicating that gender factors do not influence the transition from bus and private car users.

	Low purchase cost		Total		Low operation cost		Total		Effort saving		Total
	Yes	No			Yes	No			Yes	No	
Male	43	164	207	Male	69	138	207	Male	75	132	207
	20.8%	79.2%	100%		33.4%	66.6%	100%		36.3%	63.7%	100%
Female	32	151	183	Female	48	135	183	Female	80	103	183
	17.5%	82.5%	100%		26.3%	73.7%	100%		38.7%	61.3%	100%
Total	75	315	390	Total	117	273	390	Total	155	235	390
	19.3%	80.7%	100%		30.0%	70.0%	100%		39.8%	60.2%	100%
X ² =0.4805, p-value=0.4882				X ² =2.0081, p-value=0.1565				X ² = 1.9699, p-value=0.1605			
	Flexible trip time ※		Total		Time saving		Total		High accessibility		Total
	Yes	No			Yes	No			Yes	No	
Male	67	140	207	Male	51	156	207	Male	55	152	207
	32.4%	67.6%	100%		24.7%	75.3%	100%		26.6%	73.4%	100%
Female	80	103	183	Female	42	141	183	Female	51	132	183
	38.7%	61.3%	100%		23%	77%	100%		27.9%	72.1%	100%
Total	147	243	390	Total	93	297	390	Total	106	284	390
	37.7%	62.3%	100%		23.9%	76.1%	100%		27.2%	72.8%	100%
X ² =4.8544, p-value=0.02758				X ² =0.0735, p-value=0.7863				X ² =0.0302, p-value=0.8621			
	Environmentally friendly ※		Total		Health *		Total				
	Yes	No			Yes	No					
Male	46	161	207	Male	15	192	207				
	22.3%	77.7%	100%		7.3%	92.7%	100%				
Female	19	164	183	Female	5	178	183				
	10.4%	89.6%	100%		2.8%	97.2%	100%				
Total	65	325	390	Total	20	370	390				
	16.7%	83.3%	100%		5.2%	94.8%	100%				
X ² =8.9694, p-value=0.002745				X ² =3.1933, p-value=0.07394							

※ p-value < 0.05, * p-value < 0.1

Table 6.15 Chi-squared test result of e-bike adoption reason: Nanjing survey

Concerning the purpose of e-bike adoption, there is no difference between female and male respondents in commuting and picking up children (Table 6.14), reflecting an underlying social phenomenon that families where both parents work have become normal in urban areas and that females and males play similar roles in their families. However, regarding the other purposes of e-bike adoption, there are significant differences between female and male respondents. More female respondents use

e-bikes for shopping, leisure, visiting friends and accessing the metro (Table 6.14). This result may indicate that female respondents have more activities than male respondents. Also, the result could suggest that e-bikes pervade deeper into the lives of female respondents. In other words, the advantages of e-bikes better fit the travel demands of female respondents. In addition, the e-bikes could satisfy the demands of various trip purposes. This result may reinforce that e-bikes have the potential to increase the mobility radius of female citizens.

From the Chi-squared test results, the following e-bike advantages are widely accepted in both male and female respondents: low purchase cost, low operation cost, effort saving, time saving, and high accessibility (Table 6.15). An interesting finding is that men are more sensitive to the positive environmental impact of e-bikes (see Table 6.15). When asked whether e-bikes are environmentally friendly, the number of male respondents is double that of female respondents, and the number of male respondents who believe that e-bikes are beneficial to health conditions is also nearly twice as large as the female respondents. Female respondents are more attracted by the time flexibility feature: 38.7% of female e-bike users adopt e-bikes because they provide time flexibility, compared to 32.4% of male respondents (Table 6.15). The result could be an indicator that female e-bike users pay more attention to the practical advantages of e-bikes.

6.4.2 The reason for the spontaneous emergence of e-bikes

	Bicycle	Bus	Walking	Motorcycle	Metro	Private Car
Percentage of e-bike users transferred from each mode	38.25%	36.50%	28.25%	17.5%	14.5%	11.75%

Table 6.16 Percentage of e-bike users transferred from each mode: Nanjing survey

Now we investigate why citizens abandoned vehicles such as bicycles, public transport, walking, metro and motorcycles, which were dominant during the Chinese Regime (Table 6.16), in order to adopt an innovative vehicle. Logit regression is applied to analyse the relationship between mode choice and e-bike adoption purpose, and the relationship between mode choices and the reason for choosing e-bikes. The tested mode choices are buses, walking, metro, private cars, bicycles, and motorcycles. The e-bike adoption purposes include commuting, going to school, picking up children, shopping, visiting friends, travel connections to the metro, leisure, and business. The reasons for choosing e-bikes are low purchase costs, low operation costs, effort saving, flexible trip times, saving time in traffic jams, high accessibility, being environmentally friendly, and health.

Previous vehicle	Transition purpose	Correlation	<i>p</i> -value
Bus	Commute	0.8408	0.000466
Walking	Transition to metro	0.7051	0.0388
Metro	Pick up children	1.0586	0.0193
	Leisure	0.9371	0.0126

Table 6.17 Travel characteristics, vehicle transition and purpose: Nanjing survey

Previous vehicle	Transition reasons	Correlation	<i>p</i> -value
Bus	Flexible trip time	1.0303	0.00006
	Saving time in the traffic jams	1.1774	0.0006
	High accessibility	0.7487	0.00136
Walking	Effort saving	0.4935	0.0298
Metro	Low purchase cost	1.2471	0.0000009
	Effort saving	0.776	0.0113
	Saving time in the traffic jams	0.8449	0.00707
	Being Environmentally friendly	0.9750	0.00208
Motorcycle	Low operation cost	0.6189	0.0252

Table 6.18 Travel characteristics, vehicle transition and reasons: Nanjing survey

Each mode choice is paired with the e-bike adoption purposes listed in order to test whether a significant relationship exists between mode choice and e-bike adoption

purpose. After that, each mode choice is paired with the listed e-bike adoption reasons to examine the relationship between them. Table 6.17 lists the significant relationships between mode choice and e-bike adoption purposes, and the significant relationships between mode choice and e-bike adoption reasons are listed in Table 6.18. It is noted that Table 6.17 and Table 6.18 only list the mode choices which show significant relationships with e-bike adoption in our test. Therefore, the e-bike users who transferred from bicycles are not listed in the tables, because they do not have a statistically significant relationship with specific e-bike adoption purposes and specific e-bike adoption reasons. The relationship significance test results are also shown in Table 6.17 and Table 6.18.

E-bikes users transferring from buses

In our sample, 39% of e-bike users transferred from using the bus, which is the second most frequent response. Tables 6.17 and 6.18 show that e-biker users transferring from buses tend to use e-bikes for the purpose of commuting. The transition reasons include flexible trip times, saving time in traffic jams, and high accessibility. The transition reasons indicate the advantages of e-bikes over buses for the purpose of commuting, because buses do not always operate on time, especially during rush hours, and bus routes cannot cover all urban areas. When respondents are asked under which condition they would transfer to using a bus, many of them choose the “if new bus routes were added” option.

E-bikes users transferring from walking

In our sample, 28% of e-bikes users shifted from walking, and they mainly use e-bikes for travel connections to the metro. The transition motivation is to save effort, which may also imply that the number of metro stations is not sufficient to cover the urban areas in Nanjing. Hence, e-bike adoption is also a complement to using public

transport.

E-bikes users transferring from the metro

The e-biker users transferring from using the metro tend to use e-bikes for picking up children, leisure and travel connections. The transition reasons are given as follows: cheap purchase costs, effort saving, saving time during peak times, and being environmentally friendly. Firstly, e-bikes offer personal motorised mobility with a low purchase cost. Secondly, e-bikes provide a door-to-door service, saving the trip time from home to the metro stations.

E-bikes users transferring from motorcycles

The e-bike users transferring from motorcycles tend to continue using e-bikes. The main motivation is the low operation cost. In China, the average gasoline price is 6.70 CNY/Litre (calculated on 3 August, 2015, Global Gasoline Price). Generally, the oil consumption of a 125cc motorcycle per 100 kilometres is 2.5 litres, which costs CNY 16.875. The average travel distance of an e-bike carrying a 48V and 12Ah battery is 44 km with full charge (Bicycle Industry Information Centre, 2011). One full charge of an e-bike consumes 0.6912 kWh. In this case, the electricity consumption per 100 km of the e-bike is 1.571 kWh. In Nanjing, the electricity price at off-peak time (21:00–8:00) is 0.3583 CNY/kWh, while the price at peak time (8:00–21:00) is 0.5583 CNY/kWh (Editorial Board of Gazette of the People's Government of Jiangsu Province, 2012). Therefore, the highest rate of e-bike charging is CNY 0.8771, and the lowest rate is CNY 0.5625, which is nearly 30 times less than that of motorcycle operation costs. Although the travel distance may decrease if batteries are used for more than one year, the operation cost of e-bikes is still very low compared with motorcycles.

The above results illustrate that the travel characteristics of e-bikes are flexible trip times, high accessibility, time saving and effort saving which matches other e-bike studies (Cherry and Cervero, 2007; Weinert *et al.*, 2007). In addition, the travel characteristics are associated with people's feelings about e-bike adoption. The positive associations are freedom (48.62%) and practical usage. To summarise, the mechanism of e-bike spontaneous transition is that e-bikes satisfy the demand of personal mobility from both internal and external perspectives.

6.4.3 Barriers to e-bike transitions

Battery issues

As the power supply and key component of e-bikes, the battery determines the travel distance, e-bike weight, travel experience and operation cost. So the battery performance is a critical factor influencing e-bike purchase.

Apart from that, lead pollution causes environmental risks and harm because most of the e-bikes carry lead-acid batteries. It is not an easy task to recycle the disused and discarded batteries of e-bikes. In the study by Chun in 2013, only 33% of lead-acid batteries are properly recycled by professional companies, while others are illegally recycled in more hazardous and polluting ways. Lead pollution caused by lead-acid batteries induced the restriction policy on e-bikes. In 2011, a notice to regulate pollution from lead-acid batteries and the lead recycling industry was issued by the Ministry of Environmental Protection, which precluded many lead-acid battery manufactures from the market (Xu, 2012). But a side-effect of this is battery shortages, which increased the battery prices and further increased the cost of e-bikes. Hence, it still could be a technology barrier which in turn suggests that in the future e-bike transition has further scope to develop.

E-bike safety issues

The safety issue contains two aspects. On the one hand, e-bike users view themselves as a group that is vulnerable to motorised vehicles. On the other hand, e-bikes users' violation behaviour is believed to threaten the safety of other group users.

From other users' viewpoints, e-bikes are "dangerous" and "uncontrolled". The violation behaviours of e-bike users mainly include running red lights, speeding, overloading, driving the wrong way and sudden lane changes without warning. When other groups were asked about e-bike development, many of the respondents suggested that e-bike users should increase their safety awareness.

Road safety is the main reason why e-bikes are restricted or banned. In 2001, a "Notice of Strengthening E-bike Regulation" was published by the Ministry of Public Security, the Ministry of Industry and Information Technology, the State Administration for Industry and Commerce, and the General Administration of Quality Supervision Inspection and Quarantine. These clearly state that local governments at various levels should regulate the e-bike industry and e-bike users' behaviour. After that, four provinces and 42 cities issued corresponding e-bike regulation to clarify the e-bike traffic regulations.

6.5 Conclusion

To understand e-bike transition and e-bike adoption characteristics, a survey was conducted in Nanjing City. This chapter explores how e-bikes were embedded in the current transport regime (RQ3) and what are the mechanisms underlying e-bike rapid uptake (RQ5). Specifically, we need to understand who is using e-bikes, the trip

purpose of using e-bikes, the reasons for selecting e-bikes, feeling associated with e-bike adoption, safety concern, and the attitudes of other mode users to e-bikes.

E-bike users are mainly career-age commuters and have much higher than average education levels than other inhabitants of Nanjing City, which are very different from other countries. The trip time of e-bikes usually ranges from 20 to 30 minutes. The most popular e-bike type is hybrid style with a lead-acid battery. Also, e-bike users prefer to buy e-bikes from local shops rather than online shopping.

E-bike transition is highly embedded in the current transport regime, for the reasons that: 1) The general attitudes of e-bike users, non-e-bikes users and traffic police towards e-bikes are positive; and 2) e-bikes have been adopted widely in many aspects of daily life settings, including commuting, going shopping, picking up children.

The reasons why respondents choose e-bikes include low cost, effort saving, flexible trip times, time saving in traffic jams, and high accessibility. User attitudes also affect the reasons why respondents choose e-bikes, that is, travelling by e-bike gives a sense of freedom and provides practical usage. The attitude to e-bike rapid development among the citizens (car drivers, pedestrians, bicycle users, and traffic police) tends to be positive. Most of the citizens admit the advantages of e-bikes such as being environmentally friendly, convenience for daily use, road resource saving, and noise reduction. However, they also suggest that e-bike users should improve their safety awareness. In terms of infrastructure, they advocate to widen bicycle lanes.

Safety and battery issues are the main negative factors impeding e-bike transition. The two issues induce e-bike restriction and a policy to ban them in some cities. Citizens claim that e-bike users show various traffic violation behaviours, including running red lights, overloading, fast speed, and sudden lane changes. Also, e-bike users are

more likely to have conflict with motor vehicle users and pedestrians. In our sample, most of the e-bikes carried lead-acid batteries, which cause lead pollution. Also, due to the nature of lead-acid batteries, e-bike users claim that they are heavy and difficult to charge, which causes user anxiety in social practices.

Chapter 7

A Case Study of Electric Bicycles in Nanjing: Sustainable Transport Consumption Behaviour and Socio-technical Transition Part 2

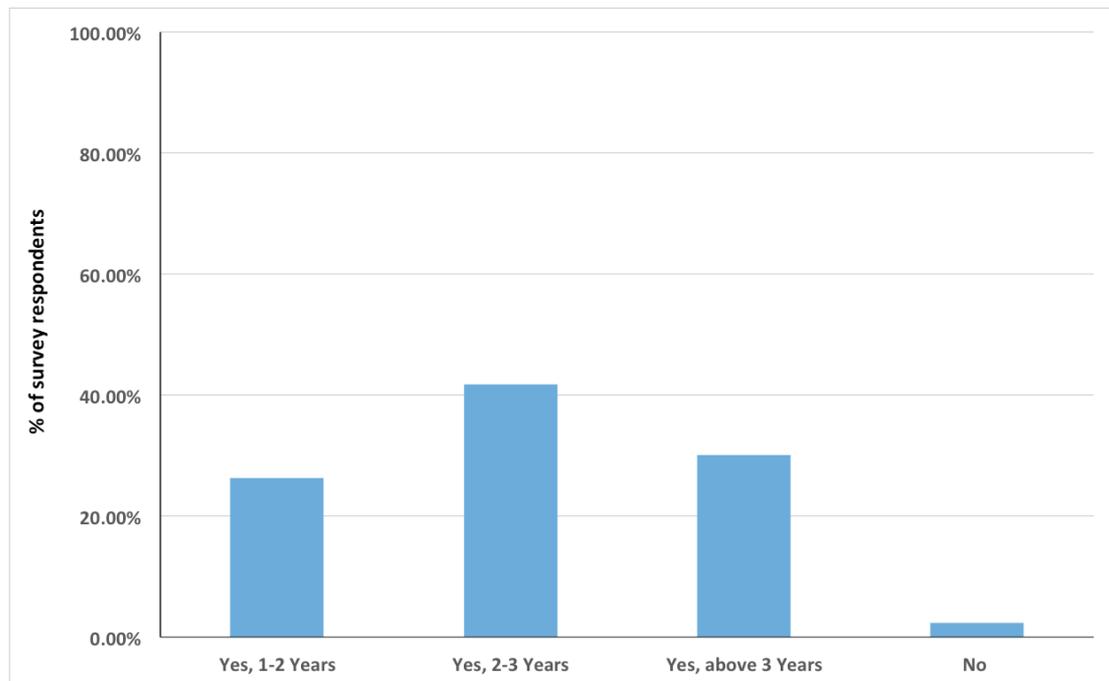
7.1 Introduction

The preceding chapter has revealed that e-bikes are embedded well in the current regime. Concerning the wide adoption of e-bikes in the transport system, if e-bike users abandon e-bikes in the future or e-bikes are banned in a large scale, it will lead huge pressure to transport system. In this case, it is urgent to understand e-bike users' future transport mode choice and travel behaviour. This chapter is intended to know how much longer e-bikes can keep being “embedded” in the transport regime (RQ4). Specifically, we focus on the following questions: 1) What factors influence the future choice of e-bike use? 2) What alternative travel modes will be available and what factors influence the corresponding future choices? 3) Are e-bikes a future sustainable mobility or only an intermediate mode to cars? The research results in this chapter are a part of Nanjing case study, and the data used are based on the surveys in Nanjing City.

The chapter is organised as follows. Firstly, the survey results of the future choice of e-bikes and other alternative travel modes are discussed in Section 7.2. To further explore the mode choice behaviour, Section 7.3 discussed the factors influencing the future choice of e-bikes and alternative travel modes using the Generalised Linear Model (GLM) and Binomial GLM. A further analysis is performed in Section 7.4. The final section is the conclusion of the chapter.

7.2 The future choice in the sets of e-bikes and other alternative travel modes

E-bike future adoption



(Sample size: 403 e-bike users)

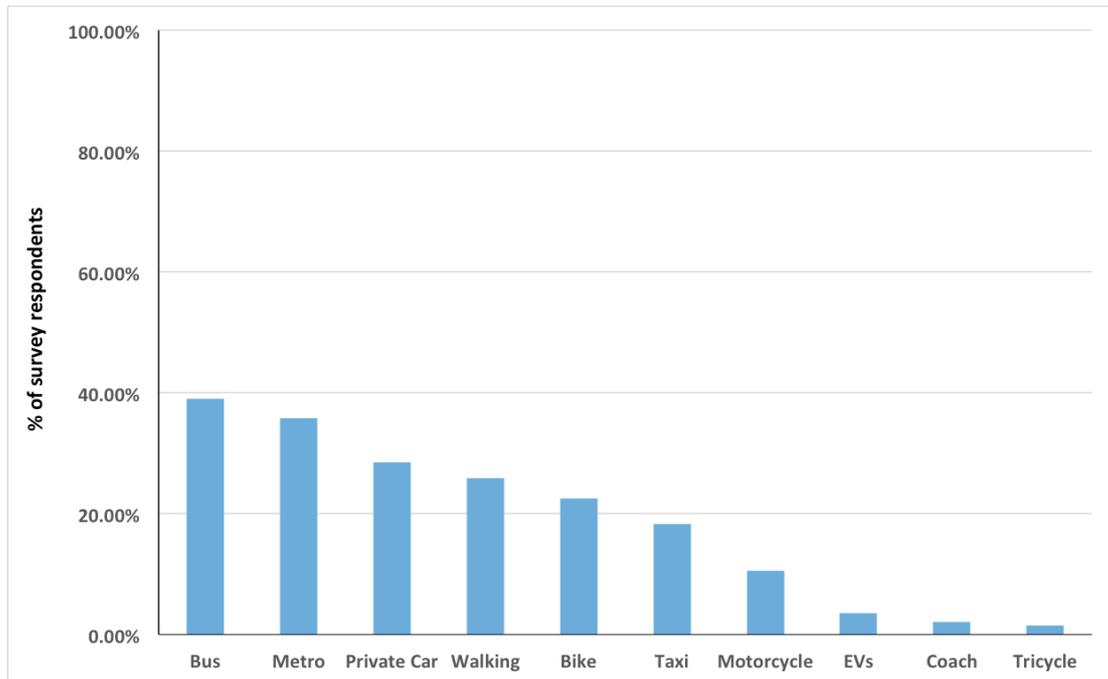
Figure 7.1 Expected future use of e-bikes: Nanjing survey

In our survey of e-bike users, more than 40% of participants expected to continue using e-bikes in the following two to three years, 30% of participants expected above three years, and 20% of participants in the following two years (Figure 7.1). The percentage of people expecting to transfer to other travel modes is only 2%. This suggests that e-bikes have satisfied the current demand of travellers to a great extent.

Alternative travel mode choices if e-bikes are unavailable

Concerning the possible alternative travel modes in the future if e-bikes are unavailable, for example due to e-bike policy, public transport is the primary choice

(buses are 38.96% and the metro is 36.72% respectively), followed by private cars with 28.54% of responses (Figure 7.2).



(Sample size: 403 e-bike users)

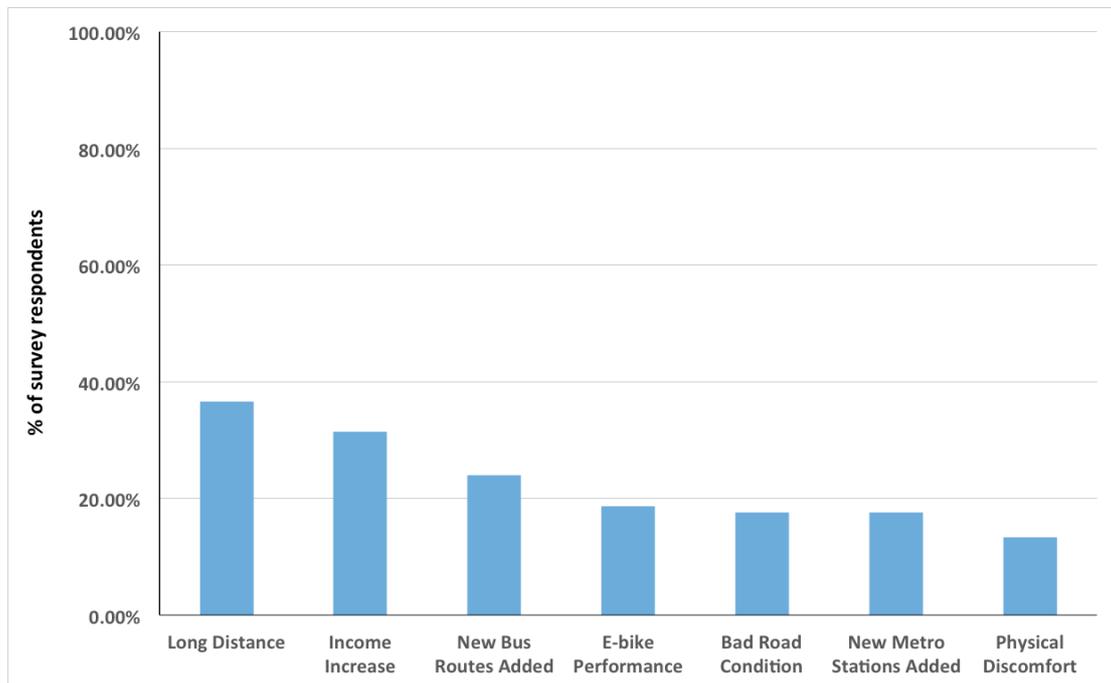
Figure 7.2 Alternative mode choices in the absence of e-bikes: Nanjing survey

In comparison, fewer than 25% of e-bike users expected to be using bicycles or walking in the future. This may indicate that the travellers have an increasing requirement for travel speed, so bicycles are not attractive to them. One of the reasons could be that the travel distances have grown due to the separation of housing, working, and other activities in a growing urban area, which results in a requirement for faster vehicles. In addition, when e-bike users were asked whether they would transfer to motorcycles if e-bikes were to be banned in the future, only 10.53% of them responded that they would consider it in the future. The reasons could be the high purchase cost, heavy weight and high operation cost of motorcycles. Very few people expected to adopt Electric Vehicles (EVs), coaches, and tricycles, which only occupy a very tiny share of the market.

In the surveys in other cities, buses are the most popular alternative travel mode as in

Nanjing (this study), Shanghai, Kunming, and Shijiazhuang (Cherry and Cervero, 2007; Weinert *et al.*, 2008), whereas private cars are the most popular alternative mode in Xi'an (Xu *et al.*, 2014). The alternative mode choice may vary with the cities due to the difference of city scales, the household income and the level of the development of public transport system.

Reasons for transferring to other alternative mode choice



(Sample size: 393 e-bike users)

Figure 7.3 The reasons for future alternative mode choice: Nanjing Survey

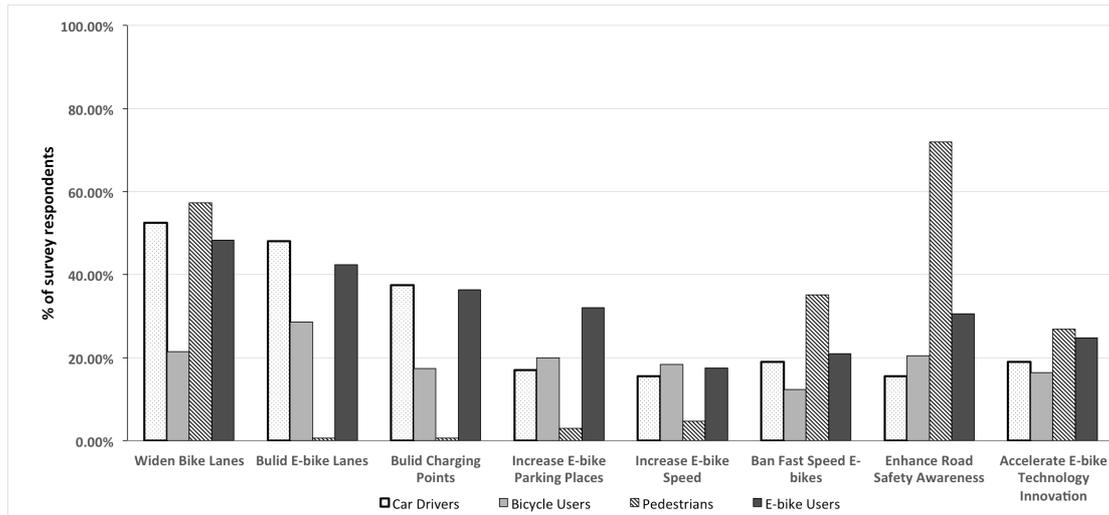
For long distance trips, it is highly possible that e-bike users will transfer to other travel modes, which indicates that motorised vehicles have more advantages over e-bikes for long-distance trips (Figure 7.3). The problem may arise from the limitation of e-bike batteries. The second essential factor motivating e-bike users to transfer to other travel modes is the increase of income, which implies that economic considerations are a key point underlying the current e-bike adoption behaviour. With an increase of income, users are willing transfer to other modes, for example private

cars. Thirdly, the improvement of the public transport system can attract a large number of travellers from e-bikes. In our survey, new added bus routes contributed to more than 20% of the transition from e-bikes, and newly added metro stations contributed to 18%. The transfer from e-bikes to other modes due to a dissatisfaction with the e-bike performance is less than 20%. This indicates that e-bike technologies have satisfied the travel demand to a great degree. Other reasons influencing future choices include bad weather conditions and physical discomfort, but these are less than 20%.

Understanding alternative mode choices is crucial in order to predict the effect of e-bike administration policy. If e-bikes are banned, it will cause a significantly higher demand for buses and the metro. Another possibility is that the “e-bike bans” policy will induce a significant increase in the use of private cars, which will place a higher burden on the traffic system and produce more pollution. If urban governments can allow for the development of e-bikes, traffic congestion will be lower than would otherwise be the case, and at the very low cost. The travellers also will retain an additional choice to achieve personal mobility.

Future suggestions for e-bike development

Future suggestions for e-bike development are revealed by different groups, as shown in Figure 7.4. A Chi-squared test of independence was performed to examine whether there were statistically significant differences amongst different traveller groups in relation to their suggestions for e-bike development. After the test, statistically significant differences were found in the suggestions such as widening bike lanes, building e-bike lanes, building charging points, increasing parking places, increasing e-bike speed, banning high-speed e-bikes, and enhancing road safety awareness (Table 7.1). On the other hand, no statistically significant differences exist when the suggestion is accelerating e-bike innovations (Table 7.1).



(Sample size: 200 car drivers; 200 bicycle users; 200 pedestrians; 393 e-bike users)
Figure 7.4 Future suggestions for e-bike development: Nanjing survey

Approximately 60% of pedestrians suggested that bicycle lanes should be widened, which is also advocated by 55% of car drivers and 50% of e-bike users. However, bicycle users prefer building separate e-bike lanes, implying that the existing bicycle lanes are too narrow to satisfy the mixed use of both bicycles and e-bikes, which could cause traffic conflicts between them.

More than 70% of pedestrians thought that e-bike users should enhance road safety awareness. The result indicates that pedestrians feel that their own safety has been threatened seriously by the e-bike users riding without sufficient safety awareness. Even 30% of e-bike users also held the same opinion as pedestrians, which further exposed the traffic safety problems caused by e-bikes.

It is not surprising that different groups interpreted the road situations and gave suggestions from their own standpoints and experiences. For example, car drivers thought that the speed of e-bikes was acceptable, while nearly 40% of pedestrians suggested banning high-speed e-bikes. Another example is the fact that e-bike users, car drivers and pedestrians suggested widening bicycle lanes. Yet from the perspective of bicycle users, the introduction of separate e-bike lanes is more

reasonable, which implies that e-bikes were viewed as a threat to the safety of bicycle users when sharing the same lane. However, the overall attitudes of all groups of respondents to e-bike development are positive. They agreed that e-bikes have contributed to personal mobility and are very environmentally friendly.

	Widen bike lanes		Total		Build e-bike lanes		Total		Build charging points		Total
	Yes	No			Yes	No			Yes	No	
CD	105	95	200	CD	96	104	200	CD	75	125	200
BU	43	157	200	BU	57	143	200	BU	35	165	200
P	115	85	200	P	1	199	200	P	1	199	200
EbU	190	203	393	EbU	167	226	393	EbU	143	250	393
Total	453	540	993	Total	321	672	993	Total	254	739	993
X ² = 63.2734, p-value<0.00001			X ² = 134.972, p-value<0.00001			X ² =111.983, p-value<0.00001					
	Increase e-bike parking places		Total		Increase e-bike speed		Total		Ban fast speed e-bikes		Total
	Yes	No			Yes	No			Yes	No	
CD	34	166	200	CD	31	169	200	CD	38	162	200
BU	40	160	200	BU	37	163	200	BU	24	176	200
P	6	194	200	P	9	191	200	P	70	130	200
EbU	126	267	393	EbU	68	325	393	EbU	82	311	393
Total	206	787	993	Total	145	848	993	Total	214	779	993
X ² =70.684, p-value<0.00001			X ² =21.2325, p-value=0.000094			X ² =33.0677, p-value<0.00001					
	Enhance road safety awareness		Total		Accelerate e-bike technology innovations		Total				
	Yes	No			Yes	No					
CD	31	169	200	CD	38	162	200				
BU	41	159	200	BU	33	167	200				
P	144	56	200	P	54	146	200				
EbU	120	273	393	EbU	97	296	393				
Total	336	657	993	Total	222	771	993				
X ² =177.9534, p-value<0.00001			X ² =8.9585, p-value=0.029847								

CD: Car Drivers; BU: Bicycle Users; P: Pedestrians; EbU: E-bike Users

Table 7.1 Chi-squared test of future suggestions for e-bike development: Nanjing survey

From the theoretical perspective, the suggestions about future e-bike development are closely related to the landscape and regime change. In terms of the suggestions for

improving bicycle lanes, if a great number of vehicle users have this requirement, it will give rise to an intensive pressure on the regime, which will potentially destabilise the existing mobility regime. Subject to this pressure, policy makers could take measures to improve the transport infrastructures in favour of e-bikes. Suggestions regarding the enhancing of road safety awareness may be understood as a form of socio-cultural process, occurring at the landscape level. The suggestion to accelerate e-bike innovation is a requirement of socio-technical transition, and can be understood as the expansion of a niche activity. Innovation in technology places pressure on numerous regimes, including the e-bike industry and the automobile industry in terms of new skills and technical competence requirements, safety and environmental regulation, purchasing practices, and new capital investments.

7.3 The Factors influencing the future choice of e-bikes and alternative travel modes

The explosive growth of e-bikes has already attracted the attention of government, but many city authorities treated e-bikes as an obstacle to China's motorisation pathway and issued an "e-bike bans policy", ignoring the fact that the spontaneous emergence of e-bikes had already embedded them into Chinese citizens' lives. It is predicted that if e-bikes are suddenly banned, other travel modes will be subject to substantial pressure due to a great number of users transferring from e-bikes. Understanding the factors influencing the alternative travel mode choices can help allocate the traffic resource in the future.

In order to better understand the influencing factors of e-bike users' model behaviour and predict e-bike use in the future, e-bike use choice models were investigated based on demographic information (age, gender, income, and education), positive and negative associations, and other alternative specific characteristics (such as safety

issues, e-bike prices, and previous travel experiences). The corresponding research questions are:

- 1) What factors influence the future choice of e-bike use?
- 2) Assuming that e-bikes are not available, for example due to an e-bike ban policy, what alternative travel modes will be available and what factors influence the corresponding choices?

7.3.1 The factors influencing the future choice of e-bike use

Number of observations=403, ACI=814, Multiple R ² : 0.7108, Adjusted R ² : 0.6991				
Variable	Estimate	Std. Error	t value	Pr(> t)
(Intercept)	0.860177	0.090531	9.501	< 2e-16***
Age	0.048985	0.040494	1.210	0.227169
Age ²	-0.006252	0.005554	-1.126	0.261004
Number of e-bikes in household	0.060415	0.022406	2.696	0.007329**
Number of bicycles in household	0.041188	0.014251	2.890	0.004077**
Number of cars in household	-0.031256	0.018843	-1.659	0.098010 .
Walking (previous travel mode)	0.051944	0.025849	2.010	0.045203*
Bus (previous travel mode)	0.058758	0.025161	2.335	0.020061*
Metro (previous travel mode)	-0.066453	0.035637	-1.865	0.063007.
Have accidents (1 if have accident, 0 otherwise)	-0.053495	0.024080	-2.221	0.026920*
Flexible time (reason of e-bike adoption)	0.048543	0.024680	1.967	0.049936*
The feeling of freedom	0.082445	0.023384	3.526	0.000475***
Pro-e-bike attitude (1 if pro-e-bike, 0 otherwise)	0.065828	0.032211	2.044	0.041697*
E-bike tends to be out of work during use (user anxiety)	-0.034381	0.011064	-3.108	0.002032**
E-bike price	0.033379	0.008400	3.974	8.51e-05***
Commute (travel purpose)	-0.076390	0.024637	-3.101	0.002079**

Significant. Codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1; Age²: *The square of Age*

Table 7.2 Results of predicting e-bike use choice model

The survey data were used to develop a Generalised Linear Model to predict e-bike usage in the future. The data were coded to represent the attitudes to e-bike development: supportive or opposing (1 if it is supportive, 0 otherwise). The results of

the General Linear Model are shown in Table 7.2. The dependent variable is the years of future e-bike adoption. The independent variables entering the model include user demographics, the previous experience, and positive and negative associations and attitudes. In the regression analysis of the previous study by Cherry and Cervero (2007), the tested independent variables included user demographics, pro-e-bike attitudes, reasons for e-bike adoption, travel time by bicycle minus e-bike, gender (one for male and zero for female users) times age, and gender times the square of age. Inspired by the study, we also chose user demographics, pro-e-bike attitudes, reasons for e-bike adoption, and e-bike travel time as independent variables. In addition, we introduced many new independent variables because they were closely related to e-bike future adoption, including previously used travel modes, e-bike price, safety considerations, feelings about e-bike adoption, e-bike user anxiety, and travel purposes.

The results of the Generalised Linear Model show that future e-bike adoption is significantly associated with the household ownership of various sorts of vehicles. E-bike ownership has the greatest influence and plays a positive role. The ownership of bicycles also increases the probability of future e-bike adoption in the following years. By contrast, car ownership decreases the chances of e-bike adoption in the future. This may indicate that household members who have not achieved personal motorised mobility are more likely to use e-bikes, while household members who are accustomed to using cars are less likely to use e-bikes.

Concerning the effect of previously used travel modes, the respondents who previously adopted walking or buses expect to transfer to e-bikes in the following years, which is possibly due to a larger demand for personal motorised vehicles than before. In contrast, the e-bike users who previously travelled by metro are less likely to use e-bikes in the future. This could indicate that consumers are more satisfied with the service of the metro than buses. It is not surprising because the metro timetable is

highly reliable and generally, waiting time is also much less than buses. Therefore, if e-bikes are no longer used, it is more likely that e-bike users transfer to using the metro instead of the bus.

Now we investigate how future e-bike adoption time is affected by the time flexibility and the experience of freedom when riding e-bikes. Firstly, flexible travel time is an essential characteristic of personal motorised mobility, which produces “personalised, and subjective temporalities” (Urry, 2007), and allows motorised vehicle users to travel spontaneously rather than following the official timetable of buses and trains. The importance of travel time flexibility is also reflected in our survey: the respondents who agreed that e-bikes provide flexibility are more likely to continue to use e-bikes in the future. Secondly, another essential characteristic of personal motorised mobility is the experience of freedom. Compared with cars, e-bikes have lower requirements on the infrastructure conditions and do not need specific parking facilities as cars do. Furthermore, e-bikes can be used in a wider range of situations, such as on narrow or hilly roads and during traffic jams at peak times. Compared to bikes, e-bikes are more effort saving and this extends the travel range. If e-bike users feel independent when using e-bikes, the possibility of e-bike adoption for a longer period of time will increase.

As expected, the participants who held the opinion that e-bike development benefits the urban transport system are more likely to choose e-bikes as their future travel mode. In contrast, user anxiety is negatively associated with e-bike usage. The e-bike users who had accidents with other vehicles are especially unwilling to adopt e-bikes in the future. It is commented that the positive associations with usage are more individual and internal; for example, the feelings associated with e-bike usage. On the other hand, negative associations are more external and can be influenced through contextual change; for example, improving e-bike performance, and enhancing traffic safety awareness.

The models show that e-bike prices were positively associated with e-bike adoption. One explanation may be that the expensive e-bikes are normally of a better quality and exhibit better performances which fully satisfy the desire of consumers. For example, the scooter style e-bikes, the most expensive type, have a strong frame, a robust brake system, high speed and long battery life. Another reason may be that the respondents plan to use e-bikes for a long period of time, and therefore are motivated to invest in expensive e-bikes.

The trip purpose of e-bikes has a negative relationship with e-bike future adoption. If e-bikes are used mainly for commuting, the possibility of adopting e-bikes in the future is relatively small, probably because e-bikes confront the competition from other travel modes when commuting.

Without statistical significance, the factors such as gender, income, education, and trip time are precluded in the final model. That is, the future of e-bike adoption does not depend on the gender, income, or the educational level of the person.

7.3.2 The factors influencing the alternative travel mode choice

It is important to understand the impact on alternative travel modes if e-bikes were to be banned, as the transfer of modes will incur environmental costs and have mobility impact in the urban transport system. In our sample, the five alternative travel modes are chosen, including buses (39.2%), metro (37.3%), private cars (29%), walking (24.9%) and bicycles (22.9%), because they are the most popular ones. To understand the factors influencing the aforementioned alternative travel mode choices, each alternative mode is tested by a Binomial Generalised Linear Model to examine the relationship with the potential influence factors. The initial factors (independent

variables) entering the models include demographics, previous travel mode, attitude to e-bike adoption, and the reasons for alternative mode transformation, because these factors were thought to have impact on mode choices according to individual behaviour literatures (Handy, 1996; Hiscock et al., 2002; Srinivasan and Rogers, 2005; Devarasetty et al., 2012; Boschmann and Brady, 2013). However, according to the P value and ACI value, only the factors with significant correlation factors are kept and analysed finally. The relationship between each mode and these influencing factors are discussed below.

Bus

Number of observations = 403, ACI = 480.96, Likelihood Ratio=70.75, Pseudo R²=0.218				
Variable	Estimate	Std. Error	t value	Pr(> t)
(Intercept)	-1.22001	0.24334	-5.014	5.34e-07***
Income	-0.15946	0.07737	-2.061	0.039312*
Long trip distance	0.38240	0.17034	2.245	0.024771*
Previously used travel mode (bus)	0.79132	0.17230	4.593	4.37e-06***
Road condition is not suitable for e-bike	0.72400	0.19768	3.662	0.000250***
Request an accuracy of time	0.81026	0.21053	3.849	0.000119***
Demand of high accessibility	0.59011	0.17902	3.296	0.000979***

Significant. Codes : 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1

Table 7.3 Predicting the likelihood that current e-bike users will transfer to bus usage if e-bikes are unavailable

The dependent variable in this model is whether buses are the alternative choice (1=Yes, 0=No), when e-bikes are unavailable. Income is negatively associated with bus usage (Table 7.3). That is, the low cost of travelling with buses is a critical factor attracting lower income travellers, so the travellers with higher income are less likely to choose buses and are willing to pay more for a better transport service instead. Road conditions also have an influence on choosing buses. The worse the road condition is, the more likely it is that a consumer will choose to use the bus. Other factors positively associated with bus adoption include long trips, previous travelling experiences by bus, and a high demand of time requirement and accessibility.

Metro

The dependent variable for this Binomial Generalised Linear Model is whether the metro is the alternative choice (1=Yes, 0=No), when e-bikes are unavailable. The relationship between income and the probability of metro adoption is positive (Table 7.4), indicating that the travellers with a higher income tend to choose the metro. Consistent with this, the travellers who use e-bikes mainly due to their low cost are less likely to use the metro in the future.

Number of observations = 400, AIC = 448.15, Likelihood Ratio=100.56, Pseudo R²=0.304				
Variable	Estimate	Std. Error	t value	Pr(> t)
(Intercept)	-0.44456	0.26865	-1.655	0.097967 .
Income	0.12452	0.06944	1.793	0.072922 .
Demand of low operation cost	-0.31813	0.16140	-1.971	0.048723*
Request an accuracy of time	0.49310	0.19662	2.508	0.012146*
No time requirement	-0.73227	0.27305	-2.682	0.007323**
New metro stations added	0.54511	0.18336	2.973	0.002951**
Previously used travel mode (bus)	0.78801	0.14326	5.500	3.79e-08***
Previously used travel mode (car)	-0.74032	0.27575	-2.685	0.007258**
E-bike price	-0.20961	0.05403	-3.879	0.000105***
Household ownership of bikes	0.20827	0.09187	2.267	0.023389*
Physical discomfort	0.65347	0.21059	3.103	0.001915**

Significant. Codes : 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1

Table 7.4 Predicting the likelihood that current e-bike users will transfer to metro use if e-bikes are unavailable

The requirement of time accuracy also plays an important role in metro adoption. If a trip has a strict requirement on time accuracy, travellers are more likely to use the metro. Consequently, if there are more new metro stations built, the travellers are more likely to use the metro. So increasing the number of metro stations is an effective method for attracting prospective metro riders.

The e-bike users who previously used buses are more likely to transfer to using the

metro. This could be an indicator that the metro better fits travellers' demands than buses. In contrast, the respondents who previously used private cars are less likely to transfer to the metro, because the respondents who are accustomed to personal motorised vehicles have no preference for travel modes without travel flexibility. For the same reason, respondents with expensive e-bikes have fewer chances to transfer to metro. By contrast, the travellers who have bikes in their households are more likely to adopt metro use, especially when e-bikes are unavailable, indicating that the motorised transport is a future tendency. Furthermore, if respondents are physically uncomfortable, the probability of choosing the metro will increase. This could be because metro facilities better suit their needs.

Private cars

Number of observations = 396, AIC = 411.98, Likelihood Ratio=86.98, Pseudo R²=0.283				
Variable	Estimate	Std. Error	t value	Pr(> t)
(Intercept)	-3.016897	0.578781	-5.213	1.86e-07***
Gender (Female)	0.302403	0.150441	2.010	0.044419*
Age	0.694568	0.314618	2.208	0.027268*
Age²	-0.104303	0.045859	-2.274	0.022941*
Household ownership of cars	0.420522	0.119104	3.531	0.000414***
Previously used travel mode (walking)	0.302770	0.163433	1.853	0.063946 .
Previously used travel mode (car)	0.403878	0.238591	1.693	0.090500 .
Income increased	0.451054	0.160022	2.819	0.004822**
Trip time	0.008088	0.002744	2.948	0.003201**
Trip distance (short)	-0.605688	0.232945	-2.600	0.009319**
E-bike restriction police	0.485822	0.221792	2.190	0.028493*
Safety consideration	0.959678	0.248279	3.865	0.000111***
Demand of high accessibility	0.296126	0.162452	1.823	0.068326 .

Significant. Codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' Age²: *The square of Age*

Table 7.5 Predicting of the likelihood that current e-bike users will use private cars if e-bikes are unavailable

The dependent variable for this Binomial GLM is whether using a private car is the alternative choice (1=Yes, 0=No), when e-bikes are unavailable. The positive relationship with car usage is found in female e-bike users (Table 7.5), meaning that

female travellers have stronger intentions to transfer to using private cars.

It is noted that although female travellers presented a strong willingness to transfer to private car use, they may not actually take it into action, because there is a so-called value-action gap between the attitude and corresponding behaviour. The attitude-action gap has been found in various studies, especially in the sustainable consumption and behaviour studies. For example, Lane and Potter (2007) explored the consumer attitude-action gap in the adoption of cleaner vehicles in the UK. Olson (2013) uncovered the attribute trade-offs on green products preferences and choices to explain why the consumers with pro-green attitudes frequently buy traditional alternatives. The reason why the value-action gap exists is that there are numerous internal factors (*e.g.* motivation, emotion, awareness, values, attitudes, and knowledge) and external factors (*e.g.* economic, social and cultural) that affect behaviour and the reasons behind consumer choices and not only attitudes (Blake, 1999; Kollmuss and Agyeman, 2002; Mairesse, *et al.*, 2012). Other psycho-social factors, including the safety perception, and motives, also have a significant impact on travel behaviour (Pizam and Mansfeld, 1999; Cullinane, 2002; Hiscock *et al.*, 2002). Therefore, it is also possible for the value-action gap to occur in e-bike users when they have the intention to transfer to other travel modes, so the probability of female travellers shifting to private cars in the future would be less than what is predicted by the model.

In the model, the use of private cars is closely correlated with the safety concerns regarding e-bikes. E-bike users with greater safety concerns about e-bike are more likely to transfer to cars, meaning that they perceive that private cars are safer.

Age and age² (the square of age) are significantly associated with private car use, suggesting that the older the traveller is, the more likely he or she is to use cars. But up to a certain age, the trend is the opposite. The reason is that a large number of older citizens in China cannot drive because motorisation in China started very late.

As expected, the household ownership of cars is positively associated with car usage. Consistent with the effect of household ownership of cars, the travellers who previously adopted cars are more likely to use private cars, if e-bikes become unavailable. The result may indicate that private cars are the “expensive dream travel vehicle” for travellers.

Trip time is significantly positively related to private car adoption, indicating that the longer trip times or distances lead to a higher probability of choosing private cars. Other potential groups of e-bike uses inclined to transfer to car use are: 1) The respondents choosing e-bikes for high accessibility and 2) the ones who are worried about the future release of an e-bike restriction policy.

Walking

Number of observations = 397, AIC=399.53, Likelihood Ratio=75.13, Pseudo R²=0.254				
Variable	Estimate	Std. Error	t value	Pr(> t)
(Intercept)	-0.871374	0.501176	-1.739	0.082095
Income	-0.230349	0.099483	-2.315	0.020587*
Income increased	-0.511154	0.244762	-2.088	0.036764*
Walking (previously used travel mode)	0.421115	0.226280	1.861	0.062740.
Road condition is not suitable for e-bike	0.947014	0.235090	4.028	5.62 ^c -05***
E-bike price	0.246562	0.070663	3.489	0.000484***
Trip time	-0.023572	0.007059	-3.339	0.000840***
Request an accuracy of time	-0.774549	0.349270	-2.218	0.026581*
No time requirement	0.969219	0.330402	2.933	0.003352**
New bus routes added	0.633668	0.224947	2.817	0.004848**
Pro-e-bike attitude	-0.561309	0.244391	-2.297	0.021632*
Have traffic accidents using e-bikes	0.512976	0.207033	2.478	0.013221*

Significant. Codes : 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1

Table 7.6 Predicting of the likelihood that current e-bike users will transfer to walking if e-bikes are unavailable

The dependent variable for this Binomial Generalised Linear Model is whether

walking is the alternative choice (1=Yes, 0=No) if e-bikes are unavailable. Income enters the model with a negative sign, suggesting that the survey participants with higher incomes or high expectations for future income are less likely to choose walking as an alternative mode (Table 7.6). This may be because walking is the cheapest way to travel. It is also possible that these respondents with higher income are able to locate further from city centres in new housing developments, so walking ceases to be a viable option. So the respondents who previously travelled by walking are more likely to walk when e-bikes become unavailable.

If the respondents show a positive attitude towards e-bike development, they are less likely to choose walking. It is interesting that the participants who have more expensive e-bikes are more likely to transfer to walking in the future. A possible explanation is that the e-bikes with good performance satisfy users' travel demands, so they have no interest in other vehicles. But walking is a complement to e-bikes.

It is not surprising that trip time is negatively associated with walking, indicating that the shorter the trip time the more likely it is that respondents will choose to walk. But if the trip has a high requirement on the accuracy of time, the respondents are less likely to choose walking.

The result also shows that respondents are more likely to choose walking when new bus routes are added. This could be because respondents need to walk to bus stations. The result could be an indicator that urban transport mobility tends to be multimode.

However, taking into account the safety issues of using e-bikes, walking is more likely to be chosen. That is, if the respondents experience accidents when using e-bikes, they are more likely to choose walking. If road conditions are not suitable for e-bike travelling, this can also increase the number of people willing to transfer to walking.

Bicycle

The dependent variable for this Binomial Generalised Linear Model is whether bicycles are the alternative choice (1=Yes, 0=No), when e-bikes are unavailable. The e-bike users who previously adopted bicycles are more likely to transfer back to bicycles if e-bikes are unavailable (Table 7.7). From our model, the household ownership of bicycles enters the model with a positive sign, suggesting that the more bicycles owned by the household, the more likely it is that consumers will choose bicycles.

Number of observations = 397, AIC = 408.39, Likelihood Ratio=35.64, Pseudo R²=0.130				
Variable	Estimate	Std. Error	t value	Pr(> t)
(Intercept)	-1.5548	0.3524	-4.412	1.02e-05***
Household ownership of bicycles	0.2437	0.1152	2.115	0.03441*
Household ownership of cars	-0.3946	0.1984	-1.989	0.04673*
E-bike performance	0.6609	0.2481	2.664	0.00772**
E-bike price	-0.1284	0.0776	-1.654	0.09805.
Safety consideration	0.6384	0.2304	2.771	0.00559**
New metro stations added	0.4960	0.2580	1.922	0.05460.
Bicycle (previously used travel mode)	0.5581	0.2137	2.612	0.00901**

Significant. Codes : 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1

Table 7.7 Predicting the likelihood that current e-bike users will transfer to bicycle use if e-bikes are unavailable

By contrast, the households who own more cars are less likely to use bicycles, which agrees with our previous discussion that car users will continue to use cars in the future.

As expected, if the respondents are not satisfied with the e-bike performance, they tend to transfer to bicycle use. A parallel finding is that the more expensive e-bikes the respondents have, the less likely they are shift to bicycle use, because expensive e-bikes normally perform better and can satisfy users' requirements.

Interestingly, additional metro stations can promote bicycle use, indicating that they may be used to transfer to metro stations. So similar to walking, bicycles can also be a complement to public transport. Finally, safety concerns regarding e-bikes is positively associated with bicycle usage, which suggests that respondents believe that bicycles are safer than e-bikes.

7.4 Analysis

7.4.1 Comparison of influencing factors

Table 7.8 listed the factors which can influence mode choices. Firstly, as an important socio-demographic factor, age² has a significant relationship with travel behaviour. In our model, age² influences car use significantly. That is, the older the person is, the more likely he or she is to choose car use. But up to a certain point, he or she is less likely to choose car use, probably indicating that older citizens are unwilling to adopt new technology or accept driving training. Cherry and Cervero (2007) found a similar relationship between respondent age and e-bikes. Their e-bike future adoption model suggested that e-bike usage increases with age up to certain point and then decreases. Other travel behaviour studies also reveal that there exists a significant difference between young travellers and old travellers from theoretical perspectives (Newbold *et al.*, 2005; Boschmann and Brady, 2013).

	E-bike	Bus	Metro	Car	Walking	Bicycle
Gender (Female)	N	N	N	+	N	N
Age	+	N	N	+	N	N
Age²	-	N	N	-	N	N
Income	N	-	+	N	-	N
Income increased	N	N	N	+	-	N
Household ownership of e-bikes	+	N	N	N	N	N
Household ownership of bicycles	+	N	+	N	N	+

	E-bike	Bus	Metro	Car	Walking	Bicycle
Household ownership of cars	-	N	N	+	N	-
Pro-e-bike attitude	+	N	N	N	-	N
Have accidents (1 if have accident, 0 otherwise)	-	N	N	N	+	N
Safety consideration	N	N	N	+	N	+
E-bike Price	+	N	-	N	+	-
Road condition is not suitable for e-bike	N	+	N	N	+	N
Long trip distance	N	+	N	N	N	N
Short trip distance	N	N	N	-	N	N
Trip time	N	N	N	+	N	N
Request an accuracy of time	N	+	+	N	-	N
No time requirement	N	N	-	N	+	N
Demand of high accessibility	N	+	N	+	N	N
Demand of low operation cost	N	N	-	N	N	N
E-bike performance	N	N	N	N	N	+
New metro stations added	N	N	+	N	N	+
New bus routes added	N	N	N	N	+	N
E-bike restriction police	N	N	N	+	N	N
Physical discomfort	N	N	+	N	N	N
Commute (travel purpose)	-	N	N	N	N	N
Flexible time (reason of e-bike adoption)	+	N	N	N	N	N
E-bike tends to be out of work during use (user anxiety)	-	N	N	N	N	N
The feeling of freedom	+	N	N	N	N	N
Bus (previous travel mode)	+	+	+	N	N	N
Metro (previous travel mode)	-	N	N	N	N	N
Car (previous travel mode)	N	N	-	+	N	N
Walking (previous travel mode)	+	N	N	+	+	N
Bicycle (previous travel mode)	N	N	N	N	N	+

“+” positive sign, “-” negative sign, “N” no relationship; Age²: The square of Age

Table 7.8 The influence factors of travel mode choice behaviour

Income seems to influence the travel mode choice significantly. Income is significantly related to travel mode choices in our model. Travellers with higher income tend to use more expensive travel modes, such as metro and cars. Our conclusion is also supported by the travel behaviour research of Dieleman *et al.* (2002), who has similar finding that the higher the household income, the more likely

it is that they use cars in their travel behaviour research. However, the statistically significant relationship between income and mode choice was not found by Cherry and Cervero (2007). Our study further revealed that people with high expectations for future income tend to buy private cars. The result reinforces the automobility culture of China that the car is a symbol of wealth, whereas other vehicle users are identified as less wealthy or from a poor educational background.

The households in China tend to have more than one type of vehicle. In our sample, nearly 50% of e-bike users have both e-bikes and cars in their households, and nearly 80% of car drivers have e-bikes in their households. This may indicate that the respondents who have both e-bikes and cars are likely to adopt e-bikes. Hence, e-bikes and cars can complement each other for a better motorised mobility.

According to the previous travel behaviour research (Handy, 1996; Cervero, 2002; Naess, 2003; Naess and Jensen, 2004; Srinivasan and Rogers, 2005), the infrastructure construction of public transport has a significant impact on mode choice behaviour. Our research results also fit their observations. In our research, newly added metro or bus routes do not only increase the probability of using public transport, but also increase the chances of bicycle adoption and walking. This result may suggest that the door-to-door service of e-bikes could be partly replaced by the combined use of bicycles and metro routes. However, in the bike future use predictive model by Cherry and Cervero (2007), the factor of infrastructure construction of public transport was not considered.

In this study, trip time requirement has an extensive influence on travel behaviour. For the same trip length, if an accurate time is required, buses and the metro are more likely to be chosen. In the opposite situation, walking is more likely. In addition, if a trip is not urgent, travellers tend to choose slow speed transport mode. If it is an urgent trip, travellers tend to choose fast speed transport mode. The trip time

requirement has not been considered in other e-bike mode choice study. This finding is different from Cherry and Cervero (2007) who conducted a Logit model to examine the factors which have an impact on the mode choice. Their model did not consider the trip time accuracy requirement, but only took into account the travel time gap between e-bikes and bicycles as the independent variable. They suggested that the wider the travel time gap between e-bikes and bicycles, the more likely it is that people will choose e-bikes (Cherry and Cervero, 2007). In addition, the longer the travel time of a particular mode, the lower the probability of choosing that mode is (Cherry and Cervero, 2007). However, the trip time requirements affect the mode choice to a greater degree than actual trip time.

Our study also fits utility-maximising rules. Generally, a traveller chooses the suitable travel mode according to the opportunity cost of the time that was spent on the journey. In our models, when the trip has no time requirement, a traveller is more likely to walk to the destination. If the trip is urgent, a traveller has a strong desire to save time and thus will choose a more expensive but faster travel mode. In addition, our model also fits the income effect, which is defined as a common phenomenon that the price change in consumption results in the change of the consumer's real income, and then the consumer purchases more or less products until a new equilibrium is reached again for the real income (Deaton and Muellbauer, 1980). In our study, the lower the income of the traveller, the more he or she is to use buses or to walk rather than using a car, which suggests that they are sensitive to the price and will choose basic travel services which match their income level. As income grows, a traveller will pay more for the travel service with better quality; for example, the metro or a car, so the price of the transport modes can stay in equilibrium.

Safety issues influence travel mode choice behaviour as an important psycho-social factor. If e-bike users are sensitive to traffic safety problems, or experienced accidents before, they are less likely to use e-bikes, and are more likely to travel by walking,

bicycles and cars. Sönmez and Graefe (1998) found that perceptions of risk and safety from past travel experience is significantly associated with future travel behaviour by applying information integration theory, protection motivation theory, and logic regression. Their result concluded that perceptions of safety from past travel experience increased the probability to travel there again, while the perceptions of risk from past travel experience decreased the probability to travel (Sönmez and Graefe, 1998). Compared to the previous literature, which performed qualitative analysis on safety issues, our study incorporated the safety factor to the regression models of e-bike mode choice for quantitative analysis.

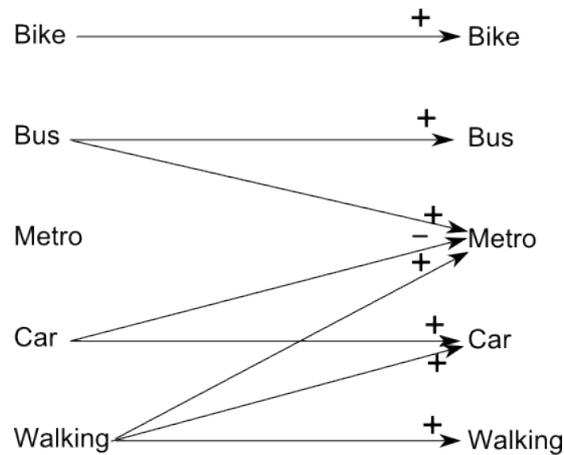


Figure 7.5 Travel mode transition flow when e-bikes are unavailable

In addition, it is found that the e-bike experience can change people's inclination for using alternative modes, as illustrated in Figure 7.5. One is a positive relationship between the previous and future travel mode choices. The travellers who previously travelled by bicycle are more likely to shift to bicycle use in the absence of e-bikes. The similar trends are also found in e-bike users who previously used buses, cars and walking. The other one is the tendency to transfer to metro and private car use. Pedestrians and those who previously travelled by bus are more likely to transfer to the metro use. In addition, the travellers who previously walked exhibited a great demand for car adoption. The result implies an increasing demand for faster speed vehicles. The experience of e-bike adoption partly changed the future choice of travel

modes.

7.4.2 Gender differences in future mode choices

The future travel model choices of female and male e-bike users are influenced by different e-bike usage experiences. This gender difference is embodied in the future adoption of motorcycles and private cars, but not found in the future choices of buses, walking, bicycles, and metro (Table 7.9).

	Bicycle		Total		Motorcycle *		Total		Walking		Total
	Yes	No			Yes	No			Yes	No	
M	43	168	215	M	28	215	212	M	51	164	215
	21.9%	78.1%	100%		13.1%	86.9	100%		23.8%	76.2%	100%
F	43	175	178	F	13	165	185	F	47	131	178
	24.2%	75.8%	100%		7.4%	92.6%	100%		26.6%	73.5%	100%
Total	90	303	393	Total	41	352	397	Total	98	252	393
	22.9%	77.1%	100%		10.4%	89.6%	100%		24.9%	75.1%	100%
X ² =0.175, p-value=0.6757			X ² = 2.825, p-value= 0.0928				X ² =0.325, p-value= 0.540				
	Bus		Total		Metro		Total		Private cars※		Total
	Yes	No			Yes	No			Yes	No	
M	86	129	215	M	73	142	215	M	51	164	215
	40.0%	60.0%	100%		34.0%	66.0%	100%		23.8%	76.2%	100%
F	68	110	178	F	73	105	178	F	63	115	178
	38.3%	61.7%	100%		41.1%	58.9%	100%		35.4%	64.4%	100%
Total	154	239	393	Total	146	247	393	Total	114	279	393
	39.2%	60.8%	100%		37.2%	62.8%	100%		29.0%	71.0%	100%
X ² =0.132, p-value=0.79579			X ² = 2.077, p-value=0.14963				X ² = 6.443, p-value=0.0111				

M: Male; F: Female; ※: p-value <0.05; *: p-value<0.1

Table 7.9 Chi-squared test results of alternative travel modes

The significant difference between female and male e-bike users in terms of future motorcycle choice is similar to the gender differences in the previous motorcycle adoption: the percentage of male respondents (13.1%) is more than female respondents (7.4%).

The gender differences in future private car choice are especially significant. 35.4% of female e-bike users are willing to shift to using private cars in the absence of e-bikes, while only 10.7% of them previously travelled by private cars. In comparison, fewer male e-bike users (23.8%) will shift to private cars in the future. The result is also supported by the prediction of our Binomial Generalised Linear Model that female respondents are significantly positively related to private car use.

7.4.3 Future transition of e-bikes

E-bikes may serve as an intermediate mode in Nanjing's motorisation pathway because e-bikes are weakly embedded in the future transport regime. The first reason is that many respondents are willing to shift to private cars with an increase in income according to our survey results. In addition to practical usage considerations, this is also closely related to the automobility culture in China. A car user is normally viewed as a person with wealth and a well-educated background. In contrast, the current symbolism and social connotation of e-bikes is that e-bikes users are identified as "poor, not well-educated" (Tyfield, 2014). However, it should be pointed out that the above negative opinions on e-bike users are not completely consistent with the facts. For example, our survey reveals that the average education and income level of the e-bike users is much higher than the overall average level of Nanjing City. 63.57% of e-bike users have obtained a college degree or above, and 45.23% of e-bike users have completed a university degree. 87.6 of the e-bike users are employed and their income is in a higher-middle range. Nevertheless, such a negative impression of e-bikes in the public domain is hard to change in a short time, so it will be likely to influence the future choice of e-bikes and profoundly shape the trajectory of socio-technical transition. Secondly, the possible e-bike restrictions and bans policy bring more uncertainties to the future of e-bikes.

7.5 Conclusion

The Chapter used the data collected from the survey in Nanjing to explore the research question how much longer e-bikes can continue to be embedded in the transport regime (RQ4). The analysis is based on MLP and some theories on travel behaviours.

The Generalised Linear Model predicts the choice of future e-bike adoption. User attitudes, demographics, safety issues, and user anxiety about battery performance are all significant factors that influence travel mode choice in the Generalised Linear Models and Binomial Generalised Linear Models. The probability of choosing e-bikes is positively associated with the household ownership of e-bikes, the household ownership of bicycles, the cost of e-bikes, a feeling of freedom, pro-e-bike attitudes, and the demand for flexible trip times, while the negative factors are the household ownership of cars, user anxiety about e-bike performance, and experience of accidents.

If an “e-bike ban policy” is issued, the possible alternative modes are ranked as follows: buses, the metro, private cars, walking and bicycles. Hence, the public transportation will be subject to a great transportation pressure. The Binomial Generalised Linear Model shows that the alternative mode choice is significantly related to income. The lower income respondents tend to use buses or will walk, while higher income respondents prefer to use the metro and private cars. If the trip requires an accuracy of time, the respondents are more likely to choose motorised vehicles. If the trip has no time requirement, the respondents are more likely to choose slower and cheaper travel modes, such as walking. New metro stations will increase the likelihood of choosing to use the metro and bicycles. New bus routes will increase the chances of adopting walking as a mode of transport. Participants with high expectations for future income increase tend to buy private cars, which suggests that

the e-bike is highly possible to become an intermediate mode to cars in terms of personal mobility vehicle choice.

Chapter 8

Conclusion

8.1 Responses to research questions

The thesis investigated the e-bike socio-technical transition phenomenon in China, using an abductive case study approach, which includes three research units (China, Beijing, Fuzhou) based on the secondary data and one substantive case study (Nanjing) based on primary data collected from survey questionnaires. The thesis analysed the e-bike industry and policy in China, following up with the historical analysis of the e-bike transition process. It concluded that e-bikes spontaneously emerged in China, which is not a result of direct and purposive policy support. The e-bike transition pathways are identified. After that, the survey questionnaire results were discussed in order to understand how e-bikes are embedded in the current and future transport regime and the underlying mechanisms behind e-bike transition. The answers to the research questions posed in Chapter One (Introduction) are as follows:

RQ1. Can socio-technical transition occur without deliberate policy support?

Through the overview of the top three e-bike production regions, namely, Tianjin, Zhejiang, and Jiangsu, and more importantly, an analysis of the e-bike transition in China using transition theory, it is found that the emergence of e-bikes in China is spontaneous without positive, purposive policy intervention. In the application of transition theory, the Multi-Level Perspective (MLP) is applied to examine the e-bike transition phenomenon, because it provides a useful analytical framework for understanding the complicated socio-technology transition process. From a national level, the “Electric Bicycle--General Technical Requirements” issued in 1999 clarified the definition of e-bikes, and the “Road Safety Law” issued by the NPC in 2004 rendered e-bikes a legal status as non-motorised vehicles. However, no policy was issued to directly support the e-bike industry development from central governments. Moreover, some local governments have a negative policy

intervention for e-bike development.

RQ2. How can we explain the rapid emergence and enduring popularity of e-bikes in China?

The MLP was used to analyse a wide range of transition processes, but it does not provide clear information about the spatial dimensions of understanding socio-technical transition, which could be problematic when put into practice, especially for the case of China which has a heterogeneous geography and complicated policy structures. In order to overcome this problem, the Multi-scalar MLP is applied in this thesis, dividing China into three scales which vary according to spatial dimension, culture consideration and policy structure: macro-level (the entire nation), meso-level (provinces), and micro-level (cities). In addition, the transition pathways in the MLP are identified to examine the e-bike transition process in China.

On macro-level, there are two transition pathways: the transformation pathway (P1) (1980–1999), and the de-alignment and re-alignment pathway (P2) (1999 onwards). On the transformation pathway, e-bikes stayed on the niche level due to immature technology and weak customer service. On the de-alignment and re-alignment pathway, a window of opportunity is created by landscape pressures and e-bike technology development. The landscape pressures arose from the fact that the motorcycle industry did not gain government support any longer and e-bikes were legally approved to travel on bicycle lanes in 2003.

In addition, on the micro-level (Beijing and Fuzhou), the e-bike transition process also followed the P1 and P2 pathways. The landscape pressure was from e-bike bans released by local governments. Beijing initially proposed an e-bike ban policy in 2002, and then lifted it in 2006 due to pressure from outside criticism and the increasing demand for personal motorised mobility. Fuzhou initially issued a ban on the sale of e-bikes in 2001 by the Public Security Department. The e-bike ban policy was lifted because e-bike users sued the government, but the Fuzhou government banned e-bikes again in 2003. This ban policy was lifted in 2007 due to outside criticism and the fact that Beijing had lifted its e-bike ban policy the previous year. After lifting the e-bike bans, e-bike sales increased very quickly in these two cities.

RQ3. How are e-bikes embedded in the current transport regime?

More than 1,000 survey questionnaires were conducted to collect substantial data about the e-bike transition process. Before the survey, semi-structured interviews were conducted as Exploratory Research and the results were used to help design the questionnaires in the survey. The participants of the survey questionnaires were e-bike users, bicycle users, car drivers, pedestrians, and traffic police. The questions in the survey covered a wide range of categories, including the demographics of e-bike users, the current e-bike adoption status, e-bike mode choice reasons, non-e-bike users and traffic police officers' attitudes towards e-bike development.

The survey results show that e-bike users are mainly young career-aged commuters and have a much higher average education level than the overall population of Nanjing city. The majority of e-bike users in Nanjing adopt hybrid style e-bikes equipped with lead-acid batteries. Following the data analysis, the result reinforces a conclusion that e-bikes have already reached the current transport regimes. In addition, e-bikes seem to be well embedded in the current transport regime. Two reasons can explain this. Firstly, the attitudes of the citizens to e-bike rapid development (car drivers, pedestrians, bicycle users, and traffic police) are generally positive. In particular, the majority of respondents highly commended the convenience of e-bikes. Secondly, e-bikes have been as widely adopted in many aspects of people's daily life settings, including commuting, going shopping, and picking up children, as other transport modes in the regime level such as buses, metro, bicycles and walking.

RQ4. How much longer can e-bikes continue to be embedded in the transport regime?

To study the future model choice behaviour of e-bike users, the Generalised Linear Model (GLM) and Binomial GLM are utilised to analyse the survey data. The probability of choosing e-bikes is positively related to the household ownership of e-bikes and ordinary bicycles, e-bike prices, the feelings of freedom associated with e-bikes, positive attitudes towards e-bikes and a demand for flexible trip times. The household ownership of cars, user anxiety of e-bike performance, and experience of accidents are negatively related.

If an "e-bike ban policy" is issued widely, buses, the metro, private cars, walking and bicycles are possible alternative modes. The results of the Binomial GLM show that the alternative mode choice is significantly related to income. The respondents with lower

incomes tend to walk and use buses, while higher income respondents prefer the metro and private cars. If the trip has no time requirements, the respondents are more likely to choose slow and cheaper travel modes, such as walking. There is also a strong demand for private cars.

Although e-bikes have already developed to a large scale, they are still weakly embedded in the future transport regime, which may serve as an intermediate mode on Nanjing's motorisation pathway. E-bikes can be easily replaced by buses, the metro, bicycles and walking. In particular, e-bike users appear to transfer to using cars if their income increases. Many local governments have already proposed an e-bike ban policy (e.g. Guangzhou, and Shenzhen). Last but not least, e-bikes would be blocked by an existing transport regime dominated by cars and bicycles.

RQ5. What are the mechanisms underlying the rapid emergence of e-bikes?

As mentioned above, e-bike users in China are mainly young career-aged commuters. In the survey results, e-bikes are mainly used for commuting and picking up children. The main reasons for selecting e-bikes are effort saving, flexible trip times, time saving in traffic jams, and high accessibility, but the influence from advantages such as being environmentally friendly and healthy is negligible. Moreover, the primary feelings associated with e-bike adoption are freedom and practical usage. Therefore, e-bike adoption is able to achieve personal mobility. Besides, e-bikes increase the travel distance and travel frequency regardless of regional difference, which indicates that e-bikes adapt well to urbanisation and various travel purposes. Furthermore, e-bikes have low purchase and operation costs, and therefore are treated as an affordable personal mobility, perfectly matching the demands of young career-aged commuters. This is the underlying reason for the e-bike's spontaneous emergence.

8.2 The contribution of the thesis to the literature

8.2.1 Theoretical aspect

1) The traditional MLP framework did not consider the spatial dimensions of socio-technical

transition. However, due to the large population and area of China, the e-bike transition is a complicated process, influenced by the heterogeneous geography and policy structures. To address this problem, the thesis adopted the MLP in the Multi-scalar manner to study the e-bike transition in different geography and policy hierarchies. The idea of multi-scalar MLP was proposed in previous literature, but it is only limited to be a concept and did not provide a guideline to explicitly distinguish the scalars in the national context. It is the first time that Multi-scalar MLP is applied to analyse a transition process and the scalars are specified correspondingly.

2) Most of the MLP literature focuses on the policy support for sustainable mobility transition. However, successful e-bike transition in China occurs without deliberate policy intervention, which would be inspiring in the MLP studies. It is noteworthy that although policy has not played a supportive role in e-bike transition up until now and potentially even hindered it, policy is a key to e-bikes' future embeddedness in China according to RQ4 findings.

3) Most transitions take a long time (*e.g.* sailing ship to steam ship takes 70 years). In comparison, it has taken less than 20 years for e-bikes to enter the regime in China. The short time dimension of socio-technical transition is also an important finding.

4) The MLP mainly focuses on institutional organisations but lacks an understanding about how behavioural-institutional change occurs. It does not pay the attention to the issues of individual impacts on the socio-technical transition. This gap is filled by this study, where 1,053 questionnaires in Nanjing city are used to provide a comprehensive study of e-bike use patterns, charging patterns, other mode users' attitudes, and e-bike regulations in China, and the individual mode choice and travel behaviours are examined by value-action gap theory and utility-maximising theory.

8.2.2 Empirical aspect

The previous e-bike research did not convey sufficient information about e-bike status, and moreover, lacks the knowledge of charging use patterns and the interactions between e-bike users and other vehicle users. To fill this gap, the thesis has some contributions from an empirical aspect:

- 1) To the best of the author's knowledge, it is the first time to use transition theory to study the e-bike transition process.
- 2) The thesis includes a wide range of travel mode users, including e-bike users, bike users, car drivers, and pedestrians. In addition, our study invited traffic police who were not considered in the previous e-bike literature.
- 3) This study covers many topics that have not been addressed in the previous literature, such as e-bike users' anxieties, feelings associated with e-bike adoption, charging behaviours, the attitudes towards e-bike transition, and the suggestions on e-bike future development, *etc.*
- 4) There are three contributions of our quantitative work on mode choices. Firstly, our model tested a wide range of factors influencing travel mode choices which have not been considered in previous e-bike studies, including previously used travel modes, e-bike price, safety considerations, feelings associated with e-bike adoption, e-bike user anxiety, and travel purposes. Secondly, the factors influencing other alternative mode choices to e-bikes are tested in our study, which were not considered in the e-bike studies.

8.3 E-bike transitions and policy recommendations outside China

In the social science research area, e-bike study themes are different between China and other countries due to the inequality of e-bike development. In terms of the environmental impact, the e-bike industry in China faces issues related to lead-acid pollution and electricity generation, while many countries treat e-bikes as a sustainable transport method. In the safety studies, running red lights is the main traffic violation behaviour in China, while high speed is the main problem in other countries and areas. The health study in China provides very limited information, whereas in other countries it has been proven that e-bikes can increase physical activity. There are some evidences of e-bike crash data and injury data in China, but very little information from other countries and areas. These differences suggest that e-bikes in other countries are still in the niche market. It seems that e-bikes have a more positive impact in other countries, because e-bikes are treated as a sustainable form of transport to

provide clean mobility and improve health.

Although there are differences between China and other countries due to the inequality of the e-bike development, the e-bike transition experience in China provides some valuable recommendations. Because of the wide adoption of “non-standard” e-bikes, many cities in China have started to issue “e-bike ban” policies. One reason for this is that the national standard for e-bikes has not been updated since 1999, which ignores the changes of consumer demand and technology development. In this case, it is strongly recommended that the e-bike standard is updated in order to keep pace with technology development and market demand, especially, the technology requirements, including maximum speed, maximum weight, and charging systems. In addition, the survey result of this study shows that batteries are a barrier to e-bike development. Therefore, accelerating battery technology development is recommended in order to promote e-bike development. Furthermore, safety issues are the main concern related to e-bike adoption in China. Enhancing the safety awareness of all transport mode users is recommended. It is also worth clarifying these rules for e-bike users.

Although e-bikes have been on the market in the Netherlands, German, Japan, and India, there is little information about e-bike market in these countries; for example, who buys e-bikes, e-bike prices, and popular e-bike types. Clarifying this information would help to identify the needs of e-bikes, which would benefit the import of proper e-bike products and shape their design.

8.4 Limitation and Future work

8.4.1 Empirical Development

1. Sample of the survey

The sample can be more representative if the survey locations can cover a wide range of suburb or rural areas. Furthermore, it is more beneficial to the survey quality if public transport users are included in the survey in Nanjing.

2. Policy makers

The e-bike transition in China was not directly supported by policy makers. How can we change this situation? More could also be done to understand why policy so strongly favoured New Energy Vehicles (cars) in China but did not attach this importance to e-bikes even though they have more mature technology and practical usage. This research did not include the views of policy makers. In the future it would be helpful to include such views.

3. Environmental performance

Environmental performance is mainly concerned with e-bike batteries. But it is also helpful to investigate the full life cycle impact of e-bikes in different contexts and settings.

4. E-bike industry

The industry itself has been neglected, in China and in other countries. Nonetheless, some significant companies are now involved in the e-bike market, *e.g.* Giant and Bosch and others in the EU and USA. The non-car battery electric vehicle market is growing rapidly, with myriad new applications. It would be helpful to understand more fully the overall economics of the e-bike industry, as well as technology development and competition issues.

5. Interactions/synergies between e-bikes and other transport modes

Interactions between e-bikes and other transport modes, especially public transport, should be explored. One example is how travellers choose different transport modes depending on their trips. If more travellers use e-bikes, is it possible to mitigate crowded public transport? In addition, along with other transport mode developments, how do e-bikes incorporate the technologies from other types of vehicles and improve themselves?

8.4.2 New theoretical aspects

1. Spatial dynamics of mobility transitions, especially in an urban setting. It is notable that in the time period that e-bike use has grown substantially in China, there has been a parallel

process of urbanisation that may explain some of this growth in use.

2. What happens to “residual” forms of mobility as new niches emerge and the regime is displaced? For example, we still see sailing ships in use, but as leisure activities and not as practical transport tools. Is this the future for motorbikes, or petrol/diesel cars?

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Appendix A

Research Ethics Approval

STANDARD ETHICAL APPROVAL FORM

This form should be completed for every research project that involves human participants. It can also be used to identify whether a full application for ethics approval needs to be submitted. The researcher or, where the researcher is a student, the supervisor, is responsible for exercising appropriate professional judgement in this review. This checklist must be completed before potential participants are approached to take part in any research.

SECTION 1 - RESEARCH CHECKLIST

1.1	Does the study involve holding personal information (names, attributable information or personal identifiers of any form) on a database?	YES
1.2	Does the study involve participants who are particularly vulnerable or unable to give free and informed consent (children, people with learning disabilities, students in academically dependent relationships)?	NO
1.3	Will it be necessary for participants to take part in the study without their full knowledge and explicit consent (perhaps through covert observation)?	NO
1.4	Will the study involve discussion of sensitive topics (political or religious views, illegal activities, sexual activity, drug use and so forth) that could be uncomfortable to participants or harmful if divulged to others?	NO
1.5	Will the study involve potentially harmful procedures of any kind or be conducted in a hazardous environment that could expose the researchers or participants to higher risk than is encountered in normal life? http://www.cf.ac.uk/osheu/index.html	NO
1.6	Will financial inducements (cash, vouchers or a prize draws) be offered to participants?	NO
1.7	Will the study involve patients or patient data in the NHS?	NO

If you have answered 'NO' to all questions 1.1 to 1.7 above, please complete this form and submit TWO copies to Lainey Clayton in room F43. Both forms will be stamped as evidence of submission. One copy will be retained by the School for audit/office purposes and the other by the researcher/s. Undergraduate and postgraduate students should include/bind their copy of the form with their research report or dissertation.

If you have answered 'YES' to any of the questions above, you will need to complete a full ethical review form (ETHICS 2, available on Learning Central CARBS RESEARCH ETHICS)

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Ethical form 2

**FULL ETHICAL APPROVAL FORM (STAFF/PhD STUDENTS) or students
referring their form for a full ethical review**

(For guidance on how to complete this form, please see Learning Central – CARBS RESEARCH ETHICS)

If your research will involve patients or patient data in the NHS then you should secure approval from the NHS National Research Ethics Service. Online applications are available on <http://www.nres.npsa.nhs.uk/applicants/>

Name of Lead Researcher: Xiao Lin

School: Business School

Email: linx8@cf.ac.uk

Names of other Researchers:

Email addresses of other Researchers :

Title of Project: The future prospect of electric bicycles in sustainable mobility in China

Start and Estimated End Date of Project: 10/2011--10/2015

Aims and Objectives of the Research Project: The traditional mobility way depends on the fuel to a great extent, which leads to a large amount of energy cost and hazardous to the environment. A promising alternative substituting fuel-based mobility tools is e-bikes, which have developed spontaneously in China and exhibited huge potential for its energy-saving and environment-friendly features. However, e-bike has not drawn sufficient attention from academic and government as it deserves. It is urgent to understand why and how e-bikes developed in China, so that to further boost its development. Our research is intended to fill this gap, and the research result can provide a basis on which the consumers, manufactures, and policy makers can take corresponding measures to switch to a sustainable mobility way. Moreover, due to the complexity of the situations in China, the research possess important theoretical significance in the areas of , for example, transition theory, automobility culture, and the

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business models, which will inspire and benefit similar research in other countries and industry sectors.

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Please indicate any sources of funding for this project: Self-funded

1. Describe the methodology to be applied in the project

Following a case study approach, this study is the main stage of my whole research in terms of data collection. There are two main aims of the research. The one is to investigate e-bikes users' characteristic and their mode choice behavior in order to understand how e-bike embedded in users' daily life. The other aim is to understand pedestrians, motorists and traffic polices' attitude to rapid e-bike development. Targeted case study cities are Nanjing and Jiujiang. Data collection method used is survey and interview. More specifically, face-to-face questionnaire and unstructured interview will be mainly used and supplemented by online questionnaire and telephone interview. Additionally, secondary data such as organisation and policy documentation also will be collected throughout the data collection period.

PLEASE ATTACH COPIES OF QUESTIONNAIRES OR INTERVIEW TOPIC GUIDES TO THIS APPLICATION

2. Describe the participant sample who will be contacted for this Research Project. You need to consider the number of participants, their age, gender, recruitment methods and exclusion/inclusion criteria

Targeted participants of the survey involve e-bike users, pedestrians, motorists, and traffic polices. The sample size for participants is estimated to be 600 (e-bike users), 300 (pedestrians), 300(motorists), and 100 (traffic polices). Recruitment methods mainly include personal networking and intercept survey. The surveyed activity centres include bike parking, car parking and shopping malls thought out the urban area. The e-bike users, pedestrians and motorists will be selected between 18 to 70 years old, including different sex, salary level, education background, and occupation. The inclusion criteria of traffic police should be that they have e-bike related duties.

Targeted participants of the interview involve e-bike retailers and manufacturers. The sample size for participants is estimated to be 20. Recruitment methods mainly include personal. Both phone call and

email will be used to gain access. The gender and age are not likely arising ethical issues as these information are not important in the research. Targeted participants should be familiar with the local e-bike market.

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3. Describe the method by which you intend to gain consent from participants.

Personal networking is the main method used to access potential participants. In addition, potential participants also will be accessed through email and phone. Both the consent form and approval form will be emailed or faxed. Also, separate cover letters will explain the purposes of the research and how the interview is conducted. For all potential interviewees, they will be informed that their participation is voluntary and they are free to ask any questions that related to this research.

PLEASE ATTACH A COPY OF ALL INFORMATION WHICH WILL BE GIVEN TO PROSPECTIVE PARTICIPANTS (including invitation letter, briefing documents and, if appropriate, the consent form you will be using).

4. Please make a clear and concise statement of the ethical and health and safety considerations - <http://www.cf.ac.uk/osheu/index.html> - raised by the project and how you intend to deal with them (please use additional sheets where necessary)

The ethical issues in this research include anonymity, privacy and confidentiality which follow the guidance of Cardiff Business School Research Ethics, ASA's guidelines. Identification of participants will be anonymously given. The privacy of the correspondents will be respected and protected. We will provide an agreement and guaranteed it is clear enough to be fully understood by participants. Also, if the interviews are recorded, it will be approved by interviewees. The confidentiality of the data will be kept in safety, and electronic data will be encrypted.

STUDENTS SHOULD BIND THE SIGNED AND APPROVED FORM INTO THEIR REPORT, DISSERTATION OR THESIS

Please complete the following in relation to your research project.

		Yes	No	n/a
(a)	Will you describe the main details of the research process to participants in advance, so that they are informed about what to expect?	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
(b)	Will you tell participants that their participation is voluntary?	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
(c)	Will you obtain written consent for participation?	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
(d)	Will you tell participants that they may withdraw from the research at any time and for any reason?	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
(e)	If you are using a questionnaire, will you give participants the option of omitting questions they do not want to answer?	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
(f)	Will you tell participants that their data will be treated with full confidentiality and that, if published, it will not be identifiable as theirs?	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
(g)	Will you offer to send participants findings from the research (e.g. copies of publications arising from the research)?	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
(h)	If working with children and young people please confirm that you have given due consideration to University guidance available at: http://www.cardiff.ac.uk/govrn/cocom/resources/2010%20November%20Safeguarding%20Children%20&%20VA's.doc	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>

PLEASE NOTE:

If you have ticked **No** to any of 5(a) to 5(g), please give an explanation on a separate sheet.

(Note: N/A = not applicable)

There is an obligation on the principal researcher/student to bring to the attention of Cardiff Business School Ethics Committee any issues with ethical implications not clearly covered by the above checklist.

Signed: 
(Principal Researcher/Student)

Print Name: Xiao Lin

Date: 28/04/2014

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SUPERVISOR'S DECLARATION (Student researchers only): As the supervisor for this student project I confirm that I believe that all research ethical issues have been dealt with in accordance with University policy and the research ethics guidelines of the relevant professional organisation.

Signed:



Print Name: Peter Wells

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CARDIFF UNIVERSITY

Date: 28/04/2014

*TWO copies of this form (and attachments) MUST BE OFFICIALLY STAMPED by
Ms Lainey Clayton, Room F43, Cardiff Business School*

STATEMENT OF ETHICAL APPROVAL

This project has been considered using agreed School procedures and is now approved.

Official stamp of approval of the
School Research Ethics Committee:

Date:

28/4/2014

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Consent Form

CARDIFF BUSINESS SCHOOL RESEARCH ETHICS

The study that I involved is on understanding the e-bikes development in China. The aim of this research is to explore the reasons why the rapid development of e-bikes happens in China. And the findings of this study will give an alternative transport model to develop a sustainable mobility in China.

I understand that my participation in this project will involve completing questionnaires and semi-structured interview about the attitudes toward using e-bike which require approximately 20 minutes of my time.

I understand that participation in this study is entirely voluntary and that I can withdraw from the study at any time without giving a reason.

I understand that I am free to ask any questions at any time. If for any reason I have second thoughts about my participation in this project, I am free to withdraw or discuss my concerns with Professor Peter Wells (wellspe@cf.ac.uk).

I understand that the information provided by me will be held confidentially and securely, such that only the researcher can trace this information back to me individually. The information will be retained for up to one year and will then be anonymised, deleted or destroyed. I understand that if I withdraw my consent I can ask for the information I have provided to be anonymised/deleted/destroyed in accordance with the Data Protection Act 1998.

I, _____ consent to participate in the study conducted by the PHD student, Xiao LIN (linxiao.lin@gmail.com), of Cardiff Business School, Cardiff University, under the supervision of Professor Peter Wells.

Signed:

Date:

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Informed Consent Declaration – For Interviewees

This study is being conducted by Xiao LIN (PhD student) of the Cardiff Business School under the supervision of Professor Peter Wells (wellspe@cf.ac.uk).

Participation in the project will involve being interviewed on future prospect for electric bicycles in sustainable mobility in China. The aim of this research is to explore the reasons why the rapid development of e-bikes occurs in China.

Participation in the study is entirely voluntary and participants can withdraw from the study at any time without giving a reason. Participants may also ask questions at any time and discuss any concerns with either the researcher Xiao LIN (linxiao.lin@gmail.com) or Professor Peter Wells (wellspe@cf.ac.uk).

The findings of the study will form part of my Dissertation for my PhD

All information provided during the interview will be held anonymously so that it will not be possible to trace information or comments back to individual contributors. Information will be stored in accordance with the current Data Protection Act.

Participants can request information and feedback about the purpose and results of the study by applying directly to the researcher Xiao LIN (linxiao.lin@gmail.com).

Date

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Appendix B

Survey Questionnaire for E-bike users

Part 1 About you

Q1. Gender

1. Male
2. Female

Q2. Age

- | | | | |
|-------------|----------|-------------|----------|
| 1. Below 19 | 2. 20–29 | 3. 30–39 | 4. 40–49 |
| 5. 50–59 | 6. 60–69 | 7. Above 70 | |

Q3. Educational background

1. Below junior high school
3. High school or technical secondary school
4. College or Undergraduate
5. Postgraduate

Q4. What is your occupation?

1. Senior corporate executive
2. Enterprise general staff
3. Skilled worker
4. Self-employer
5. Public servant or institutional organisation staff
6. Student
7. Retiree
8. Unemployed
9. Other____

Q5. What is your monthly salary (CNY)?

1. Below 1,500
2. 1,500–3,000
3. 3,000–4,500
4. 4,500–6,000
5. Above 6,000

Part 2 You and your e-bike

Q6. Which vehicles have you replaced with e-bikes?

1. Bicycle
2. Motorcycle
3. Walking
4. Bus
5. The metro
6. Private car
7. Taxi
8. Coach
9. Tricycle
10. Other____

Q7. For which purpose do you use e-bikes?

1. Commuting
2. Going to school
3. Picking up children
4. Going shopping
5. Leisure
6. Visiting friends
7. Travel connections to the metro
8. Business
9. Other____

Q8. What is your maximum trip time when travelling by e-bike? _____ (minutes)

Q9. Why do you use e-bikes?

1. Low purchase cost
2. Low operation cost
3. Effort saving
4. Flexible trip time
5. Saving time in the traffic jams
6. High accessibility
7. Environmentally friendly
8. Health
9. Other ____

Q10. Are you worried or not worried about the following factors if using an e-bike? Please tick (✓) your choice.

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
I would be worried about the narrow bike lanes					
It would expose me to wet or windy weather					
The speed of e-bikes are too fast					
E-bikes are too heavy					
E-bikes are prone to failure during driving					
I would be worried about rear seat safety					
I would be worried about low battery capacity					
I would be worried about charging difficulty					
I would be worried about maintenance difficulty					
It would put my e-bike at risk of being stolen					
Other					

Q11. Which feelings do you associate with using an e-bike?

1. Being fashionable
2. Freedom
3. Relaxation

4. Being greener
5. A sense of identity
6. Practical usage
7. Other____

Q12. The reasons why you do not use e-bikes:

1. Long travel distance
2. Short travel distance
3. Limited travel time
4. Plenty of travel time
5. Bad weather
6. Bad road conditions
7. Safety issues
8. Physical discomfort
9. Other____

Q13. Which vehicles do you have in your household? How many of these vehicles do you have?

____E-bike ____Bicycle ____Motorcycle ____Private car
____ Other ____

Q14. For how long did you use the e-bike (year or month)? _____

Q15. What is the brand of your e-bike? _____

Q16. What is your e-bike type?

1. Bicycle style
2. Hybrid style with pedals
3. Hybrid style without pedals
4. Scooter style
5. Tricycle style
6. Mobility scooter
7. Other____

Q17. What is the price range of your e-bike (CNY)?

1. Below 2,000
2. 2,000– 3,000
3. 3,000– 4,000
4. Above 5,500

Q18. Where did you buy your e-bike?

1. Shopping mall
2. Franchised store
3. Online shopping
4. Other ____

Q19. What are the primary factors that influenced your e-bike purchase?

1. Price
2. Maximum speed
3. Motor power
4. Gradeability
5. Battery life
6. Distance per charge
7. Appearance
8. Brand
9. Customer service
10. Weight
11. Anti-theft system
12. Comfort level
13. Factor of safety
14. Environmentally friendly
15. Other ____

Q20. What is your battery type?

1. Lead acid battery
2. Silica gel battery
3. Lithium battery
4. Other ____

Q21. How often do you renew your battery?

- | | |
|--------------------------|--------------------------|
| 1. Never changed | 2. Less than once a year |
| 3. Every 1 to 1.5 years | 4. Every 1.5 to 2 years |
| 5. Every 2 years or more | |

Q22. What time do you charge the battery?

1. 0:00–5:00
2. 5:00–8:00
3. 8:00–17:00
4. 17:00–20:00
5. 20:00–24:00

Q23. Where do you usually charge the battery?

1. Home
2. Workplace
3. Parking place
4. Public charging points
5. Business centre
6. Service centre
7. Other ____

Q24. What are the drawbacks of e-bike batteries?

1. Heavy weight
2. High price
3. Self-discharge
4. Slow charging
5. Safety issue
6. Large size
7. Short cycle life
8. Maintenance
9. Other ____

Q25. Where do you park your e-bike?

1. On the road
2. E-bike parking
3. Work place
4. Other ____

Q26. What is your main concern about road safety?

1. Motor vehicle users occupy bike lanes
2. Motor vehicle users travel too fast
3. Bicycle users travel too slowly
4. Pedestrians occupy bike lanes
5. Pedestrians walk the wrong way
6. Other e-bike users drive the wrong way
7. Other e-bike users travel too fast
8. Other e-bike users install umbrellas
9. Improper turns
10. Running red lights
11. Other____

Q27. Have you ever had an accident, and if so, with whom?

1. Never
2. Yes, with a pedestrian
3. Yes, with a driver
4. Yes, with a bicycle users
5. Yes, with another e-bike user

Q28. Do you intend to use e-bikes in the future?

1. Yes, in 1–2 years
2. Yes, 2–3 years
3. Yes, in 3 years or more
4. No

Q29. If you decide not use e-bikes in the future, what would your reasons be?

- | | |
|-------------------------|-----------------------------|
| 1. Long distance | 2. Income increase |
| 3. E-bike performance | 4. Bad road condition |
| 5. New bus routes added | 6. New metro stations added |
| 7. E-bike bans | 8. Physical discomfort |
| 9. Safety issues | 10. Other____ |

Q30 If you decide not use e-bikes in the future, which vehicles will you use?

1. Bicycle
2. Motorcycle
3. Walking
4. Bus

5. The metro
6. Private cars
7. Taxi
8. Coach
9. Tricycle
10. Electric vehicle
11. Other____

Part 3 Future suggestions

Q31. Which aspects of e-bikes should be improved greatly?

1. Lighter weight
2. Faster speed
3. A better variety of models
4. Battery performance (lighter, longer life cycle)
5. Better control
6. More comfortable to use
7. More fashionable
8. More accessories
9. Easy to maintain
10. Other____

Q32. Does rapid e-bike development have positive/negative effects on the urban transport system?

- | | | |
|--------------------------------|--------------------------------|---------------|
| 1. Positive | 2. More positive than negative | 3. Same |
| 4. More negative than positive | 5. Negative | 6. No opinion |

Q33. Which effects do you think e-bikes have on the urban transport system?

1. Relieve traffic jams
2. Worsen traffic jams
3. No noise
4. Facilitate daily trips
5. Environmentally friendly

6. Save road resources
7. Worsen traffic control difficulty
8. Obstruct other vehicles
9. Increase accidents
10. Other____

Q34. Which suggestions are important for e-bike development in the future?

1. Widen bicycle lanes
2. Build e-bike lanes
3. Build charging points
4. Increase e-bike parking places
5. Increase maximum e-bike speed
6. Ban fast speed e-bikes
7. Enhance road safety awareness
8. Accelerate e-bike technology innovation
9. Establish an e-bike commercial insurance system
10. Increase the penalties for breaking legislation
11. Other____

Appendix C

Survey Questionnaire for Non-e-bike users

Part 1 About you

Q1. Gender

1. Male
2. Female

Q2. Age

- | | | | |
|-------------|----------|-------------|----------|
| 1. Below 19 | 2. 20–29 | 3. 30–39 | 4. 40–49 |
| 5. 50–59 | 6. 60–69 | 7. Above 70 | |

Q3. Educational background.

1. Below junior high school
3. High school or technical secondary school
4. College or Undergraduate
5. Postgraduate

Q4. Occupation

1. Senior corporate executive
2. Enterprise general staff
3. Skilled worker
4. Self-employer
5. Public servant or institutional organisation staff
6. Student
7. Retiree
8. Unemployed
9. Others____

Q5. What is your monthly salary (CNY)?

1. Below 1,500
2. 1,500–3,000
3. 3,000–4,500
4. 4,500–6,000
5. Above 6,500

Part 2 About e-bikes

Q6. Do you have an e-bike in your family?

1. Yes, I do
2. No, I do not

Q7. To what extent do you think e-bikes have an impact on your safety?

1. A lot
2. Some
3. Very little
4. Not at all
5. No opinion

Q8a. As a **pedestrian**, what is your main concern about e-bike users? (Multiple choice)

1. Speeding
2. Driving in pedestrian lanes
3. Improper turns
4. Reckless driving
5. Driving the wrong way
6. Carrying too many persons
7. Overloading cargo
8. Installing an umbrella
9. Drink driving
0. Other ____

1

Q8b. As a **bicycle user**, what is your main concern about e-bike users? (Multiple choice)

1. Speeding

2. Running red lights
3. Improper turns
4. Reckless driving
5. Driving the wrong way
6. Carrying too many persons
7. Overloading cargo
8. Installing an umbrella
9. Drink driving
10. Other ____

Q8c. As a **car driver**, what is your main concern about e-bike users? (Multiple choice)

1. Speeding
2. Emerging into a motor vehicle lane
3. Reckless driving
4. Running red lights
5. Improper turns
6. Unsafe lane changes
7. Driving the wrong way
8. Carrying too many persons
9. Overloading cargo
10. Installing an umbrella
11. Drink driving
12. Other ____

Q9. Does the rapid development of e-bikes have positive or negative effects on the urban transport system?

1. Positive
2. More positive than negative
3. Same effects
4. More negative than positive
5. Negative
6. No opinions

Q10. Which effects do e-bikes have on the urban transport system?

1. Relieve traffic congestion
2. Increase traffic congestion
3. Quiet, not noisy
4. Facilitate daily trips
5. Environmentally friendly
6. Save road resources
7. Increase traffic management difficulties
8. Obstruct other vehicles
9. Increase traffic accidents
10. Others____

Q11. Which suggestions on strengthening e-bike management are useful? (Multiple choice)

1. Enhance the safety awareness of e-bike users
2. Restrict e-bike travel on main roads in the city
3. Restrict e-bike travel in the city at specific times
4. Ban e-bikes completely
5. Limit or eliminate non-standard e-bikes
6. Strengthen e-bike traffic order
7. Build e-bike lanes
8. Strengthen e-bike registration management
9. Strengthen information about e-bike regulation
10. Strengthen the supervision of e-bike production
11. Strengthen the supervision of e-bike sales
12. Establish an e-bike commercial insurance system
13. Other____

Appendix D

Survey Questionnaire for Traffic Police

Q1. Which type of behaviour displayed by e-bike users is the main source of accidents?

1. Drink driving
2. Running red lights
3. Speeding
4. Driving the wrong way
5. Improper turns
6. Installing an umbrella
7. Driving on restricted roads
8. Suddenly changing direction
9. Carrying too many persons
10. Overloading cargo
11. Other ____

Q2. Do any e-bike accidents happen when you are on duty? If yes, with which vehicle?

1. Never
2. Pedestrians
3. Motor vehicles
4. Bicycles
5. Other e-bikes

Q3. Does the rapid development of e-bikes have positive or negative effects on the urban transport system?

1. Positive
2. More positive than negative
3. Same effects
4. More negative than positive
5. Negative
6. No opinions

Q4. Which effects do you think e-bikes have on the urban transport system?

1. Relieve traffic congestion

2. Increase traffic congestion
3. Quiet, not noisy
4. Facilitate daily trips
5. Environmentally friendly
6. Save road resources
7. Increase traffic management difficulties
8. Obstruct other vehicles
9. Increase traffic accidents
10. Others____

Q5. Do you agree or disagree with the following suggestions for strengthening e-bike administration?

	Agree strongly	Agree	Neutral	Disagree	Disagree strongly
Enhance the safety awareness of e-bike users					
Restrict e-bike travel on main roads in the city					
Restrict e-bike travel in the city at specific times					
Completely ban e-bikes					
Increase the number of traffic police					
The requirement of an e-bike driving license					
Strengthen e-bike registration administration					
Build e-bike lanes					
Strengthen the supervision of e-bike production					
Establish an e-bike commercial insurance system					

Appendix E

The Technical Details of E-bikes

E.1 The technical details of three styles of e-bikes

Most e-bikes fall into three categories: bicycle style electric bikes, scooter style bikes, and something between bicycle styles and scooter styles (hybrid style).

1) Bicycle style e-bikes

The maximum speed is around 20–30km/h. The low-end e-bikes are usually equipped with a 36V lead acid battery, a 180-250W motor and single speed. The high-end products usually set up intelligent controllers and derailleur gears.

2) Scooter style e-bikes

The scooter style normally has a larger 48V battery and higher powered motor (300–500W), which allows it to reach a maximum speed of 50 km/h.

3) Hybrid style e-bike

The hybrid style e-bike is usually equipped with a 48 V battery. Generally, the maximum speed is 30 km/h.

E.2 Essential Components of e-bikes

1) Controllers

The controller is the key component for controlling the speed of the e-bike (Haobin *et al.*, 2008). With updated technology, the controller makes modern electric bicycles more intelligent. As a traditional e-bike, the driving force is completely from the motor, which leads to battery life reduction and a higher electricity energy consumption. Based on this, a new type of controller, called a microcontroller, was designed with new functions, including capacity detection, over-current protection,

brake mechanism, constant speed control, speed loop control and current loop control, and this turned out to have better dynamic characteristics and ran steadily (Zhang *et al.*, 2013). Therefore, more energy could be saved.

2) Motors

The motor serves as the heart of e-bikes. The main function of a motor is to transfer stored electricity into motive power which makes a force to turn a wheel and drive a machine. The motor determines the maximum support, maximum speed, and maximum torque. The development of motors has fundamentally influenced e-bike development. In the 1980s, there was a short revival of e-bike production and sales. The main actors were famous bicycle manufacturers such as Forever and Phoenix bicycle manufacturers in Shanghai (Huang, 1999). At that time, e-bikes simply resembled bicycles with a chain-driven rear wheel and a motor with a 14–18 NM motor output torque (Ruan *et al.*, 2014). This motor has high noise, low efficiency, and poor slope-climbing ability. In addition, the duration of the motor only lasts a few months, which leads to quick wear and tear. The motor has to be replaced every three months in order to maintain the performance of the e-bike (Ruan *et al.*, 2014). This immature motor technology has slowed down e-bike industry development in China.

Motor type	Technical parameters	Characteristics	Duration	Price
Pan cake coil brush motor	Voltage: 36V Power: 320W Efficiency: 68%–72%	High material cost High noise Low efficiency	1–3 years	Low
Printed coil brush motor	Voltage: 36V Power: 330W Efficiency: 72%–76%	High material cost High noise Low efficiency	1.5–4 years	Low
Compressed coil brush motor	Voltage: 36V Power 330W Efficiency: 74%–78%	High material cost High noise Middle efficiency	1.5–4 years	Middle
Brushless motor	Voltage: 36V Power: 250W Efficiency: 68%–72%	Low material cost Low noise High efficiency	10–20 years	High

Adapted from: Zhen *et al.*, 2006.

Table E.1 Type of motors used for electric bicycles

Until the late 1990s, pan cake coil brush motors, printed coil brush motors and compressed coil brushed motors were developed. The shortcomings of these three types of motors included high noise, low efficiency, highly material consuming,

causing shock on battery, although these motors did have a longer lifespan (Table E.1). As a result, the e-bikes released in the later 1990s did not need to be renewed every three months, which made the e-bikes more popular. From 2000 to 2004, brushless motors were developed (Zhen *et al.*, 2006). Compared with the coil brushed motor, the brushless motors, which are usually called brushless direct current motors, have low material cost, low noise, higher efficiency and a very long lifespan (10–20 years). In addition, the brushless motors have no shock on batteries. This significant improvement stimulated the e-bike market. In 2005, the sales of e-bikes reached 15 million (Zhen *et al.*, 2006). Today, most of e-bikes are equipped with a rear wheel brushless hub motor.

3) Batteries

	Lead acid battery	Lithium-ion battery
Capacity	36V/10Ah	36V/10Ah
Energy Density	30Wh/kg	130Wh/kg
Price	300 CNY	850 CNY
Volume	≥ 6.5L	<2.14L
Weight	≥13kg	≤3.5kg
Self-discharge rate	> 20%	< 5%
Charging time	7–10 h	6–8h
Environmental impact	lead	Non
Lifespan	1–2 years	4–5 years

Adapted from: Bowen, 2014.

Table E.2 Lead acid battery and lithium battery comparison

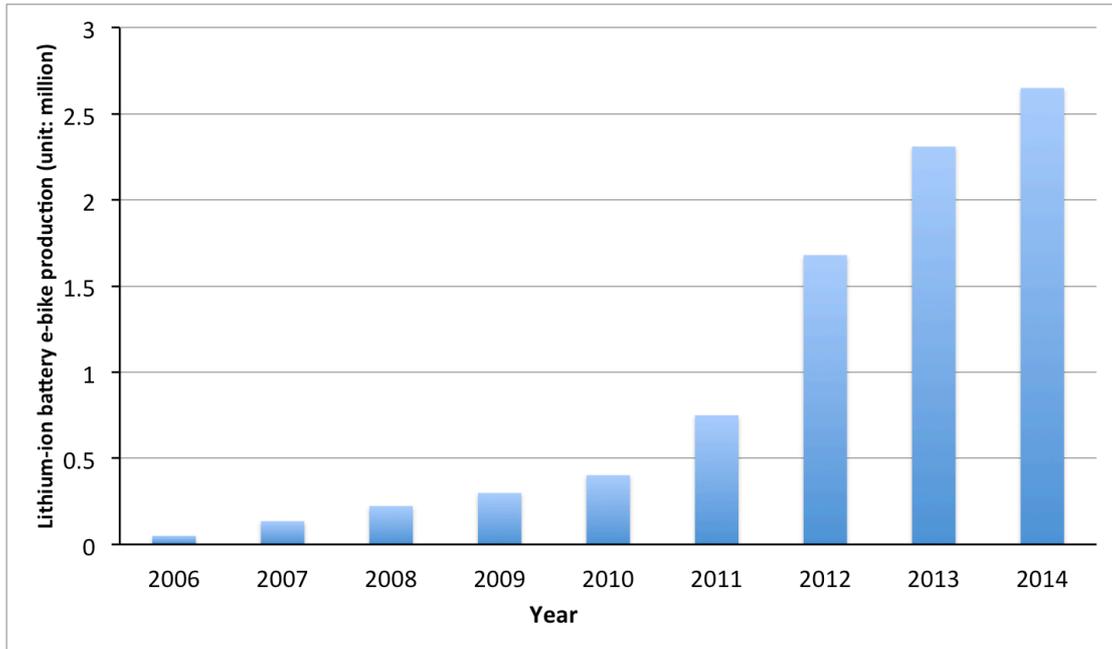
For these three styles of e-bikes, all of them use rechargeable batteries, including sealed lead acid battery, nickel-cadmium battery, nickel-metal hybrid battery, silicon gel battery and lithium-ion polymer battery (lithium-ion battery). The voltage, total charge capacity (amp hours), weight, and the number of charging cycles are the main indicators of battery quality, which influence the energy costs of e-bike operation and battery replacement costs (Zhang *et al.*, 2014). For the same e-bike frame, the choice of battery determines the total weight, travelling distance and total cost of e-bikes.

Lead acid batteries and lithium-ion batteries, which are two of the most widespread batteries, are compared in Table E.2.

From Table E.2, we can see that the lithium-ion batteries have a lighter weight and smaller volume compared with lead acid batteries with the same capacity. The characteristics of lithium-ion batteries not only reduce the total weight of e-bikes but also facilitate the space allocated. Other advantages of lithium-ion batteries include a longer life cycle, stable discharging, high energy density, and high voltage. The disadvantages are high cost, and easy explosion if not protected well. Although the safety issues associated with lithium-ion batteries have been improved, the high cost is still an obstacle. The cost of a lithium-ion battery is almost three times than that of a lead acid battery. As price is a primary consideration, many customers still choose lead acid battery e-bikes rather than lithium-ion battery e-bikes.

The lead acid battery has dominated the e-bike market since 1998. The main reasons for this are that they are safer, cheaper, easier to produce and have a high discharging current. The disadvantages are a short lifespan, heavy weight, low energy density and pollution. Because of lead pollution, the lead acid battery is confronted with a great challenge. In 2011, a policy to regulate pollution from lead acid batteries and the lead recycling industry was issued by the Ministry of Environmental Protection. As a consequence, many lead acid battery factories were closed. The lack of lead acid battery suppliers directly influences the e-bike industry.

At the same time, the “Notice of Strengthening E-bike Regulation” was published by the Ministry of Public Security, the Ministry of Industry and Information Technology, the State Administration for Industry and Commerce, and the General Administration of Quality Supervision Inspection and Quarantine. This required e-bike manufacturers to strictly follow the 1999 e-bike national standard (MIIT, 2011). Therefore, in order to satisfy the requirement that “an e-bike total weight is no more than 40kg”, an increasing number of manufacturers adopted lithium-ion batteries as the simplest way to reduce the total weight of e-bikes (see Figure E.1). The production of lithium-ion battery e-bikes doubled between 2010 and 2011, followed by an increase rate of over 200% in 2012 (Wang, 2015). In 2013, the output of li-ion batteries reached 1.68 million and this has increased 420 times since 2006 (Wang, 2015).



Adapted from: QQDCW, 2011; EVTank, 2015; Wang, 2015.

Figure E.1 The production of lithium-ion battery e-bikes (unit: million)