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1 The Death of a Transport Regime? The Future of Electric Bicycles and
2 Transportation Pathways for Sustainable Mobility in China

3

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31

32 **Abstract**

33 This paper has an empirical and theoretical focus: to empirically assess electric
34 bicycle development in China, and to theoretically test and apply the “Multi-Level
35 Perspective” on transitions and innovation. We examine the electric bicycle (e-bike)
36 sector in China to understand the future prospects for urban mobility and the
37 interaction of e-bikes as a form of vernacular technology within the existing transport
38 regime. For this purpose, we address the following questions: 1) What factors will
39 influence the future adoption of e-bikes? 2) How are alternative travel modes
40 evaluated against e-bikes? 3) Will e-bikes become a popular sustainable mobility
41 mode in the future or only an intermediary mode to cars? To provide answers, we
42 conducted a survey in Nanjing city in order to assess the attitude of e-bike users, and
43 other mode users (e.g. pedestrians; bicycle users). We then analyse responses from
44 this survey through the lens of sociotechnical transitions theory, notably the “Multi-
45 Level Perspective” notions of niches, regimes, and landscape. The paper explores the
46 influential factors underpinning future e-bike adoption and the decision-making
47 calculus behind alternative mode choices. Generalised Linear Models are used to
48 investigate the factors influencing future e-bike adoption and alternative mode choices
49 based on the survey data. We conclude that e-bikes are an intermediary mode on
50 Nanjing’s motorisation pathway, and that they therefore may eventually reflect a
51 dying regime.

52

53

54 **Keywords:** Sustainable mobility; electrification; bicycles; urban transport; modal
55 choice; China.

56

57

58

59 **Highlights:**

60

- 61 • Sociotechnical change occurs through the evolutionary interaction of niche,
62 regime, and landscape pressures
- 63 • The paper provides survey data from over 1,000 respondents on the future of
64 e-bike use in China
- 65 • E-bike use is widespread, but not deeply embedded as a transport mode
- 66 • E-bike continued use is vulnerable to policy shifts or increased personal
67 wealth

68

69

70

71 Nomenclature

72

| | |
|-----------------|---|
| ACI | Acoustic complexity Index |
| GLM | Generalised Linear Models |
| $\Pr(> t)$ | <i>P</i> -value for that t-test |
| <i>p</i> -value | Probability for a given statistical model |
| R ² | The coefficient of determination |
| Std. Error | Standard Error |
| VIF | Variance Inflation Factor |

73

74 **1. Introduction**

75

76 This paper investigates whether electric bicycles, a somewhat neglected but socially
77 important mobility technology, are likely to be an enduring feature of future modal
78 choice for urban transport in China. Drawing from the concept of socio-technical
79 transitions (Geels, 2002), we aim to make empirical and theoretical contributions.
80 Empirically, we ask: 1) What factors will influence the future adoption of e-bikes? 2)
81 How are alternative travel modes evaluated against e-bikes? 3) Will e-bikes become a
82 popular sustainable mobility mode in the future or only an intermediary mode to cars?
83 And theoretically, we ask: 1) Are e-bikes an established or dying transport regime?
84 Such questions require us to examine technologies through a range of possible
85 pathways, and thereby to assess their interaction within “regimes”, a term that
86 encompasses a constellation of mutually reinforcing features that becomes the
87 accepted nature of everyday life. These concepts have been applied to the realm of
88 transport (Geels *et al.*, 2012), and underpin the research reported in this paper.
89 Household decisions on mobility choices have long been recognised as a key feature
90 of urbanism in general (Dieleman *et al.*, 2002; Hansen, 2015). Research has identified

91 how urban structures can give rise to certain mobility choices (Shirgaokar, 2015), but
92 there has been less attention on how current and future mobility choices may enable
93 or constrain urbanism typologies. Thus it is proposed here that the uptake of e-bikes
94 in China is reflective of and contributory to a wider process of urban-rural drift (both
95 permanent and temporary) in which such e-bikes may be more of a temporary
96 expedient or ‘stepping stone’ on the pathway to full (car-based) automobility rather
97 than a laudable ‘green mobility’ platform.

98

99 To provide some clarity, the term “electric bicycles” (e-bikes) is generally used to
100 refer to two-wheel transport machines with an electric motor used to power the
101 vehicle, or to assist with pedalling (SBQTS, 1999). Most e-bikes fall into three
102 categories: bicycle style e-bikes (usually termed ‘Pedelecs’ in Europe), scooter style
103 e-bikes (e-scooters), and something in-between these termed a hybrid style. All e-
104 bikes have three main components: Motors, rechargeable batteries, and controllers,
105 which differentiate an e-bike from other alternative transport modes. Compared with
106 traditional bicycles, e-bikes are faster and require less physical effort. Compared with
107 motorcycles, e-bikes are lightweight and have no exhaust emissions. Compared with
108 buses, e-bikes provide greater accessibility and flexibility of use. Compared with cars,
109 e-bikes are easy to operate, convenient to use, do not require a licence, more
110 affordable, and easier to park. With these advantages, e-bikes have attracted an
111 increasing number of users transferring from walking, bicycles, motorcycles, buses,
112 and cars (Cherry and Cervero, 2007; Weinert *et al.*, 2007; Zhang, 2011; Xu *et al.*,
113 2014). E-bikes are highly embedded within the regime of mobility in China, being
114 employed for both utility and leisure uses (Cherry, 2007; Cherry and Cervero, 2007;
115 Weinert *et al.*, 2007; Zhang, 2011; Ye *et al.*, 2014).

116

117 Although drawing from socio-technical transitions theory in which niches, regimes,
118 and landscapes are dynamic and always in flux, we treat e-bikes in this paper as a

119 “regime” in their own right, although such a regime also interacts with other regimes
120 (and niches). We consider e-bikes a regime for at least two reasons. Firstly, the
121 annual sales of e-bikes in China are about 30 million units (Jamerson and Benjamin,
122 2013), meaning they have established economies of scale and also their own
123 supportive policies, stakeholder groups, and industry practices. Nowadays, more than
124 220 million e-bikes are in use in China (Yang and Yang, 2016). The explosive growth
125 of e-bikes has already attracted the attention of government, and also resulted in
126 consequent supportive government regulations (Rose, 2012). Second, e-bike pathways
127 are, consistent with MLP theory, contested, and generate friction. For instance,
128 Chinese authorities argue that e-bikes cause numerous traffic accidents, and
129 undermined urban road transportation rule compliance due to the traffic violation
130 behaviour of e-bike users - such as running red lights, and overloading (Wang *et al.*,
131 2011; Du *et al.*, 2013; Lu *et al.*, 2015). In addition, e-bikes have been restricted by
132 some urban authorities because of potential lead pollution created by the use and
133 disposal of lead-acid batteries (Chen *et al.*, 2009). It is a concern that only 33% of
134 lead-acid batteries were properly recycled by official companies in China, while 67%
135 were illegally recycled in hazardous and polluting ways (Chun, 2013). The
136 uncontrolled lead recycling process increases the likelihood of a negative impact on
137 human health, such as developmental disorders and a lower IQ (Sanders *et al.*, 2009).

138

139

140 The paper is organised as follows. The following sections introduces the research
141 methods and theoretical approach of the paper, research design, case and field
142 procedures, and model specification. Then, the survey results of the future choices of
143 e-bikes users with respect to e-bikes and other alternative travel modes are discussed
144 in Section 6. To further explore the mode choice behaviour. And the factors
145 influencing future modal choices using the Generalised Linear Models (GLM). A
146 further analysis is performed in Section 7. The final section presents the conclusions

147 following the research as well as suggested areas for further development.

148

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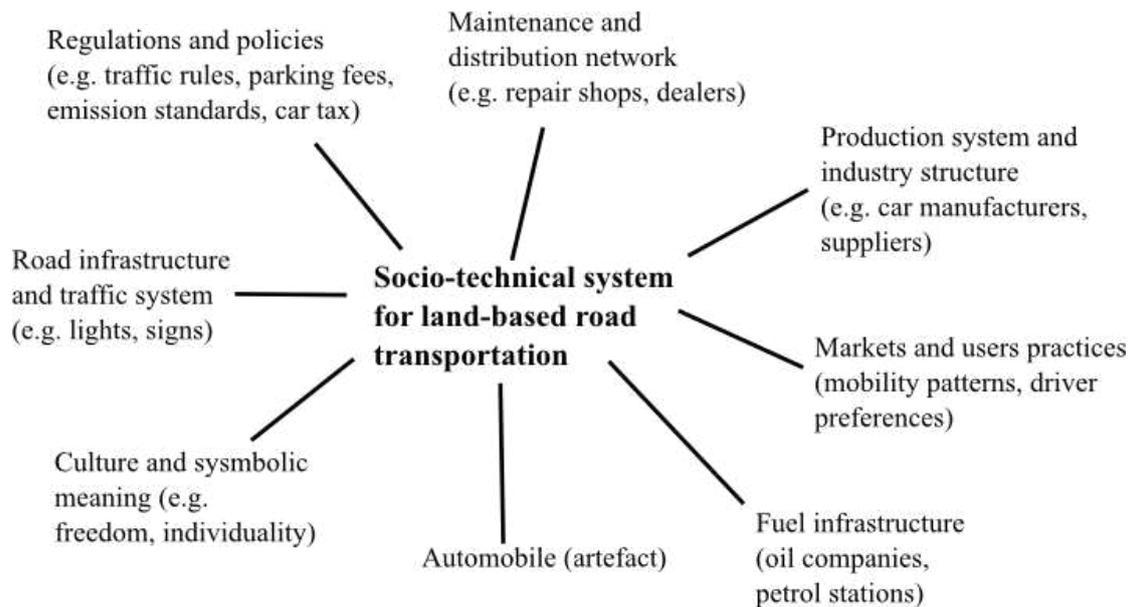
150 **2. Research methods and approach**

151

152 The conceptual framework employed in this study is rooted in the “multilevel
153 perspective on innovation,” or MLP, arising from innovation studies, evolutionary
154 economics, and science and technology studies. This approach posits that cars and
155 even electric forms of mobility create part of a socio-technical system, one that
156 involves not only technological “artefacts” (such as the car) but broader social,
157 cultural, economic, and political factors depicted in Figure 1. This requires analysts to
158 focus not only on infrastructure and technical systems, but human users and actors
159 (and their behaviour) as well as the institutionalization of their behavioural patterns.
160 The research reported in this paper relates to some, but not all, of the elements of
161 Figure 1. The paper has a focus on markets and user preferences, the artefact, and
162 culture and symbolic meaning. It also touches upon infrastructure and regulation and
163 policies. It does not relate to the production system, the maintenance system, or the
164 fuel infrastructure.

165

166



167

168 (Source: van Bree *et al.*, 2010)

169 Figure 1: A socio-technical system of transport

170

171 As Geels (2012) indicates, the MLP moves beyond (and in a way, integrates) the
 172 conceptual tools utilized by neo-classical economics, psychology, ecology, and
 173 political science. Economics helps reveal market failures and the motivating factors of
 174 price and affordability; psychology helps reveal attitudes and behaviour of individuals
 175 whose aggregated choices result in social outcomes; ecology looks at environmental
 176 problems and some of the failures of capitalism. Political science often examines the
 177 struggles over policy implementation and the way that global norms interact with the
 178 local level in the form of regulations and policy programs.

179

180 Applying the MLP to analyse sustainable mobility can help understand the transport
 181 system and possible transition pathways towards more sustainable mobility (Geels *et*
 182 *al.*, 2012). The MLP has been applied to study niche innovations in green propulsion
 183 technologies such as battery electric vehicles and fuel cell vehicles. Orsato *et al.*
 184 (2012) suggested that pure battery electric vehicles now were accepted culturally
 185 compared with the period of the 1970s to 1990s. Ehret and Dignum (2012) studied

186 fuel cell vehicles in Germany, finding that they were regime-preserving as they fit
187 current driver preferences as well as regime-changing as they are a disruptive
188 innovation in the energy sector. Sovacool *et al.* (2017) draw from the fit-stretch
189 aspects of the MLP to explore how innovations in charging infrastructure and battery
190 swapping being promoted by Better Place, a now bankrupt company, were “contained”
191 by incumbents and user expectations. Other studies have been concerned with human-
192 powered vehicles (Brown *et al.*, 2006), hydrogen and battery electric vehicles (Farla
193 *et al.*, 2010), biofuel vehicles and natural gas vehicles (Van Bree *et al.*, 2010;
194 Berggren *et al.*, 2015), and e-mobility (Tyfield, 2014; Nilsson and Nykvist, 2016).

195

196 The MLP has been applied to study niche innovations in low-carbon urban transport
197 system transitions. Spickermann *et al.* (2014) studied possible multimodal mobility
198 solutions in urban transport systems, and designed an integration of individual and
199 public passenger transport systems for future sustainable urban mobility. Parkhurst *et*
200 *al.* (2012) suggested that intermodal personal mobility promotion would be a possible
201 way to achieve sustainable personal mobility. In addition, innovation in public
202 transport was highlighted by Harman *et al.* (2012), including bus lanes, demand-
203 dependent services, information provision about arrival times and short distance radio
204 systems. Among the various innovations, they found that the tram-train concept was a
205 better solution to attract more commuters and widen access to cities. Pel *et al.* (2012)
206 and Lyons *et al.* (2012) investigated the role of traffic information in the transport
207 regime transition, such as “Intelligent Transport Systems”. Other ongoing niche
208 developments in low-carbon urban transport transition include mobility management
209 (Nykvist and Whitmarsh, 2008) car-sharing (Marx *et al.*, 2015), and telework (Hynes,
210 2016).

211

212 Sustainable mobility governance was proposed by Auvinen *et al.* (2015) to support
213 strategic decision-making and policy planning by simulation and modelling with

214 impact assessment based on the MLP framework. Another study (Upham *et al.*, 2015)
215 focused on the current climate-related transport policies in three countries, namely,
216 Finland, Sweden, and the UK. They found that the climate-related transport policy
217 supported by regime actors in these three countries mainly concentrated on
218 technological substitution and incremental changes rather than path-breaking
219 innovations (Upham *et al.*, 2015).

220

221 The MLP approach is premised on the view that all of these different dimensions are
222 important, and it offers three core conceptual units to reveal the complex interplay
223 among them: niche, regime, and landscape (Grin *et al.*, 2010). Niches refer to
224 “protective spaces” from which new, promising innovations can emerge. Niche actors
225 hope that through learning and continued innovation their breakthroughs can come to
226 be more widely accepted in the form of a regime. E-bikes would have begun, as most
227 technologies do, as a niche.

228

229 Novelties and niches must compete with technologies that are already part of the
230 existing socio-technical system around them, and here we have the idea of a regime,
231 which aligns “existing technologies, regulations, user patterns, infrastructures, and
232 cultural discourses” (Geels, 2004). Within this environment, innovation is usually
233 incremental and non-radical due to the influence of path dependence and lock-in.
234 Change can occur, but it is usually managed and predictable, giving rise to stable
235 trajectories. As Geels (2012) notes, the notion of a regime introduces a structuralist
236 element in our analysis, by assuming that actor behaviour is constrained by rules
237 located at the collective level of a regime. As previously intimated, we would
238 maintain that e-bikes in China currently serve as such a regime.

239

240 Finally, a socio-technical landscape is the wider macro context operating in the
241 background (but still important), one that can exert influence over the dynamics of

242 regimes and landscapes. It therefore includes “spatial structures (e.g. urban layouts),
243 political ideologies, societal values, beliefs, concerns, the media landscape and macro-
244 economic trends” (Geels 2012).

245

246 Our theoretical utilization of “regime” results in two key insights. The first is that it
247 views change within a transport regime as a highly uneven, unpredictable, and at
248 times even disruptive process. Put another way, the MLP rejects linear causality, and
249 notes that there is no simple cause or driver (Grin *et al.*, 2010). The second is the
250 notion of co-evolution and learning; new niches and existing regimes do not exist in a
251 vacuum, they interact with each other and co-evolution occurs within and between
252 different levels. It thus goes far beyond the usual “S-curves” presented in diffusion
253 theories and adoption models. Thus, socio-technical trajectories can co-evolve along
254 different dimensions and that in this complex process multiple feedback loops
255 between state, market, science, and civil society exist.

256

257 3. Research Design

258 To explore the unique and dynamic socio-technical transition of e-bikes, the survey
259 variables were designed to be closely connected to the elements of socio-technical
260 system of transport illustrated in Figure 1: Markets and user practices; culture and
261 symbolic meaning; regulations and policies, the underlying technology of the artefact
262 itself; and the road infrastructure and traffic system. The survey did not so deeply
263 address the fuel infrastructure, the maintenance and distribution network, the
264 production system or the industrial structure, but certain important elements were
265 explored. The details of the survey variables designed for the study are discussed
266 below.

267

268 In terms of markets and user practices, market-related variables included e-bike prices,
269 e-bike types, and the factors influencing e-bike purchase. As main regime actors, the

270 choices of e-bike users are key to transition pathways. Only with the increase of e-
271 bike users, is it possible for e-bikes to break out of their niche level. Therefore, it is
272 significant to understand why e-bike users spontaneously chose e-bikes as their daily
273 vehicles to achieve the personal mobility and to what extent e-bikes were embedded
274 in their lifestyles and social practice. In this case, we particularly paid attention to the
275 user practices and individual behaviours related to e-bike usage. For example, to
276 explore the socio-demographic variables influencing individual behaviours, we
277 collected the information such as age, gender, and income of the participants. In terms
278 of the effect of psycho-social variables, we incorporated the trip purpose, the feeling
279 associated with using e-bikes, and the attitudes towards e-bikes. In addition,
280 considering the value of travel time and travel time reliability, we asked the questions
281 such as which travel mode will be used in an urgent trip and how the trip time
282 accuracy requirement determined the travel mode to understand the driving
283 preferences.

284

285 One of the main aspects of MLP studies is transition management which emphasises
286 the role of policy and tends to suggest that distinct policy intervention is fundamental
287 to turning unsustainable practices into sustainable ones. This is because it stimulates
288 and nurtures new production-consumption modes in the following aspects:
289 distributing fiscal and other incentives, providing Research and Development (R&D)
290 support, formulating regulatory frameworks, and taking charge of infrastructure
291 development (Schot *et al.*, 1994; Hoogma *et al.*, 2002, Kemp and Loorbach, 2006).
292 The requirement of policy interventions in different contexts is highlighted to steer a
293 radical transition (Smith *et al.*, 2005; Smith, 2007; Genus and Coles, 2008). To extend
294 the understanding of the role of regulations and policies in e-bike transition process,
295 e-bike users were consulted whether e-bike restriction policies (e.g. restricting e-bike
296 travel on main roads, and restricting e-bike travel in the city at specific times) had
297 impact on their future travel mode choice and which regulations and policies would

298 govern the e-bike towards a positive development, such as banning fast speed e-bikes,
299 and requiring driving licences. In addition, we asked whether road condition was an
300 important factor in terms of e-bike adoption and which suggestions on road
301 infrastructure and traffic system change would improve e-bike development,
302 including widening bicycle lanes, building e-bike lanes, and increasing e-bike parking
303 places. Then, we investigated the fuel infrastructure, including home charging points,
304 public charging points, and workplace charging points.

305

306 In terms of maintenance and distribution network, e-bike users were asked whether
307 they were worried about the maintenance difficulties encountered for e-bikes. To
308 investigate the production system and industry structure of e-bikes, we focused on
309 innovations which would enhance e-bike performance, including speed, motor power,
310 grade ability, battery life, appearance, weight, and the anti-theft system. In the
311 transport domain, the automobile is not the only regime which co-exists with other
312 regimes (e.g. bus, bicycle, metro, and e-bike). In order to explore the interactions
313 among these regimes, e-bike users were asked whether the changes in other regimes
314 had impact on their future travel mode choice, such as new bus routes added, and new
315 metro stations added. In addition, e-bike users were consulted whether they would
316 shift to cars once their income were increased. Apart from that, the survey variables
317 were designed with a deliberate on the past, present, and future of e-bike transition.
318 We explored the e-bike users' previous travel mode choices, present e-bike adoption
319 behaviour, and future e-bike adoption to understand where e-bike users were from, the
320 reasons of e-bike adoption, what the factors influence the future adoption of e-bikes,
321 and how alternative travel modes were evaluated against e-bikes.

322

323 4. Case and Field Procedures

324 With our theoretical framework laid out, we sought to test the durability of the e-bike
325 regime in China through primary data gleaned from surveys, which were conducted in

326 Nanjing City. The reasons why we chose Nanjing for performing surveys included: 1)
327 As the capital of Jiangsu province, Nanjing is an important city in China with
328 developed economics; 2) Nanjing is a base for e-bike industry in China, concentrated
329 with a large number of e-bike manufactures and retailers; 3) E-bikes are widely used
330 in Nanjing; 4) The authors have many friends in Nanjing who can help distributing
331 and collecting questionnaires. The selected sample groups are e-bike users and non-e-
332 bike users (bicycle users, private car users, and pedestrians). Moreover, Nanjing is
333 widely representative of the mobility challenges and contradictions faced by
334 populations in the major cities of China (Feng *et al.*, 2017).

335

336 The process of delivering and collecting questionnaires is mainly completed by
337 residential community workers, and office workers. Firstly, the residential community
338 workers are very familiar with the citizens who live in the communities and have a
339 good relationship with them. Consequently, residential community workers can easily
340 identify those who are e-bike users or non-e-bike users, and communicate with
341 citizens and the government. When the potential participants passed by the
342 neighbourhood committees, the community workers sent them questionnaires and
343 asked them to return them after they were completed. If citizens refused to participate,
344 the community workers simply asked others. Questionnaires were also sent to office
345 workers and collected. Once the questionnaires were completed, they were collected
346 and returned to the researcher.

347

348 Secondly, community works and office workers asked citizens in the city commercial
349 centre which vehicle they were adopted and invited them to participate the survey.
350 The advantages of choosing commercial centre are: 1) commercial centre usually
351 have a large flow of visitors with different age groups, education backgrounds, and
352 occupations, which maximises the diversities of the sample; and 2) with the large
353 stream of citizens and the high density of populations, we can find more potential

354 survey participants and also increase the number of accomplished surveys. Thirdly,
355 when the e-bike users were waiting for e-bike maintenance in e-bike retail shop, the
356 researchers asked them to participate in the survey.

357

358 The participants were therefore selected in a wide range of locations, including the
359 residential communities, commercial centre, e-bike repair shops and e-bike
360 communities throughout the urban areas. These locations are selected arising from a
361 consideration of convenience. However, a certain degree of bias is unavoidable. A
362 further effort is needed to ensure a diverse and unbiased sample through a larger scale
363 sample selection approach. One challenge of the Nanjing case study was low response
364 rate. Many people simply refused to participate in the survey, and some abandoned
365 the survey after answering two or three questions. If citizens refused to participate, the
366 community workers simply asked others. The low response rate made it time-
367 consuming to achieve a large sample size. The target sample population and sample
368 size consisted of: e-bike users (600); bicycle users (200); car drivers (200); and
369 pedestrians (200). In total 1,003 responses were collected. The achieved number of
370 responses for each group is: e-bike (403), bicycle users (200), car drivers (200), and
371 pedestrians (200).

372

373 5. Model Specification

374 The survey data were used to develop a GLM with Gaussian distribution to predict e-
375 bike usage in the future. The dependent variable is the years of future e-bike adoption.
376 The data of the dependent variables are based on responding answers of the survey
377 question “expected future use of e-bikes” (Figure 2). The reason for incorporating
378 time dimensions into the dependent variable is that it helps the respondents to provide
379 an overall consideration and rational estimation of their future choices, which
380 mitigates the effect the value-action gap (Anable *et al.*, 2006). The independent
381 variables entering the model include user demographics, previous experience, and

382 positive and negative associations and attitudes. In the regression analysis of the
383 previous study by Cherry and Cervero (2007), the tested independent variables
384 included user demographics, pro-e-bike attitudes, reasons for e-bike adoption, and e-
385 bike travel time. Inspired by the study, we also chose user demographics, pro-e-bike
386 attitudes, reasons for e-bike adoption, and e-bike travel time as independent variables.
387 In addition, we introduced many new independent variables because they were
388 thought to be potentially related to e-bike future adoption, including previously used
389 travel modes, e-bike price, safety issues, e-bike user anxiety, and travel purposes.

390

391 In our sample, five alternative travel modes were chosen, including buses (39.2%),
392 metro (37.3%), private cars (29%), walking (24.9%) and bicycles (22.9%), because
393 they are the most popular ones. To understand the factors influencing the
394 aforementioned alternative travel mode choices, each alternative mode was tested by a
395 GLM with binomial distribution to examine the relationship with the potential
396 influence factors. The initial factors (independent variables) entering the models
397 include demographics, previous travel mode, attitude to e-bike adoption, and the
398 reasons for transferring to alternative modes, because these factors were thought to
399 have impact on mode choices according to individual behaviour literatures (Handy,
400 1996; Hiscock *et al.*, 2002; Srinivasan and Rogers, 2005; Devarasetty *et al.*, 2012;
401 Boschmann and Brady, 2013; Bahamonde-Birke *et al.*, 2017).

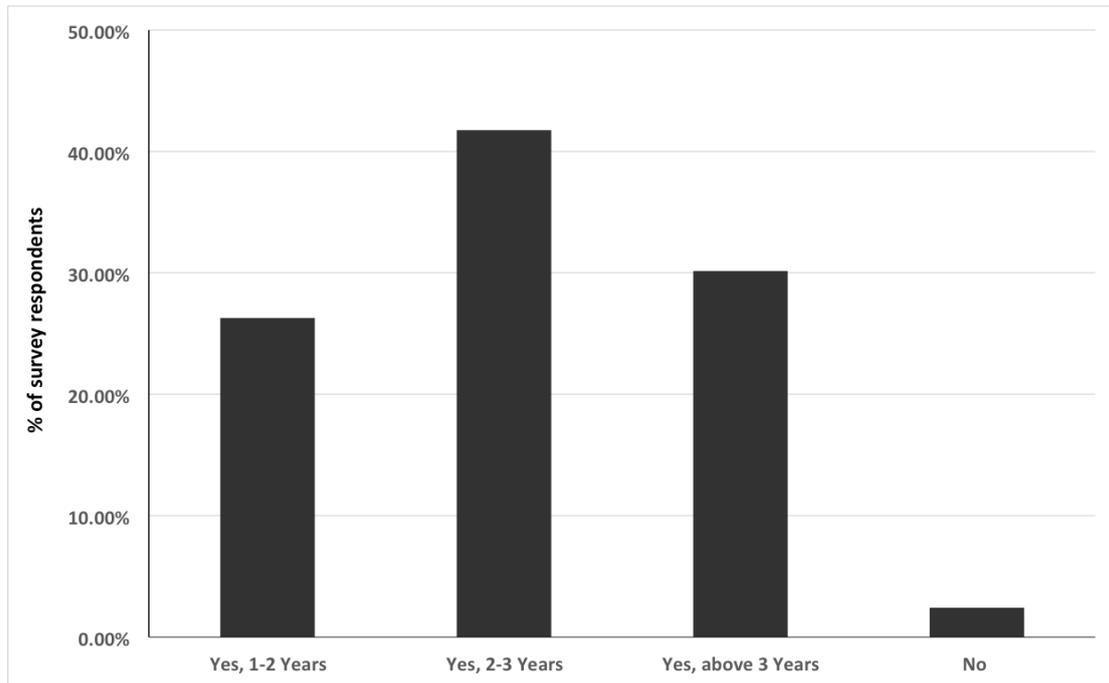
402

403 **6. Results: Unveiling survey results**

404 In our survey of e-bike users, more than 40% of participants expected to continue
405 using e-bikes in the following two to three years, 30% of participants expected above
406 three years, and 28% of participants in the following two years (Figure 2). The
407 percentage of people expecting to transfer to other travel modes is only 2%. This
408 suggests that e-bikes have satisfied the current travel demand of travellers to a great

409 extent.

410



411

412 (Sample size: 403 e-bike users)

413

414

Figure 2 Expected future use of e-bikes: Nanjing survey

415

416 These results, interestingly, reinforce our idea of the contested nature of transport

417 regimes. The e-bike regime does have a strong degree of path dependency, yet it is

418 also one in tension with other transport regimes. For instance, those in favour of e-

419 bikes argue that an “e-bike bans” policy will induce a significant increase in the use of

420 private cars, which will place a higher burden on the traffic system and produce more

421 pollution. If e-bikes are banned, it will cause a significantly higher demand for buses

422 and the metro. On the other hand, if urban governments can allow for the

423 development of e-bikes, traffic congestion will be lower than would otherwise be the

424 case, and at very low cost. The travellers also will retain an additional choice to

425 achieve personal mobility. Hence, e-bikes serve as a source of tension within and

426 between different transport modalities.

427

428 This section presents and discusses which travel modes could be the alternatives to e-
429 bikes in the future (Section 6.1). In order to identify the influential factors of future e-
430 bike adoption, GLM with Gaussian distribution is adopted. As previously summarized,
431 the initial independent variables entering the model include user demographics,
432 previous experience, safety issues, reasons for e-bike adoption, travel purposes, e-bike
433 travel time, e-bike price, and e-bike user anxiety (Section 6.2). The factors influencing
434 alternative mode choice are examined by GLM with Binomial distribution (Section
435 6.3). The initial factors entering the models include demographics, previous travel
436 mode, attitudes to e-bike adoption, and the reasons for transferring to alternative
437 modes. It is also noted that in the questionnaire, the respondents are allowed to select
438 more than one items from the given alternatives. Hence, a series of binomial logits are
439 used instead of the multinomial logits or nested logit because the latter are suitable for
440 a single choice from the alternatives.

441

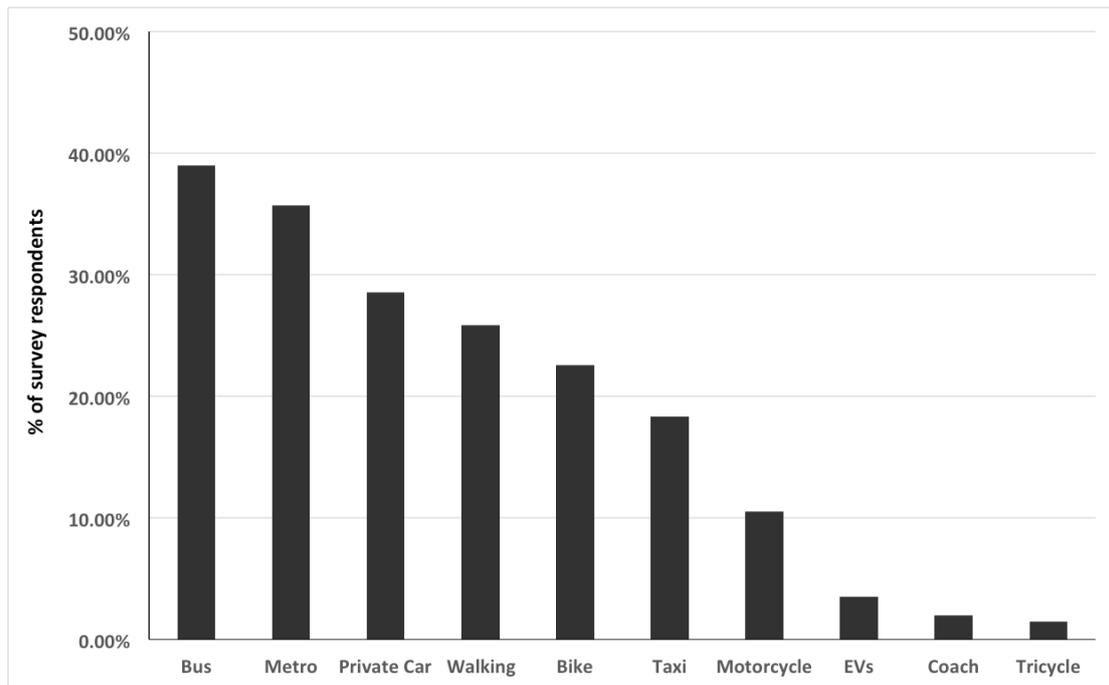
442

443 6.1 Alternative travel mode choices

444

445 Concerning the possible alternative travel modes in the future if e-bikes are
446 unavailable, for example due to e-bike policy, public transport is the primary choice
447 (buses are 38.96% and the metro is 36.72% respectively), followed by private cars
448 with 28.54% of responses (Figure 3).

449



(Sample size: 403 e-bike users)

Figure 3 Alternative mode choices in the absence of e-bikes: Nanjing survey

In comparison, fewer than 25% of e-bike users expecting 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, 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,

469 2007; Weinert *et al.*, 2008), whereas private cars are the most popular alternative
 470 mode in Xi'an (Xu *et al.*, 2014). The alternative mode choice may vary with the cities
 471 due to the difference of city scales, the household income and the level of the
 472 development of public transport system.

473 6.2 The factors influencing e-bike use

| Number of observations=403, ACI=824.91, R ² : 0.6633, Adjusted R ² : 0.6515 | | | | | |
|---|-----------|------------|---------|-------------|----------|
| Variable | Estimate | Std. Error | t value | Pr(> t) | VIF |
| (Intercept) | 0.988470 | 0.071616 | 13.802 | < 2e-16*** | |
| Age | 0.002105 | 0.009710 | 0.217 | 0.828478 | 1.021218 |
| E-bike price | 0.034761 | 0.008491 | 4.094 | 5.2e-05*** | 1.106262 |
| Number of e-bikes in household | 0.064732 | 0.022823 | 2.836 | 0.004813** | 1.064900 |
| Number of bicycles in household | 0.039486 | 0.014690 | 2.688 | 0.007512** | 1.088284 |
| Number of cars in household | -0.028584 | 0.019114 | -1.495 | 0.135640 | 1.029476 |
| Walking (previous travel mode) | 0.049217 | 0.026286 | 1.872 | 0.061943. | 1.080514 |
| Bus (previous travel mode) | 0.063649 | 0.025489 | 2.497 | 0.012950* | 1.175079 |
| Metro (previous travel mode) | -0.072159 | 0.036267 | -1.990 | 0.047360* | 1.063229 |
| Have accidents (1 if have accident, 0 otherwise) | -0.061511 | 0.024368 | -2.524 | 0.012009* | 1.033830 |
| Flexible time (reason of e-bike adoption) | 0.051698 | 0.025046 | 2.064 | 0.039694* | 1.146073 |
| Pro-e-bike attitude (1 if pro-e-bike, 0 otherwise) | 0.056270 | 0.032612 | 1.725 | 0.085278. | 1.089731 |
| E-bike tends to be out of work during use (user anxiety) | -0.038360 | 0.011145 | -3.442 | 0.000643*** | 1.051031 |
| Commute (travel purpose) | -0.073896 | 0.024766 | -2.984 | 0.003034** | 1.056441 |

474 Significant. Codes : 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1

475 **Table 1 Results of predicting e-bike use choice model**

476

477 The results of the GLM are shown in Table 1. The regression analysis is performed in
 478 the similar way to Cherry and Cervero (2007), Cherry *et al.*, (2016) and Campbell *et*
 479 *al.*, (2016), but more independent variables are introduced in our model, as mentioned
 480 in Section 2. The data were coded to represent the attitudes to e-bike development:
 481 supportive or opposing (1 if it is supportive, 0 otherwise). The independent variables

482 are closely related to markets and user practices, culture and symbolic meaning, and
483 maintenance and distribution network. The results of the GLM show that e-bike prices
484 were positively associated with e-bike adoption. One explanation may be that the
485 expensive e-bikes are normally of a better quality and exhibit better performance
486 which fully satisfies the desires of consumers. For example, the scooter style e-bikes,
487 the most expensive type, have a strong frame, a robust brake system, high speed and
488 long battery life. Another reason may be that the respondents plan to use e-bikes for a
489 long period of time, and therefore are motivated to invest in expensive e-bikes.

490

491 The model shows that future e-bike adoption is significantly associated with the
492 household ownership of e-bikes and bicycles. E-bike ownership has the greatest
493 influence and plays a positive role. The ownership of bicycles also increases the
494 probability of future e-bike adoption in the following years. By contrast, future e-bike
495 adoption is not closely related to household ownership of cars, which reinforces the
496 survey results that the people who have owned cars in the family are not precluding
497 the possibility of purchasing e-bikes.

498

499 Concerning the effect of previously used travel modes, the respondents who
500 previously adopted walking or buses tend to expect to transfer to e-bikes in the
501 following years, which is possibly due to a larger demand for personal motorised
502 vehicles than before. In contrast, the e-bike users who previously travelled by metro
503 are less likely to use e-bikes in the future. This could indicate that consumers are more
504 satisfied with the service of the metro than buses. It is not surprising because the
505 metro timetable is highly reliable and generally waiting time is also much less than
506 buses. Therefore, if e-bikes are no longer used, it is more likely that e-bike users
507 transfer to using the metro instead of the bus.

508

509 Now we investigate how future e-bike adoption expectations were affected by the

510 time flexibility when riding e-bikes. Flexible travel time is an essential characteristic
511 of personal motorized mobility, which produces “personalized, and subjective
512 temporalities” (Urry, 2007), and allows motorized vehicle users to travel
513 spontaneously rather than following the official timetable of buses and trains.
514 Compared with cars, e-bikes have lower requirements on the infrastructure conditions
515 and do not need specific parking facilities as cars do, and more importantly, can be
516 used during traffic jams at peak times. The importance of travel time flexibility is also
517 reflected in our survey: the respondents who agreed that e-bikes provide flexibility are
518 more likely to continue to use e-bikes in the future.

519

520 As expected, the participants who held the opinion that e-bike development benefits
521 the urban transport system are more likely to choose e-bikes as their future travel
522 mode. In contrast, user anxiety is negatively associated with e-bike usage. The e-bike
523 users who had accidents with other vehicles are especially unwilling to use e-bikes in
524 the future. It is commented that the positive associations with usage are more
525 individual and internal; for example, the feelings associated with e-bike usage. On the
526 other hand, negative associations are more external and can be influenced through
527 contextual change; for example, improving e-bike performance, and enhancing traffic
528 safety awareness.

529

530 The trip purpose of e-bikes has a negative relationship with e-bike future adoption. If
531 e-bikes are used mainly for commuting, the possibility of adopting e-bikes in the
532 future is relatively small, probably because e-bikes confront the competition from
533 other travel modes when commuting.

534

535 Without statistical significance, the factors such as gender, income, education, and trip
536 time are precluded in the final model. That is, the future of e-bike adoption does not
537 depend on the gender, income, or the educational level of the person.

538

539 6.3 The factors influencing travel mode choice

540

541 It is important to understand the impact on alternative travel modes if e-bikes were to
542 be banned, as the transfer of modes will incur environmental costs and have mobility
543 impacts in the urban transport system. The relationship between each mode and these
544 influencing factors are discussed below.

545

546 6.3.1 Bus

547

| Number of observations = 403, AIC = 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*** |

548 Significant. Codes : 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1

549

550 **Table 2 Predicting the likelihood that current e-bike users will transfer to bus**
551 **usage if e-bikes are unavailable**

552

553 The dependent variable in this binomial model is whether buses are the alternative
554 choice (1=Yes, 0=No), when e-bikes are unavailable. Income is negatively associated
555 with bus usage (Table 2). That is, the low cost of travelling with buses is a critical
556 factor attracting lower income travellers, so the travellers with higher income are less
557 likely to choose buses and are willing to pay more for a better transport service
558 instead. Road conditions also have an influence on choosing buses. The worse the
559 road condition is, the more likely it is that a consumer will choose to use the bus.
560 Other factors positively associated with bus adoption include long trips, previous
561 travelling experiences by bus, and a high demand of time requirement and

562 accessibility.

563

564 6.3.2 Metro

565

566 The dependent variable for this binomial model is whether the metro is the alternative
567 choice (1=Yes, 0=No), when e-bikes are unavailable. The independent variables
568 mainly belong to markets and user practices element and road infrastructure and
569 traffic system element in the regime. The relationship between income and the
570 probability of metro adoption is positive (Table 3), indicating that the travellers with a
571 higher income tend to choose the metro. Consistent with this, the travellers who use e-
572 bikes mainly due to their low cost are less likely to use the metro in the future.

573

| 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 bicycles | 0.20827 | 0.09187 | 2.267 | 0.023389* |
| Physical discomfort | 0.65347 | 0.21059 | 3.103 | 0.001915** |

574 Significant. Codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1

575

576 **Table 3 Predicting the likelihood that current e-bike users will transfer to metro** 577 **use if e-bikes are unavailable**

578

579 The requirement of time accuracy also plays an important role in metro adoption. If a
580 trip has a strict requirement on time accuracy, travellers are more likely to use the
581 metro. Consequently, if there are more new metro stations built, the travellers are
582 more likely to use the metro. So increasing the number of metro stations is an
583 effective method for attracting prospective metro riders.

584

585 The e-bike users who previously used buses are more likely to transfer to using the
586 metro. This could be an indicator that the metro better fits travellers' demands than
587 buses. In contrast, the respondents who previously used private cars are less likely to
588 transfer to the metro, because the respondents who are accustomed to personal
589 motorised vehicles have no preference for travel modes without travel flexibility. For
590 the same reason, respondents with expensive e-bikes have fewer chances to transfer to
591 metro. By contrast, the travellers who have bikes in their households are more likely
592 to adopt metro use, especially when e-bikes are unavailable, indicating that the
593 motorised transport is a future tendency. Furthermore, if respondents are physically
594 uncomfortable, the probability of choosing the metro will increase. This could be
595 because metro facilities better suit their needs.

596

597 6.3.3 Private cars

| Number of observations = 396, AIC = 418.51, Likelihood Ratio=81.582, Pseudo R²=0.171 | | | | |
|--|-----------|------------|---------|-------------|
| Variable | Estimate | Std. Error | t value | Pr(> t) |
| (Intercept) | -3.511111 | 0.510365 | -6.880 | 2.41e-11*** |
| Gender (Female) | 0.637487 | 0.250658 | 2.543 | 0.01137* |
| Household ownership of cars | 0.674912 | 0.193139 | 3.494 | 0.00053*** |
| Previously used travel mode (walking) | 0.504620 | 0.269605 | 1.872 | 0.06200. |
| Previously used travel mode (car) | 0.795335 | 0.390759 | 2.035 | 0.04249* |
| Income increase | 0.766780 | 0.267546 | 2.866 | 0.00438** |
| Trip time | 0.012819 | 0.004519 | 2.837 | 0.00480** |
| Trip distance (short) | -1.152717 | 0.405715 | -2.841 | 0.00473** |
| E-bike restriction policy | 0.784523 | 0.363037 | 2.161 | 0.03130* |
| Safety issues | 1.596260 | 0.405356 | 3.938 | 9.74e-05*** |
| Demand of high accessibility | 0.529472 | 0.267232 | 1.981 | 0.04826* |

598 Significant. Codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1

599

600 **Table 4 Predicting the likelihood that current e-bike users will use private cars if**
601 **e-bikes are unavailable**

602

603 The dependent variable for this binomial model is whether using a private car is the
604 alternative choice (1=Yes, 0=No), when e-bikes are unavailable. The independent
605 variables mainly have connection with markets and user practice element, regulations
606 and policies element and automobile regime. The positive relationship with car usage
607 is found in female e-bike users (Table 4), meaning that female travellers have stronger

608 intentions to transfer to using private cars.

609

610 It is noted that although female travellers presented a strong willingness to transfer to
611 private car use, they may not actually take it into action, because there is a so-called
612 value-action gap between the attitude and corresponding behaviour (Lane and Potter
613 2007; Olson 2013). In the model, the use of private cars is closely correlated with the
614 safety issues regarding e-bikes. E-bike users with greater safety concerns about e-bike
615 are more likely to transfer to cars, meaning that they perceive that private cars are
616 safer.

617

618 As expected, the household ownership of cars is positively associated with car usage.
619 Consistent with the effect of household ownership of cars, the travellers who
620 previously adopted cars are more likely to use private cars, if e-bikes become
621 unavailable. The result may indicate that private cars are the “expensive dream travel
622 vehicle” for travellers.

623

624 Trip time is significantly positively related to private car adoption, indicating that the
625 longer trip times or distances lead to a higher probability of choosing private cars.
626 Other potential groups of e-bike uses inclined to transfer to car use are: 1) The
627 respondents choosing e-bikes for high accessibility and 2) the ones who are worried
628 about the future release of an e-bike restriction policy.

629

630 *6.3.4 Walking*

| Number of observations = 397, AIC=399.53, Likelihood Ratio=75.13, Pseudo R²=0.254 | | | | |
|---|------------|------------|----------------|--------------------------|
| Variable | Estimate | Std. Error | <i>t</i> value | Pr(> <i>t</i>) |
| (Intercept) | -0.871374. | 0.501176 | -1.739 | 0.082095 |
| Income | -0.230349 | 0.099483 | -2.315 | 0.020587* |
| Income increase | -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 ^e -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* |

631 Significant. Codes : 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1

632

633 **Table 5 Predicting the likelihood that current e-bike users will transfer to**
634 **walking if e-bikes are unavailable**

635

636 The dependent variable for this binomial model is whether walking is the alternative
637 choice (1=Yes, 0=No) if e-bikes are unavailable. The independent variables are
638 closely related to markets and user practices, road infrastructure and traffic system
639 and automobile regime. Income enters the model with a negative sign, suggesting that
640 the survey participants with higher incomes or high expectations for future income are
641 less likely to choose walking as an alternative mode (Table 5). This may be because
642 walking is the cheapest way to travel. It is also possible that these respondents with
643 higher income are able to locate further from city centres in new housing
644 developments, so walking ceases to be a viable option. So the respondents who
645 previously travelled by walking are more likely to walk when e-bikes become
646 unavailable.

647

648 If the respondents show a positive attitude towards e-bike development, they are less
649 likely to choose walking. It is interesting that the participants who have more
650 expensive e-bikes are more likely to transfer to walking in the future. A possible
651 explanation is that the e-bikes with good performance satisfy users’ travel demands,
652 so they have no interest in other vehicles. But walking is a complement to e-bikes.

653

654 It is not surprising that trip time is negatively associated with walking, indicating that
655 the shorter the trip time the more likely it is that respondents will choose to walk. But
656 if the trip has a high requirement on the accuracy of time, the respondents are less
657 likely to choose walking.

658

659 The result also shows that respondents are more likely to choose walking when new
660 bus routes are added. This could be because respondents need to walk to bus stations.

661 The result could be an indicator that urban transport mobility tends to be multimode.

662

663 However, taking into account the safety issues of using e-bikes, walking is more
664 likely to be chosen. That is, if the respondents experience accidents when using e-
665 bikes, they are more likely to choose walking. If road conditions are not suitable for e-
666 bike travelling, this can also increase the number of people willing to transfer to
667 walking.

668

669 6.3.5 Bicycle

670

671 The dependent variable for this binomial model is whether bicycles are the alternative
672 choice (1=Yes, 0=No), when e-bikes are unavailable. The independent variables
673 mainly have connections with markets and user practice, production system and
674 industry structure, and automobile regime. The e-bike users who previously adopted
675 bicycles are more likely to transfer back to bicycles if e-bikes are unavailable (Table
676 6). From our model, the household ownership of bicycles enters the model with a
677 positive sign, suggesting that the more bicycles owned by the household, the more
678 likely it is that consumers will choose bicycles.

679

| 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 issues | 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** |

680 Significant. Codes : 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1

681

Table 6 Predicting the likelihood that current e-bike users will transfer to bicycle use if e-bikes are unavailable

682
683
684

685 By contrast, the households who own more cars are less likely to use bicycles, which
686 agrees with our previous discussion that car users will continue to use cars in the
687 future.

688

689 As expected, if the respondents are not satisfied with the e-bike performance, they
690 tend to transfer to bicycle use. A parallel finding is that the more expensive e-bikes the
691 respondents have, the less likely they are shift to bicycle use, because expensive e-
692 bikes normally perform better and can satisfy users' requirements.

693

694 Interestingly, additional metro stations can promote bicycle use, indicating that they
695 may be used to transfer to metro stations. So similar to walking, bicycles can also be a
696 complement to public transport. Finally, safety concerns regarding e-bikes is
697 positively associated with bicycle usage, which suggests that respondents believe that
698 bicycles are safer than e-bikes.

699

700

701 **7. Discussion: Comparative factors and travel mode transitions**

702 In this section an analysis is offered of the factors likely to be of influence in travel
703 mode transitions, and the role of gender issues in those factors. Put another way, we
704 connect the survey results back to our theory of sociotechnical transitions and the
705 MLP.

706

707 *7.1 Comparison of influencing factors*

708

709 Table 7 lists the factors which can influence mode choices.

| | E-bike | Bus | Metro | Car | Walking | Bicycle |
|--|--------|-----|-------|-----|---------|---------|
| Gender (Female) | N | N | N | + | N | N |
| Age | N | N | N | + | N | N |
| Income | N | - | + | N | - | N |
| Income increase | N | N | N | + | - | N |
| Household ownership of e-bikes | + | N | N | N | N | N |
| Household ownership of bicycles | + | N | + | N | N | + |
| Household ownership of cars | N | N | N | + | N | - |
| Safety consideration | 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 |
| New metro stations added | N | N | + | N | N | + |
| New bus routes added | N | N | N | N | + | N |

710 “+”: positive sign, “-”: negative sign, “N”: no significant relationship

711 **Table 7 The influence factors of travel mode choice behaviour**

712

713 Income seems to influence the travel mode choice significantly. Income is
714 significantly related to travel mode choices in our model. Travellers with higher
715 income tend to use more expensive travel modes, such as metro and cars. Our
716 conclusion is also supported by the travel behaviour research of Dieleman *et al.*
717 (2002), who has a similar finding that the higher the household income, the more
718 likely it is that respondents use cars. However, the statistically significant relationship
719 between income and mode choice was not found by Cherry and Cervero (2007). Our
720 study further revealed that people with high expectations for future income tend to
721 buy private cars. The result reinforces the automobility culture of China in which the
722 car is a symbol of wealth, whereas other vehicle users are identified as less wealthy or
723 from a poor educational background.

724

725 Households in China tend to have more than one type of vehicle. In our sample,
726 nearly 50% of e-bike users have both e-bikes and cars in their households, and nearly
727 80% of car drivers have e-bikes in their households. This may indicate that the
728 respondents who have both e-bikes and cars are likely to adopt e-bikes. Hence, e-
729 bikes and cars can complement each other for a better motorised mobility.

730

731 According to previous research (Handy, 1996; Cervero, 2002; Naess, 2003; Naess and
732 Jensen, 2004; Srinivasan and Rogers, 2005), the infrastructure construction of public
733 transport has a significant impact on mode choice behaviour. Our research results also
734 fit their observations – and in doing so, lends support to the obduracy of transport
735 regime infrastructure. In our research, newly added metro or bus routes do not only
736 increase the probability of using public transport, but also increase the chances of
737 bicycle adoption and walking. This result may suggest that the door-to-door service of
738 e-bikes could be partly replaced by the combined use of bicycles and metro routes.
739 However, in the bike future use predictive model by Cherry and Cervero (2007), the
740 factor of infrastructure construction of public transport was not considered.

741

742 Also, we find that trip time requirement has an extensive influence on travel
743 behaviour. For the same trip length, if an accurate time is required, buses and the
744 metro are more likely to be chosen. In the opposite situation, walking is more likely.
745 In addition, if a trip is not urgent, travellers tend to choose a slow speed transport
746 mode. If it is an urgent trip, travellers tend to choose a faster transport mode. This
747 finding is different from Cherry and Cervero (2007) who used a Logit model to
748 examine the factors which have an impact on the mode choice. Their model did not
749 consider the trip time accuracy requirement, but only took into account the travel time
750 gap between e-bikes and bicycles as the independent variable. They suggested that the
751 wider the travel time gap between e-bikes and bicycles, the more likely it is that
752 people will choose e-bikes (Cherry and Cervero, 2007). In addition, the longer the

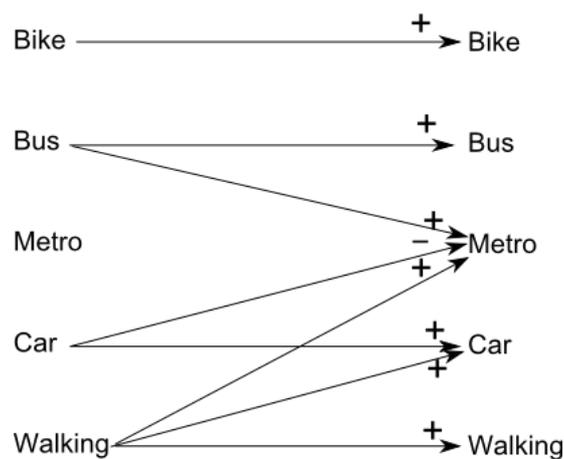
753 travel time of a particular mode, the lower the probability of choosing that mode is
754 (Cherry and Cervero, 2007). However, the trip time requirements affect the mode
755 choice to a greater degree than actual trip time. This understanding also contributes to
756 the MLP by indicating the temporality of transitions – that transport regimes are fluid,
757 and the timing of the service demanded can implicate how or why particular modes
758 are favoured. The co-evolution of urban structures and mobility possibilities in
759 specific spatial and temporal settings therefore results in distinct trajectories for
760 regimes and niches that can only be uncovered empirically, as we demonstrate here.

761

762 Our study also fits the idea that users rely on utility-maximising rules. Generally, a
763 traveller chooses the suitable travel mode according to the opportunity cost of the
764 time that was spent on the journey. In our models, when the trip has no time
765 requirement, a traveller is more likely to walk to the destination. If the trip is urgent, a
766 traveller has a strong desire to save time and thus will choose a more expensive but
767 faster travel mode. In addition, our model also fits the income effect, which is defined
768 as a common phenomenon that the price change in consumption results in the change
769 of the consumer's real income, and then the consumer purchases more or less
770 products until a new equilibrium is reached again for the real income (Deaton and
771 Muellbauer, 1980). In our study, the lower the income of the traveller, the more likely
772 he or she is to use buses or to walk rather than using a car, which suggests that they
773 are sensitive to price and will choose basic travel services which match their income
774 level. As income grows, a traveller will pay more for the travel service with better
775 quality; for example, the metro or a car. This underscores the dynamism of users and
776 flexibility of regimes, namely that creative users will consider multiple regimes as
777 they decide about particular modes. Hence part of the trajectory of regime stability or
778 instability is tied to market and technological possibilities: the emergence of e-bikes
779 as a technology package coincided with urbanization but also with a growth in
780 personal or household income that resulted in e-bike adoption on a large scale. With

781 further personal or household income growth there may be a further shift into cars.
 782
 783 Safety issues influence travel mode choice behaviour as an important psycho-social
 784 factor. If e-bike users are sensitive to traffic safety problems, or experienced accidents
 785 before, they are less likely to use e-bikes, and are more likely to travel by walking,
 786 bicycles and cars. Sönmez and Graefe (1998) found that perceptions of risk and safety
 787 from past travel experience are significantly associated with future travel behaviour
 788 by applying information integration theory (it explores how individuals form and
 789 change their psychophysical and value judgments through the integration of a number
 790 of information sources), protection motivation theory (it investigates how a person
 791 process threats and stress and how to cope with them), and logit regression. Their
 792 result concluded that perceptions of safety from past travel experience increased the
 793 probability to travel there again, while the perceptions of risk from past travel
 794 experience decreased the probability to travel (Sönmez and Graefe, 1998). Compared
 795 to the previous literature, which performed qualitative analysis on safety issues, our
 796 study incorporated the safety factor to GLM with Gaussian distribution and GLM
 797 with Binomial distribution of e-bike mode choice for quantitative analysis.

798



799

800 **Figure 4 Travel mode transition flow when e-bikes are unavailable**

801

802 In addition, it is found that the e-bike experience can change people's inclination for
803 using alternative modes, as illustrated in Figure 4. One is a positive relationship
804 between the previous and future travel mode choices. The travellers who previously
805 travelled by bicycle are more likely to shift to bicycle use in the absence of e-bikes.
806 The similar trends are also found in e-bike users who previously used buses, cars and
807 walking. The other one is the tendency to transfer to metro and private car use.
808 Pedestrians and those who previously travelled by bus are more likely to transfer to
809 the metro use. In addition, the travellers who previously walked exhibited a great
810 demand for car adoption. The result implies an increasing demand for faster speed
811 vehicles. The experience of e-bike adoption partly changed the future choice of travel
812 modes.

813

814

815 7.2 Gender differences in future mode choices

816

817 The future travel model choices of female and male e-bike users are influenced by
818 different e-bike usage experiences—emphasizing the heterogeneity of users. This
819 gender difference is embodied in the future adoption of motorcycles and private cars,
820 but not found in the future choices of buses, walking, bicycles, and metro (Table 8).

| | Bicycle | | <i>p</i> -value | | Motorcycle* | | <i>p</i> -value |
|--------|-----------|------------|-----------------|--------|---------------|------------|-----------------|
| | Yes | No | | | Yes | No | |
| Male | 43(21.9%) | 168(78.1%) | 0.6757 | Male | 28(13.1%) | 215(86.9%) | 0.0928 |
| Female | 43(24.2%) | 175(75.8%) | | Female | 13(7.4%) | 165(92.6%) | |
| | Bus | | <i>p</i> -value | | Metro | | <i>p</i> -value |
| | Yes | No | | | Yes | No | |
| Male | 86(40.0%) | 129(60.0%) | 0.79579 | Male | 73(34.0%) | 142(66.0%) | 0.14963 |
| Female | 68(38.3%) | 110(61.7%) | | Female | 73(41.1%) | 105(58.9%) | |
| | Walking | | <i>p</i> -value | | Private cars※ | | <i>p</i> -value |
| | Yes | No | | | Yes | No | |
| Male | 51(23.8%) | 164(76.2%) | 0.540 | Male | 51(23.8%) | 164(76.2%) | 0.0111 |
| Female | 47(26.6%) | 131(73.5%) | | Female | 63(35.4%) | 115(64.4%) | |

821 ※ *p*-value <0.05; * *p*-value <0.1

822 **Table 8 Chi-squared test results of alternative travel modes**

823

824 The significant difference between female and male e-bike users in terms of future
825 motorcycle choice is similar to the gender differences in the previous motorcycle
826 adoption: the percentage of male respondents (13.1%) is more than female
827 respondents (7.4%).

828

829 The gender differences in future private car choice are especially significant. 35.4% of
830 female e-bike users are willing to shift to using private cars in the absence of e-bikes,
831 while only 10.7% of them previously travelled by private cars. In comparison, fewer
832 male e-bike users (23.8%) will shift to private cars in the future. The result is also
833 supported by the prediction of our that female respondents are significantly positively
834 related to private car use. An explanation is that females are more concerned about the
835 physical safety issues compared to males. Moreover, women in the family in China are
836 normally responsible for dropping off/picking up children at/from school, which is also a
837 possible reason for the fact that women are more willing to shift from e-bikes to private
838 cars.

839

840

841

842 ***7.3 Future transitions of e-bikes***

843

844 The successful e-bike transition from niche to regime was not the direct result of
845 positive, purposive policy interventions at national or sub-national level, nor the result
846 of nurturing niches (Wells and Lin, 2015). Moreover, landscape and regime actors
847 restrained the e-bike's ascent to regime status by banning them. Due to the pressures
848 arising from outside criticism and the increasing demand for personal motorised

849 mobility, the government acquiesced to the reality and relaxed the e-bike restrictions,
850 which allowed e-bikes' further permeation. E-bikes well satisfied the current travel
851 demands for personal mobility with the advantages of affordable price, effort saving,
852 flexibility, high accessibility, and saving time in traffic jams (Lin *et al.*, 2017). This is
853 also supported by our survey results. That is, 98% of the e-bike users would like to
854 continue to use e-bikes in the future, suggesting that e-bikes did not only meet their
855 current travel demands, but also were predicted to satisfy their future personal
856 mobility. In addition, the survey variables which have significantly positive
857 relationship with e-bike future adoption, including e-bike price, commute (travel
858 purpose), flexible time (reason of e-bike adoption), bus (previous travel mode),
859 walking (previous travel mode), were closely related to markets and user practices
860 element in the regime. Therefore, the spontaneous e-bike transition was mainly
861 triggered and propelled by the markets and users. As a result, e-bikes seem to be well
862 embedded in the current transport regime.

863

864 Although e-bikes are an existing transport regime, our analysis suggests that they are
865 the one in decline, or, in other words, an intermediary regime. The first reason is that
866 e-bikes are subject to the adverse effect from landscape and regime. "Public Transport
867 Priority Development" policy is widely implemented across China (Quan *et al.*, 2006).
868 This landscape pressure forced the regime actors to re-structure urban transport
869 systems, and especially strongly promoted public transport development, such as
870 reducing ticket prices, adding more buses and bus routes, and even building an
871 entirely new metro system, which had great impact on citizens' travel mode choices.
872 In our survey results, new added metro stations and new added bus stations were
873 significantly positively associated with other travel mode adoption, such as metro,
874 bicycles, and walking. These actions tightened the living space of e-bikes, which
875 might lead to the de-alignment transition process of e-bikes.

876

877 Secondly, e-bikes have to cope with the fierce competition from automobile regime
878 and receive lock-in mechanisms (culture and symbolic meaning) in the complex
879 socio-technical regimes. Many respondents are willing to shift to private cars with an
880 increase in income according to our survey results. In addition to practical usage
881 considerations, this is also closely related to automobility culture in China. A car user
882 is normally viewed as a person with wealth and a well-educated background. In
883 contrast, the current symbolism and social connotation of e-bikes is that e-bikes users
884 are identified as “poor, not well-educated” (Tyfield, 2014). However, it should be
885 pointed out that the above negative opinions on e-bike users are not completely
886 consistent with the facts. For example, our survey reveals that the average education
887 and income level of the e-bike users is much higher than the overall average level of
888 Nanjing City. 63.57% of e-bike users have obtained a college degree or above, and
889 45.23% of e-bike users have completed a university degree. 87.6% of the e-bike users
890 are employed and their income is in a higher-middle range. Nevertheless, such a
891 negative impression of e-bikes in the public domain is hard to change in a short time,
892 so it will be likely to influence the future choice of e-bikes and profoundly shape the
893 trajectory of socio-technical transition.

894

895 Thirdly, e-bikes still confront the high possibility of e-bike restrictions and bans
896 policy from landscape and regime, bringing more uncertainties to the future
897 development of e-bike transition. As mentioned previously, in the early stage of e-bike
898 transition, landscape developers and regime actors issued e-bike bans, but then
899 revoked the policy due to the pressures from outside criticism and the increasing
900 demand for personal motorised mobility. Since then, the number of e-bikes
901 skyrocketed, accompanied with exponentially increasing traffic accidents and severe
902 lead pollution, which highlighted the negative impacts of e-bikes. Out of the concern
903 of the transport safety and environmental protection, a new round of e-bike restriction
904 and ban policies were issued by landscape developers and regime actors in 2011 in

905 Beijing, Tianjin, Guangdong Province, Yunnan Province, and Zhejiang Province,
906 seriously hindering the e-bike development. These policies were strongly opposed by
907 outside criticism (e.g. journalists, scholars, and public intellectuals) and e-bike users,
908 who suggested the government to draft new e-bike national standard and regulate e-
909 bike rather than simply banning them. However, the suggestions were not adopted in
910 the above-mentioned cities or provinces. Even worse, Guangzhou city went further in
911 the direction of restricting e-bike usage, which started to completely ban e-bikes in
912 2017. In our survey result, the e-bike restriction policy is a key influential factor,
913 which discouraged the desire of future e-bike adoption. If the landscape developers
914 and regime actors stubbornly and arbitrarily implement e-bike restriction and ban
915 policies, it will be highly possible that e-bikes can only serve as an intermediary
916 regime.

917

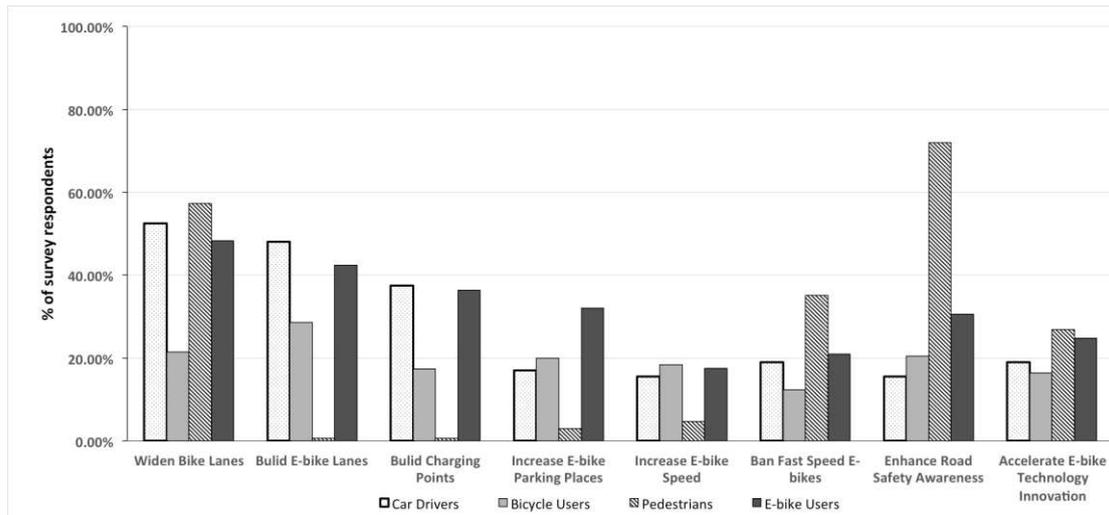
918

919 ***7.4 Perspectives on regimes in tension***

920

921 Future suggestions for e-bike development are revealed by different groups, as shown
922 in Figure 5, and they confirm our notion that regimes are currently competing and co-
923 evolving in China. A Chi-squared test of independence was performed to examine
924 whether there were statistically significant differences amongst different traveller
925 groups in relation to their suggestions for e-bike development. After the test,
926 statistically significant differences were found in the suggestions such as widening
927 bike lanes, building e-bike lanes, building charging points, increasing parking places,
928 increasing e-bike speed, banning high-speed e-bikes, and enhancing road safety
929 awareness. On the other hand, no statistically significant differences exist when the
930 suggestion is accelerating e-bike innovations.

931



(Sample size: 200 car drivers; 200 bicycle users; 200 pedestrians; 393 e-bike users)

Figure 5 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

954 of bicycle users, the introduction of separate e-bike lanes is more reasonable, which
955 implies that e-bikes were viewed as a threat to the safety of bicycle users when
956 sharing the same lane. However, the overall attitudes of all groups of respondents to
957 e-bike development are positive. They agreed that e-bikes have contributed to
958 personal mobility and are very environmentally friendly.

959

960 Bringing this back to our theoretical perspective, these results about future e-bike
961 development are closely related to the landscape and regime change (see Geels, 2002).
962 In terms of the suggestions for improving bicycle lanes, if a great number of vehicle
963 users have this requirement it will give rise to an intensive pressure on the regime,
964 which will potentially destabilise the existing mobility regime. Subject to this pressure,
965 policymakers could take measures to improve transport infrastructures in favour of e-
966 bikes. Suggestions regarding the enhancing of road safety awareness may be
967 understood as a form of socio-cultural process, occurring at the landscape level. It is
968 noted that the low response rates of “accelerate e-bike technology innovation”
969 indicated that the current e-bike technology well satisfied the needs of majorities,
970 which further supported that e-bikes have already reached the ‘regime’ level and the
971 public concern mainly arised from the safety problems that induced “e-bike ban
972 policy”.

973

974

975 **8. Conclusion and implications**

976 Based on original data collected from the survey in Nanjing city, this study has
977 explored how far the e-bike regime is likely to continue to be embedded in transport
978 choices. It therefore presents a novel, and rare, utilization of quantitative methods
979 used to test the validity and application of sociotechnical transitions theory, and the
980 Multi-Level Perspective on innovation. Our GLM predicts the choices with respect to

981 future e-bike adoption. User attitudes, demographics, safety issues, and user anxiety
982 about battery performance are all significant factors that influence travel mode choice
983 in the GLM. The probability of choosing e-bikes is positively associated with the
984 household ownership of e-bikes, the household ownership of bicycles, the cost of e-
985 bikes, pro-e-bike attitudes, and the demand for flexible trip times, while the negative
986 factors are user anxiety about e-bike performance, and experience of accidents.

987

988 If an “e-bike ban policy” is issued, the possible alternative modes are ranked as
989 follows: buses, the metro, private cars, walking and bicycles. Hence, public
990 transportation will be subject to a great transportation pressure. The binomial models
991 show that the alternative mode choice is significantly related to income. The lower
992 income respondents tend to use buses or will walk, while higher income respondents
993 prefer to use the metro and private cars. If the trip requires an accuracy of time, the
994 respondents are more likely to choose motorised vehicles. If the trip has no time
995 requirement, the respondents are more likely to choose slower and cheaper travel
996 modes, such as walking. New metro stations will increase the likelihood of choosing
997 to use the metro and bicycles. New bus routes will increase the chances of adopting
998 walking as a mode of transport. Participants with high expectations for future income
999 increase tend to buy private cars, which suggests that the e-bike is highly possible to
1000 become an intermediate mode to cars in terms of personal mobility vehicle choice.

1001

1002 Through the lens of the MLP, we can find that e-bikes are a regime in decline. This is
1003 due to the above mentioned gradual changes of regulations, use patterns,
1004 infrastructures, cultural discourse and travel preferences. These changes lead to de-
1005 alignment of e-bike markets, production systems and industry structures in the
1006 existing regime. As a result, e-bikes may only serve as intermediate transport modes
1007 on Nanjing’s motorisation pathway – and they remind us that regimes have often
1008 overlooked spatial and temporal attributes.

1009

1010 The future work is to conduct the survey in a great variety of locations with a larger scale
1011 of sample selection. Moreover, the latent variables, such as perceptions and attitudes, will
1012 be investigated systematically in the framework of Hybrid Discrete Choice models
1013 (Bahamonde-Birke *et al.*, 2017).

1014

1015

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1022

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