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Spontaneous emergence versus technology management in sustainable mobility transitions: Electric bicycles in China

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Spontaneous emergence versus technology management in sustainable mobility transitions: Electric bicycles in China

1. Introduction

‘Mainstream’ electric car technology has received widespread governmental support world-wide in the form of R&D subsidies, investment subsidies for production capacity, incentives and preferential treatment to encourage purchase and use, and related support for infrastructure developments (Brand et al., 2013) as well as much research to understand how consumer acceptance can be increased (Kim et al., 2014; Petschnig et al., 2014; Lopes et al., 2014). Despite a plethora of interventions, support and experimentation it is reasonable to conclude that the prevailing automobility paradigm remains virtually intact (Wells and Nieuwenhuis, 2012; Steinhilber et al., 2013). In China, on 28th June 2012, the State Council issued ‘Energy saving and new energy automobile industry development planning (2012-2020)’ (State Council, 2012). In this plan, energy-saving automobiles are referred to as the vehicles with internal-combustion engines as the main power system and having fuel consumption superior to the target values for the next stage; while new energy automobiles mainly include battery electric, plug-in hybrid electric and fuel cell vehicles. The plan aims to promote the development of electric vehicles and the transition to a new energy automobile industry. This plan strongly supports the development of new energy vehicles rather than electric bicycles or other electric two-wheel modes of transport. By the end of 2012 in China, government departments had purchased 10,000 new energy vehicles, but only a few were purchased as private cars (Zeng, 2013). By contrast, in the same year, an estimated 29.3 million electric two-wheelers were purchased by consumers to achieve personal mobility (Gunther, 2013).

It is striking that in China the electric two-wheeler market has grown very strongly from almost nothing to being a substantial activity in a little over ten years (Weinert et al, 2007) without overt policy support. China in 2013 was both the largest producer and largest market for electric bicycles and other electric two-wheelers in the world (Harrop, 2013), yet this market has received none of the attention, protection and support given to 'new energy vehicles' in China (Kimble and Wang, 2013); and in some cities the authorities have actively sought to discourage the use of (electric) bicycles (Weinert et al, 2007). As we show below, government policy has been significant for the electric two-wheel market, but in different ways.

This paper therefore seeks to address, in an exploratory case study, the urgent need to understand how and why the electric two-wheel market has emerged in China, and the prospects for learning from the market for applications in other countries around the world. That is, the paper seeks to identify preliminary causes of the emergence of the electric two-wheel market. Drawing on secondary data this paper seeks to chart the development of the electric two-wheel market in a policy vacuum. While there has been attempts to understand this growth from various perspectives (Weinert et al., 2008), this paper links the multi-level perspective of socio-technical transitions from Geels (2002; 2005), Kemp and others (Smith et al., 2005; Kemp et al., 2007; Kemp et al., 2011) with a multi-scalar framework in order to use transitions theory to explain the process of change outside of the traditional reference context of technology policy and management.

The paper commences with a short account of socio-technical transition pathways and the issue of whether electric two-wheelers constitute an emergent niche to challenge the existing mobility regime. Thereafter the paper provides a brief outline of the methodological and definitional issues related to the study reported here before moving onto an historical account of the shifts in pathways that could be attributed to electric two-wheelers in China with attention paid to the rapidity of change and its spontaneous character. It is concluded that the balance of product advantages and disadvantages has provided an historical moment in which electric bicycles have flourished despite neglect from traditional policy interventions, but it is rather less certain that they are to be understood as an environmental alternative to the car. From the standpoint of theory, it is suggested that socio-technical transitions thinking has somewhat neglected the contribution of the policy measures intended to achieve an impact in one aspect but resulting in changes in another aspect.

2. Spontaneous emergence or purposive nurture: the perspective of multi-scalar transitions theory

Transitions theory is a way of understanding the permeation of socio-technical change across time and space. However, those working with sustainable production and consumption frameworks or theories of sustainable transitions tend to do so with a distinct policy orientation in which forms of governance intervention are anticipated to be fundamental to a successful migration away from currently unsustainable practices. The underlying assumption is that purposive policy interventions are necessary in order to stimulate and nurture new production-consumption modes, resulting in a concern for fiscal and other incentives, learning from socio-technical experimentation, consensus building, R&D support, infrastructure development, regulatory frameworks and other features (Beck et al., 2013; Small, 2012). Processes of change are held to be relatively ponderous and subject to much inertia. In contrast, as this paper seeks to show, the disruptions to embedded regimes identified by Marsden and Docherty (2013) as necessary triggers of socio-technical change have indeed occurred in the realm of electric bicycles in China, which offers more encouragement for positive change elsewhere.

It is interesting to note that while transitions theory has embedded within it a distinctly managerial and governance perspective, some of the initial examples used to establish this increasingly prevalent theoretical framework did not necessarily display purposive interventionism. Transitions theory emerged as a lens through which to explain historical socio-technical change, rather than as a policy instrument with which to guide prospective change, though continued elaboration and refinement along with some 'hybridisation' with other theoretical perspectives has shifted the focus of this school of thought (Geels, 2011). Hence, an extended moment of historical and spatial serendipity appears to be crucial in allowing technological innovations, entrepreneurial guile and consumer bravery to create the basis of a new socio-technical regime. The typology from Berkhout et al. (2004) offers a framework in which there are four potential transition pathways depending upon the degree of planned coordination involved and the extent to which external or internal resources are deployed. Spontaneous emergence in their typology is uncoordinated (i.e. market-generated) as opposed to a vision-driven centrally planned transition that is purposive in character. Geels and Schot (2007) offer a more nuanced interpretation of transition pathways in which outcomes are not assumed to be either ‘planned’ or ‘unplanned’, but are rather an emergent mixture of the two. The Geels and Schot (2007) framework thus identifies six possible theoretical pathways arising out of grounded analysis of actual cases (P0 to P5 in the list below): Reproduction of the existing regime; the transformation pathway undertaken primarily by the regime actors; the de-alignment and re-alignment pathway triggered by significant landscape level changes; the technological substitution pathway in which niches are the main vector for change; the reconfiguration pathway in which symbiotic niche and regime interactions underwrite the transition process; and a sequence of transitions from transformation and reconfiguration to others of the above possible pathways.

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') at a moment 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 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, then 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.

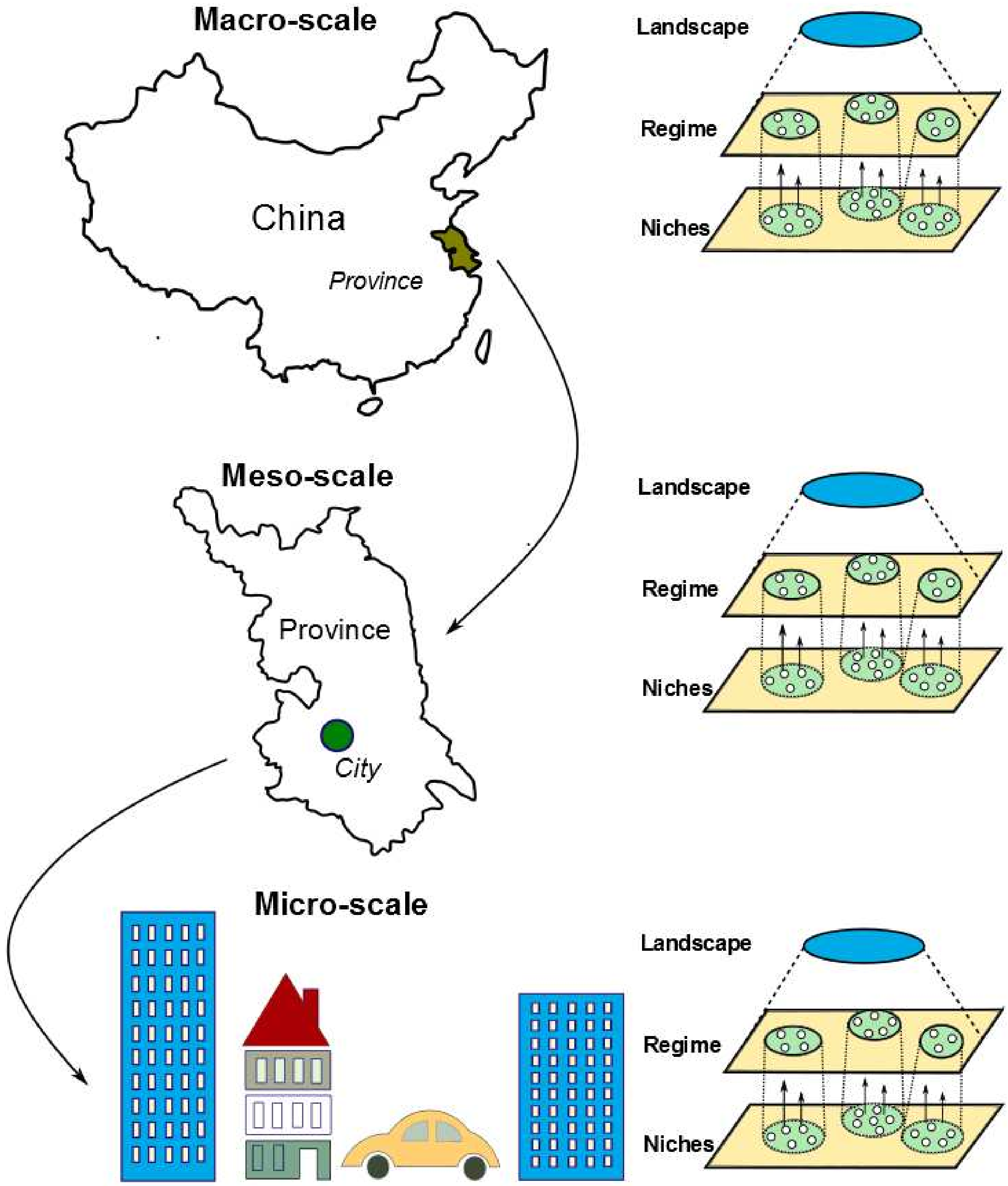
P3. *Technological substitution:* If there is much landscape pressure (‘specific shock’, ‘avalanche change’, ‘disruptive change’) at a moment when niche innovations have developed sufficiently, the latter will break through and replace the existing regime.

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

The transitions process occurs over geographic space, but the definitions of landscape, regime and niche are ambiguous in practice (Coenen et al., 2012). For example, can a city with millions people be considered as a landscape or a niche? Furthermore, the operation of the transition process in which a new regime is embedded is also one in which the spatial scale changes (Hodson and Marvin, 2012). In effect then, transitions theory is multi-scalar with regard to transitions pathways as is illustrated in Figure 1. In this view of transitions theory each embedded regime system at the macro-scale is comprised of numerous sub-systems or constituent elements in micro-scale, and each constituent element has its own micro-structure with a self-contained multiple perspectives. Hence, at the macro-level, the coupling and de-coupling between the sub-systems is seen as the primary mechanism underpinning the transition process in the global system. Transition theory applied in this multi-scalar manner is especially useful for a large and complicated system like that represented by China. While the unitary nation state is often the logical empirical forum for analysis, the geo-political structures within the nation state can be of great significance. For example, large cities in China have a population that rivals or surpasses many nation states, and those cities are economically and socially diverse. City and provincial authorities have relatively independent policy-making power in certain key areas, notably in this case transportation. In combination, however, the cities also serve as constituent elements of China from a macro-viewpoint. As we discuss below, the transition to electric two-wheelers in China has not been ‘homogeneous’ and ‘synchronous’. Instead it is influenced by different transition processes in various cities in which outcomes are both uncertain and contested.

Figure 1: Transition theory in a multi scalar framework



An important question is the extent to which electric two-wheelers, however defined, represent an alternative to the existing mobility regime, a substitution technology temporarily displacing petrol-engine motorbikes and scooters, or an addendum to the range of mobility alternatives. In other words, does the rapid and substantial uptake of electric two-wheelers contribute to more sustainable mobility, and simultaneously undermine the viability of the existing (less sustainable) mobility regime? It is probably too early to answer these questions definitively. In the first instance, however, it is necessary to establish the scale of the electric two-wheeler market as a transport mode and to understand the circumstances under which this market has emerged – as is the purpose of this exploratory paper. From the perspective of the established mobility regime in China from the 1980s onwards we can define traditional bicycles, motorcycles, cars and buses as the primary constituent elements. In this respect it could be argued that electric two-wheelers as an emergent niche potentially act to displace existing bicycles and motorcycles. While such displacement might be disruptive to the supply industries associated with bicycles and motorcycles, it is debatable whether electric two-wheelers constitute a potentially disruptive niche in the sense understood in transitions theory. In mature markets outside China, where two-wheel modes are relatively scarce, electric two-wheelers are seen as potential contributors to more sustainable mobility (albeit with concerns over safety), but are nonetheless part of a wider personal mobility paradigm.

3. Methodology

The term 'electric two-wheelers' (and the more common term of e-bikes) conflates several distinct categories of electrically-powered or assisted vehicles with two wheels intended to carry one or two people. We in this paper have adopted the following categories of two-wheel battery electric vehicles (2W-BEVs) as illustrated in Figure 2:

Figure 2: Two-wheel battery electric vehicle models

(From left to right: e-bike; e-scooter; hybrid model. Source: corporate product websites)

i) Electrically-assisted bicycle. There are two sub-types of electrically-assisted bicycle. The first is a modified traditional bicycle with pedals, chain drive to the rear hub, and possibly gears on the rear wheel. It is a human / electric hybrid where the battery and electrical system is imposed on the traditional design, and is of low cost. This is a non-advanced hybrid human-electric two-wheel bicycle. More recently has emerged what is known in Europe as a 'pedelec', which is a purpose-designed electrically-assisted bicycle with a more sophisticated integration of the electrical components, battery and drive system, and with increasingly sophisticated software management systems to integrate the human power input with the electrical power input. This is an advanced hybrid human-electric two-wheel bicycle. These are higher cost and typically also heavier (24kg compared with 17kg for the average city bicycle). According to the definition given by the General Technical Requirements of China, electric bikes are referred to as a special class of bikes which possess the following main characteristics: 1) they only have two-wheels, 2) they can be driven by manpower, 3) the rechargeable battery serves as the assistance power, 4) the maximum speed should not be more than 20 km/h, 5) the maximum weight is recommended to be 40 kg, and 6) the width of tyre should not be more than 54mm. Hence, electric bikes without pedals are not viewed as the standard by the law. However, without licence requirements for 2W-BEVs, there are many non-standard examples in use. Hence, in the scope of the present article is more general than that defined by the General Technical Requirements, for example including those with fake pedals.

ii) Electric power low speed bicycle. This is also purpose designed with architecture or design frame of bicycles but without pedals at all (or sometimes fake pedals). They are designed as low-speed 2W-BEVs, with the ancillary components such as brakes not intended to cope with higher speeds.

iii) Electric power scooters and motorcycles. As with the bicycle-derived vehicles, these may be either adapted from traditional designs (that used internal combustion engines) or purpose-designed as electrics. The vast majority to date are of the scooter design, with small wheels and a fairing in front of the driver. They are designed for higher speed, easily attaining 50kph and are both heavier and more expensive than bicycle-derived designs.

There is, it is worth noting, an emergent 3W-BEV category, just as the traditional 'tuk-tuk' is derived from scooters with small two-stroke engines.

The 2W-BEV sector has been witness to rapid product evolution as quality and performance have increased: Though it is difficult to be precise on this point there has been some evolution out of the 'adapted bicycle' category or non-advanced hybrids and into the more sophisticated advanced hybrid 'pedelec' and electric scooter categories. In addition there has been a migration away from lead-acid batteries into Lithium Ion batteries.

In China the official, but apparently weakly enforced, definition of an electric bicycle describes a weight and performance limit (specifically 40kg and 20kph) for such machines.

This paper has not sought to evaluate the relative environmental performance of 2W-BEVs, though that is clearly an important issue when considering sustainable mobility. Initial research by Cherry et al. (2009) and Van Der Kuijp et al. (2013) argues that the major concerns are the lead used in the batteries, and the question of how the electricity is generated. Further, there are concerns as to whether 2W-BEVs substitute for other transport modes (and if so, which modes) or offer some degree of additional travel possibilities. Initial evidence from Xu et al. (2014) argues that in the case of the city of Xi'an the modes from which 2W-BEVs transferred were buses (38.3%), bicycles (31.4%) and walking (16.3%) – though the study also argued that additional trips were induced by the 2W-BEVs. Other concerns arise with mixed modes and infrastructures, particularly in terms of the deaths and injuries arising from 2W-BEV use on the roads (where they are vulnerable users) or on dedicated bicycle routes or pedestrian paths (where arguably it is the other users that are vulnerable) (Feng et al., 2009; Rose, 2012; Yao and Wu, 2012, Bai et al, 2013).

Table 1: Life-cycle analysis of 2W-BEVs and other vehicles in China

	Energy Use (kWh/100 pax-km)	CO_2 (g/pax-km)	SO_2 (g/pax-km)	PM (g/pax-km)	CO (g/pax-km)	HC (g/pax-km)	NO_X (g/pax-km)	Pb (mg/pax-km)
Motorcycle	21-42	64-128	0.04-0.08	0.20-0.40	6.3-12.5	1.13-2.25	0.08-0.15	16-32
Bicycle	4.88	4.70	0.01	0.06	0	0	0	0
Electric bicycle	3.8-9.9	15.6-40.5	0.07-0.17	0.07-0.19	0.007-0.017	0.027-0.064	0.010-0.027	145-420

(Source: Derived from Asian Development Bank, 2009)

Table 1 shows that traditional pedal bicycles are the most environment-friendly vehicles on all key parameters, but their limited power limits range in daily transport. 2W-BEVs produce less CO, PM, and HC emissions compared to motorcycles even given China's electricity generation mix although the emissions of SO_2 and lead are higher. Emissions attributable to electricity generation are at least outside urban areas (Ji et al., 2012); and 2W-BEVs greatly reduce noise pollution.

The paper relies upon secondary sources of data and previously published research - but this can be problematic with regard to China. Official data are not always comprehensive or reliable. For example, official road traffic deaths per annum are put at about 60,000 whereas the World Bank and World Health Organisation estimate the figure to be nearer 240,000. In addition, China's apparently monolithic political structure belies a fragmented and hierarchal administrative and policy framework in which there are varying degrees and kinds of policy latitude (Hasmath and Hsu, 2009; Jeffreys, 2009; Li and Wu, 2012). Moreover, the enforcement or translation of policy into action may be erratic across different jurisdictions and times, and subject to deep cultural variations (Liu et al, 2012) despite formal structures (Zhou, 2010; Mu, 2013) making understanding of governance a difficult problem (Bo, 2013). Such issues are compounded when, as is the case with regard to 2W-BEVs, their rapid recent emergence has overtaken any administrative categorisation and thus data are not captured and recorded nationally on a consistent basis. The paper therefore integrates a range of sources with due allowance for lack of coverage, consistency, reliability and the presence of bias. Chinese 2W-BEV Industry websites were used as sources on the various technologies used, and some of the insights into the changing regulatory regime. Chinese user websites and forums also provided insights on such topics, with supplementary information derived from online journals in China and Europe.

4. **China and spontaneous emergence of 2W-BEVs**

This section of the paper provides an historical narrative on the emergence of the 2W-BEV market in China from a transitions pathway perspective. Drawing on the literature and the available evidence we identify two pathways in the 2W-BEV transition at the national level over time. These are described at a national level as P1, the transformation pathway phase (1980-1999); and P2, the de-alignment and re-alignment pathway phase (1999 onwards). The basis of these phases and their constituent pathways is discussed below. While these pathways are described as fundamentally sequential for analytical purposes, the unfolding of such pathways across the diverse space that constitutes China inevitably means that such pathways overlap and interact at different spatial scales and times. Elaborating this latter point, we provide embedded case studies of two cities (Beijing and Fuzhou). Table 2 provides an overview of the changes at a household level in terms of vehicle ownership in China as a context for the pathways discussion.

Table 2: Ownership of vehicles per 100 urban households, China 1985-2012

Table 2: Ownership of vehicles per 100 urban households, China 1985-2012

	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	2.80	190.48	NA	NA
1993	3.53	197.16	NA	NA
1994	5.26	192.00	NA	NA
1995	6.29	194.26	NA	NA
1996	7.94	193.23	NA	NA
1997	11.6	179.10	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	20.40	165.42	0.60	NA
2002	22.19	142.71	0.88	2.72

2003	24.00	143.55	4.25	1.36
2004	24.48	140.21	2.18	6.50
2005	25.00	120.04	3.37	9.54
2006	25.30	117.57	4.32	12.61
2007	24.81	NA	6.06	17.50
2008	21.39	NA	8.83	23.12
2009	22.40	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.

(Source: National Bureau of Statistics of China, 1984-2013)

4.1 The transformation pathway 1980-1999 (P1)

When the established regime is self-reproducing as described by Geels and Schot (2007) it is possible also that niches may start to emerge, but not progress further unless landscape changes occur or internal niche developments permit of an expanded trajectory. Under pathway P1 a transformation may begin to unfold when landscape pressures increase moderately, but if the niches are insufficiently developed they will not displace elements of the existing regime. The two-wheel mobility niche was occupied by traditional bicycles on the one side, and motorbikes on the other, and these constituted elements of the dominant mobility regime. In 1978, at the very beginning of the China's reform and opening-up policy, the central government established the motorcycle industry as a priority to develop the transport system. With the strong support from landscape and regime actors, the motorcycle industry increased output sharply from 135,400 in 1981 to 11,534,000 in 2000 (see Chen, 2006) by which time the motorcycle industry could be considered as part of the existing mobility regime, and reproducing itself along with reinforcing landscape developments (Li and DaCosta, 2013). It could be argued that this self-reproduction phase also broadly applied to traditional bicycles that remained prevalent during this era although this part of the market is not well documented.

The 2W-BEV industry started to develop with niche innovations during the 1980s. The very first 2W-BEV modes were non-advanced hybrids that resembled normal pedal bicycles with a chain-driven rear wheel. The 2W-BEV reduced user effort and effectively increased range at relatively modest additional cost, and so were accepted by some users. Moreover, in the event of battery or motor failure, it was still possible to ride the bicycle on pedal power alone. Several small 2W-BEV manufactures were established around the Shanghai, Zhejiang and Tianjin areas. In 1988, 40,000 2W-BEVs were produced in Shanghai (Yang, 2010). However, these 2W-BEVs used dilute lead-acid batteries which had the nature of heavy weight, low battery efficiency and liability to leakage, resulting in 2W-BEVs failing to satisfy practical requirements (Huang, 1999). Fundamentally, these machines were traditional pedal bicycles with batteries and motors added, and hence drew from a separate constituency than the mainstream mobility regime actors. In addition, some critical technology problems with the motor and control systems impeded market development. With limited technology and customer service 2W-BEVs remained of negligible significance.

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

In broad terms the P2 pathway runs from 1999 onwards, although the situation started to change around 1995, when some manufacturers produced rear-wheel motor electric bicycles with a capability to achieve 20kph, thereby beginning to arouse some attention (Huang, 1999). Furthermore, and crucially, 2W-BEVs were granted permission from central government to travel on roads and as such opened a niche market with 54,500 output in 1998, 126,000 output in 1999, and 276,000 output in 2000 (see Table 3).

Table 3: Output of motor bicycles and e-bikes from 1997-2000

Date	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%

(Source: Liu, 2008)

However, generally 2W-BEV development was still blocked by the blooming motorcycle industry. Table 3 shows that 2W-BEV output in each year from 1998 to 2000 was only 0.62 per cent, 1.11 per cent, and 2.39 per cent of motorcycle output, respectively. Reinforcing landscape developments helped stabilize the motorcycle as a constituent of the prevailing dynamically stable regime. This situation was altered when the central government decided against further support for the motorcycle industry, thereby marking an important moment in terms of de-alignment.

The groundwork for this spontaneous emergence along a re-alignment pathway was undertaken in 1999 when a 2W-BEV national standard was established by the central government, which for the first time specified the speed, weight and power of 2W-BEVs. In the following year, the Department of State Traffic Control Bureau drafted a ‘Road Traffic Safety Law’ to allow 2W-BEVs to travel on bicycle lanes. In 2004, this law was passed, defining 2W-BEVs as a non-motorized vehicle and permitting a 2W-BEV user to use it without a driver’s license. The national standard became the trigger boosting the initial (pedal cycle derived) 2W-BEV market. Importantly, the Chinese government had set bicycle production as a national priority and established bicycle lanes in cities since 1949 and so some minimal but important infrastructure and manufacturing provisions were already in place.

Industrial concentration accompanied the process of market expansion and the shift to mass production. With low cost, fast speed, personal mobility and convenient accessibility, electric two-wheel vehicles further diffused into the market, particularly in urban areas. In 2005, the sales of 2W-BEVs exceeded that of the gasoline motorcycle in China (see Ruan et al., 2012). After that, the electric two-wheel vehicle market continued to expand, with much higher sales than that of motorcycles.

Additionally, Ruan et al. (2012) show the motorcycle sales trend is one of fluctuation after the imposition motorcycle bans but without a significant decline. This is mainly attributed to 'The home appliances going to the countryside plan' by Ministry of Finance and Ministry of Commerce for stimulating the sales of household appliances (including motorbikes) in the country's vast rural areas at prices 13 per cent lower than those in cities in 2008. In most of the cities, however, motorbikes experienced a de-alignment process.

In this situation, a flood of companies entered the 2W-BEV market, including some famous bicycle companies (Yongjiu, Phoenix) and motorcycle companies (Sundiro, Qianjiang Motorcycle). In 2003, more than 1,000 companies sought market share, ending up with fierce competition. In order to occupy the market, the companies focused on technology innovation, price, and customer service. Core technologies (motors, batteries, and controllers) were significantly improved. The 2W-BEV industry accelerated its growth, hastening marketing expansion. During 2003, the first e-scooter model was developed, signifying a substantive technology improvement. Advanced hybrid 2W-BEV models became prevalent, because of their lighter weight and low cost (see Figure 2). Electric scooters able to carry cargo and / or a passenger, and of greater speed, established the dominant designs and provided clear directions for further improvement and process innovations. For example, by 2010, only 16.1 per cent of 2W-BEVs were of non-advanced hybrid designs based on traditional bicycles, 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).

Apart from adopting different two-wheel architectures, 2W-BEV manufactures also focussed on battery design, since 2W-BEV performance directly relies on battery technology. As discussed previously, the very first (non-advanced) 2W-BEV models used dilute lead-acid battery, which eventually resulted in market failure. After that, 2W-BEV models adopted valve-regulated lead-acid (VRLA) batteries with the advantages of lower cost and high reliability, which matched with the lower income class source of demand. In 2005, more than 95 per cent of 2W-BEVs used AGM (absorptive glass mat) VRLA in China, with the rest using Li-ion, Ni-MH, or NiCad (Weinert et al., 2007). Growth in disposable income from 2000 onwards was probably a factor in demand for greater performance, and a willingness to pay for that performance, in terms of appearance, the degree of comfort and flexibility. The battery technology employed also continued to improve. Many 2W-BEV manufactures started to apply Gel (gelified electrolyte) VRLA batteries. In order to achieve customization, 2W-BEV retailers may sell frames and batteries separately thereby allowing customers to combine a battery with the best-designed frame according to their preferences.

From around 2010 onwards the cumulative penetration of 2W-BEVs can be said to have contributed to the displacement of other modes in urban areas (Xu et al., 2014). China became more international in focus and sensitivity while retaining the one party state system, but equally became concerned with key environmental problems such as deteriorating air quality in major urban areas (He et al., 2013). This latter issue was highlighted during the 2008 Olympics in Beijing.

These ‘avalanche changes’ at the landscape level brought numerous problems into the existing motorcycle urban transport regime, especially from the regime actors’ view. In particular 1) motorcycles disrupted traffic and caused unwanted accidents, hampering the embrace of a ‘modernist’ automobile era, 2) millions of motorcycles produced contributed tailpipe emissions every year, leading to creeping environmental deterioration, and 3) motorcycles were treated as obstacles in the intensive city construction (Weinert et al, 2007).

Therefore, since 1997, many Chinese cities started to completely ban or partially ban motorcycles and scooters (see Table 4). Some cities released a limited number of motorcycle licenses every year or even suspended the issuance of new motorcycle licenses. Some cities banned motorcycles from entering the city centre or major roads in the city. As of 2009, motorcycles and scooters were banned or restricted in over 170 cities (Cao and Fan, 2009). While these bans did not challenge the core mobility regime premised on the private car, they did create an opportunistic space for the spontaneous emergence of the 2W-BEV alternative.

Table 4: Cities banning or restricting motorcycles

Provincial 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 Fujiang 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, Wuhu (in Anhui Province)
	Nanchang, Jiujiang, Jingdezhen, Ganzhou (in Jiangxi Province)
	Changsha, Xiangtan, Yueyang, Zhangjiajie, Hengyang, Binzhou, Zhuzhou, Changde, Yongzhou, Huahua(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)

(Source: Adapted from Yang, 2010)

The local motorcycle bans created opportunities for niche activities, including for example the growth of 3-wheel vehicles in taxi applications. The primary beneficiary, however, appears to have been the 2W-BEV market (Ji et al., 2012).

Hence the 2W-BEV ‘story’ and that for traditional motorbikes are closely intertwined. This 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, electric two-wheel vehicles rapidly became dominant, potentially forming the core for re-alignment of a new regime in a process that is currently ongoing.

As suggested above, the 2W-BEV transition has followed pathway P2 (de-alignment and re-alignment pathway) at national level from about 1999 onwards. Whether the transition process follows P3 (technological substitution) depends on whether the motorcycle is displaced or not. Adopting the multi-scale transition perspective, in some south China cities, 2W-BEVs and cars appear to be the dominant choices. For example, the 2W-BEV and private car ownership rate per 100 households is 34.56 and 37.97 in Nanjing, respectively (Nan, 2013). By contrast, in a view of national level, the 2W-BEV has not so much displaced motorcycles or other modes, but become additional to them. However, there appears to be no strong evidence for technological competition between 2W-BEVs and motorcycles; the technology package of motorcycles did not fail as such, neither was it abandoned by customers in the market. Rather, the bans from government simply excluded them from the market. In this regard, the uptake of 2W-BEVs is part of a wider picture of increased mobility evident in China and many other countries – although China is unique in the extent to which 2W-BEVs have been adopted.

Apart from this, the Ministry of Public Security, Ministry of Industry and Information Technology, State Administration for Industry and Commerce, and the General Administration of Quality Supervision, Inspection and Quarantine (4-ministry) published a 'Notice of Strengthening E-bike Regulation' requiring provincial governments to strictly follow the 1999 2W-BEV national standard and remove all the 2W-BEVs that were not complying with the standard criteria in 2011. Meanwhile, the Ministry of Environmental Protection issued a notice to regulate pollution from the lead-acid batteries and the lead recycling industry. Furthermore, the new national standard of 2W-BEVs is under development. These regime actions make the future for 2W-BEVs uncertain.

In the meantime, an increasing number of manufacturers have invested more in 2W-BEV technology, especially lithium battery deployment. For example, the estimated output of lithium powered 2W-BEVs grew from 461,540 in 2010 to 750,000 in 2011 (Wei, 2013). Moreover, on 1st June, 2013, China implemented 'E-bike Lithium-ion Battery Specs and Sizes', which aims to improve lithium battery quality and technology (Wei, 2013). The trend of 2W-BEV manufactures is thus to develop and produce higher performance and higher value products.

5. Two examples at the municipal level: Beijing and Fuzhouo

The P1 and P2 pathways with respect to 2W-BEVs largely happened at the micro-scale, i.e. the cities, rather than the national scale. An example is that of the enactment of the local policy on banning 2W-BEVs and then subsequently to accepting them. In this, the crucial regime actors are local government and local transport management departments. Table 5 shows the treatment of 2W-BEVs in Beijing, and Fuzhou.

Table 5: City-level policy on 2W-BEVs, Beijing and Fuzhou 2002 to 2010

City	Initial E-bike policy		Second E-bike policy	
Beijing	08/2002	Complete ban of e-bikes on 1st, Jan, 2006. Issued 63,017 temporary licenses (valid until 31.12.2005) (Duan and Zhang 2002)	01/2006	Issue licenses for e-bikes and permit licensed e-bikes to travel in the city. Issued 235,000 licenses at the end of 2006 (Duan and Zhang 2007)
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.

5.1 Beijing

Outside criticism on city policy towards 2W-BEVs firstly came from journalists who reported that regime actors (in the form of the city authorities) failed to respond to the considered will and travel requirements of the people, with the evidence that the penetration of 2W-BEVs in Beijing was 60,000 at the end of 2001, followed by 36,000 sales in 2002 (Gao, 2002; Fan, 2004; Zhang, 2004). Moreover, Beijing News conducted a poll on purchase intentions with respect to 2W-BEVs, whose results evidenced that 2.117 million people stated a purchase intention in the future (Zhang, 2006). However, the city authorities insisted on eradicating 2W-BEVs in the transport system on the grounds that it would make traffic management easier and release more urban road space that was beneficial for constructing the domestic automobile era. The regime actors paid most attention to mainstream automobile industry, for example by hosting Beijing International Auto Show, involving the automobile industry in the 10th five year plan, and in constructing a new 128km highway (Bai, 2002). In August 2002 the Beijing government proposed a complete ban on e-bikes to come into force on 1st January 2006.

Since Beijing as a city authority banned motorcycles as well in 1985, citizen personal mobility problems were exacerbated with landscape developments. Industrialisation, for instance, drew more workers to cities like Beijing, leading to accelerated urbanisation, and greater separation of homes from workplaces (Zhang et al., 2014). These newcomers could not afford the high living costs in central Beijing and thus rented accommodation in the suburban districts: thereby extending the commuting distance beyond that which could be achieved with bicycles (Zhang et al., 2013). In the meantime, the public transport system could not keep pace with demand. Conversely, the low cost 2W-BEVs which provided for longer travel distance and flexible accessibility went well with citizens' needs (Cherry and Cervero, 2007). Hence, although a ban was supposed to be coming into force, 2W-BEV sales continued to grow in Beijing after 2002. These 2W-BEV users voiced their concerns through the media to increase pressure on the regime. Moreover, academics from social science research, city planning and law published many papers to argue against the inappropriate 2W-BEV ban policy (Zong, 2002; She, 2002). Besides, 2W-BEV manufactures linked up with energy companies and the battery industry to strongly oppose the 2W-BEV ban (Zhang, 2006). In response to increased pressures, local government and the standing committee of Beijing Municipal People's Congress held a first public legislative hearing to discuss the 2W-BEV issue on 3rd September, 2004 (Beijing People's Congress, 2004). After the legislative hearing, the government still did not lift the 2W-BEV bans.

However, the situation was changed in 2006. During the fourth session of 10th Beijing People's Political Consultative Conference (14th Jan 2006 – 18th Jan 2006), the delegates proposed 'the suggestion of advocating resource saving and environment friendly transportation tools — e-bikes'. The delegates argued that 2W-BEVs were the very best choice among the available transport vehicles, possessing the advantages of affordable price, flexibility, environment friendly performance, and labour-saving convenience, which contributed to excellent personal mobility (Guo, 2006). In the proposal, there were four main suggestions: 1) lift the 2W-BEV bans, 2) issue the 2W-BEV licenses, 3) establish clear battery recycling rules, and 4) forbid 2W-BEVs to travel on the motorway. This proposal was adopted by Beijing government subsequently.

The penetration of 2W-BEVs in Beijing was an estimated 180,000 at the end of 2005, which was three times more than that of the penetration in 2001 (Liu, 2008). By contrast, the penetration of private cars in Beijing was 1.54 million in 2005 (Rong, 2006) which indicated that 2W-BEVs remained at niche level and had not yet been sufficiently developed in Beijing. After Beijing lifted the 2W-BEV ban policy, a citizen said 'I bought an e-bike before. Now that the government lifts 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-bikes now' (quoted in Ma, 2006). Also, the manager of the E-bike World Shopping Mall said that the sales increased by 50% after the lifting of the 2W-BEV ban (Ma, 2006). Because the city government altered the strategies on 2W-BEV ban policy, it became possible for the penetration of 2W-BEVs to reach 700,000 in Beijing in 2012 (Zhen, 2012), thereby stimulating the 2W-BEV market as a whole.

5.2 Fuzhou

An example of the interactive influence on the policy between public and government is the transition of 2W-BEV policy in Fuzhou, the capital of Fujian province. Fuzhou government initially acquiesced to 2W-BEV use, and then changed and banned 2W-BEVs, but eventually turned back to accepting them in 2010.

The sales of 2W-BEVs initially exploded, by taking the place of motorcycles which were banned by the Fuzhou government. With this rapid development, 2W-BEVs caused some safety and transport management problems. The Bureau of Public Security was not prepared for the management of the new transport vehicle, so straightforwardly released a ban on 2W-BEVs (Jue, 2001). Incensed by this ban, the 2W-BEV user representatives sued the Bureau of Public Security for the infringement of public legal right and interest on July 2001 (Xue, 2001). The case ended up with the success of 2W-BEV users and since then 2W-BEVs enjoyed a smooth development period. The sales of 2W-BEVs increased rapidly, reaching at 100,000 with more than 100 2W-BEV retailers. In order to further legalise 2W-BEVs, the deputies proposed to issue 2W-BEV licenses in the ninth Fujian People's Congress Conference (January, 2002). Furthermore, a consultation of 2W-BEV issues comprising of People's Congress deputies, traffic policemen, officers of Municipal Transportation, journalists, and communities, required the city authority to respect public opinions (September, 2002).

However, the Fuzhou government went an opposite way. The government held a news release conference on 1st of June 2003 to announce that the sales of 2W-BEVs would be banned, due to limited road resources, safety issues, and battery recycling issues (Wang, 2003). Not surprisingly, all the 2W-BEV companies strongly opposed this policy. 2W-BEV companies sought evidence in support of the advantages of 2W-BEVs, and to refute the reasons for 2W-BEV bans as declared by the government. The opponents obtained support from the people in a wide range of backgrounds, including the Standing Committee of the Fujian Provincial Consultative, Committee for Social and Legal Affairs, 2W-BEV user representatives, and Complaint and Supervision Department of Customer Committee. After a few days, 2W-BEV companies sued the Fuzhou Industrial and Commercial Bureau for its illegal administrative actions of forbidding 2W-BEV sales at a local court (Shu, 2003).

This case gained wide attention and strong support from the mass media, scholars, 2W-BEV companies and 2W-BEV users. Journalists conducted in-depth reports by interviewing officers of Fuzhou government, 2W-BEV retailers and 2W-BEV users (Liu, 2003). One academic 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). In addition, the prosecutors received a generous donation from the 106 e-bike companies (Jia, 2003). However, the court rejected prosecutors’ requirements finally (Da, 2003).

Since that point, 2W-BEV sales were forbidden at Fuzhou. Shortly after, however, on the 28th October 2003 another critical moment occurred when 'The People's Republic of China Road Safety Law' was issued by the State Council which identified 2W-BEVs as non-motorized vehicles, which provided the basis for the legalisation of 2W-BEVs in the range of the whole nation. However, according to the law, 2W-BEVs should be registered at the local Public Security Bureau in order to travel on roads, leaving some space for local government to release restrictive regulations (Transport Safety Law, 2003). The Fuzhou government announced that the previous Notice in 2003 was still valid. The sales of 2W-BEVs stopped at Fuzhou city. Most of the shops only offered customer service (Lin, 2005).

In 2006, with Beijing lifting 2W-BEV bans and issuing 2W-BEV licenses, the topic of lifting the 2W-BEV ban again came back into public debate in Fuzhou. At the ninth Fujian Province People's Political Consultative Conference (24th, January 2007), the suggestion of lifting the 2W-BEV ban was proposed again. In the following Fuzhou People's Congress Conference (10th February, 2007), some deputies also advocated to lift the 2W-BEV ban, based on the idea that the majority of 2W-BEV users had a lower income and the public authorities must be concerned over their demands for personal mobility. Moreover, 2W-

BEVs were presented as ‘green’ products allowing excellent personal mobility, while reducing congestion and contributing to improving air quality. Moreover, 2W-BEVs had by then been permitted to be produced by the State Council. In Chinese political hierarchy, the provincial regulations cannot conflict with higher level policy. In term of concrete measures, the provincial government should facilitate a battery recycling system and establish the standards of 2W-BEV speed, weight and models.

After the congress conferences, the Fuzhou government started to loosen the restriction on 2W-BEVs (Chen, 2007). On the 1st June 2007, 2W-BEVs were permitted to travel on two main roads in Fuzhou city centre, and then extended to two more main roads on 1st June 2008. Insisting the right of wide usage of 2W-BEVs, the 2W-BEV users expressed their opinions on TV, newspapers, magazines, community forums, and the ‘e-bike bans’ seminar on Internet (Yi, 2009; Dongnan Site, 2010).

With the continuous pressure from public, the Fuzhou government published consultation version of ‘Fuzhou E-bike Administrative Measures’ on 29th March, 2010 and held news release conference to explain the law terms and the details of the feedback system (Fuzhou Legislative Affairs Office, 2010). The 'Fuzhou E-bike Administrative Measures' was approved soon thereafter. The government further built a special website called 'Strengthen e-bike administration' which clearly listed permitted e-bike models, and the places for registration and getting a license, as well as the information of the latest e-bike policies (Fuzhou Government, 2010).

6. Conclusions

The paper has highlighted the gap between official policy support for new energy vehicles (cars) and the neglect of 2W-BEVs, yet 2W-BEVs are technically a very good application for the technology. Indeed, there is anecdotal evidence to support the view that even the vehicle manufacturers in China can see the logic of the 2W-BEV concept compared with battery electric cars (Gong et al., 2013; Perkowski, 2013). In a sense, the 2W-BEV case in China illustrates what Xenias and Whitmarsh (2013) describe as the difference between top-down, expert-driven and technocratic solutions, and those that are more emergent, local, participant-driven solutions; with the formal system in effect struggling to contain, catch, and somehow regulate an activity that refuses to go away.

This is not deny the significance of state intervention. As noted in this account, decisions such as classifying early electric bicycles as fundamentally bicycles rather than vehicles meant that licences were not required to operate them; while giving permission for these electric bicycles to use the roads opened up many potential transport possibilities. In addition, it is probable that restrictions on the entry of cars into urban areas, and the shortage of parking spaces, were contributory to the attraction of 2W-BEVs in general, while banning traditional motorcycles helped create a vacuum in the market.

Hence this paper suggests at least some interesting perspectives on transitions. First, that the rapid uptake of a new transport form was not the direct result of positive, purposive policy intervention at national or sub-national government level, nor the result of nurturing nascent niches. There was no significant government-sponsored R&D programme in support of the 2W-BEV market, nor any financial or other incentive offered to consumers to encourage the adoption of these vehicles. Faced with the de facto existence of these 2W-BEVs, urban governments first reacted negatively, by banning them, and then acquiesced to the reality by regulating them. Regulation was itself problematic in that there was little understanding of the market (Cherry and Cervero, 2007), of user needs and practices, or of the wider integration of 2W-

BEVs into the existing transport milieu (Lin et al., 2008). As such, there may be important lessons for the development of lightweight electric cars and quadricycles (or 'low speed' electric vehicles) that do not fit existing definitional categories. Second, this transition process has occurred with remarkable rapidity under the particular conditions prevailing within China as compared with the historical cases of transitions discussed in the majority of the literature. In part this might be due to the transport vacuum caused by the outright ban on traditional motorbikes, a policy that less centralised and autocratic governments might struggle to enact (Yang, 2010). Third, it could be argued that the transition is weakly embedded, however, as illustrated by the lack of support or outright antagonism initially shown by government, and because the technology itself requires little or no special infrastructure and hence has less capacity to generate its own path dependency. The forces required to create a strong new mobility regime are not present, while the political and economic power of traditional mobility remains substantial. Further evidence is needed on mode switching around the use or non-use of 2W-BEVs and whether such vehicles are stepping stones to the private personal mobility embodied in cars. As such 2W-BEVs may help establish a behavioural lock-in into mobility patterns that are not readily provided for by rapid mass transit for example (Zhang et al., 2014). The rise and partial demise of the traditional manual bicycle over the period 1950 to 1990 is somewhat testimony to how apparently embedded practices can change with surprising speed (Rhoads, 2012; Zhang et al., 2012). Finally, we have shown that transitions theory has a greater flexibility and adaptability than previously shown in that there are pathways other than those outlined by Geels and Schot (2007) that are certainly possible, in time periods that are considerably condensed.

In terms of further research there may be potential in exploring further the interaction of technologies within distinct spatial areas of governance, particularly in terms of diverse cultures of consumption and varieties of capitalism. It is intriguing that, anecdotally at least, the markets outside China that have most embraced the 2W-BEV are those that use existing pedal bicycles as a means of transport (the Netherlands and Germany for example), whereas others such as the UK and the USA where the bicycle is a form of leisure pursuit have been far less enthusiastic. Alternatively, in the account provided here it is notable that the political and institutional system in China is able to enact abrupt and comprehensive shifts in policy that might not be so readily achievable elsewhere, although it is interesting to note that enforcement of policy may be another matter entirely.

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