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Navigating Transitions: How Electric Vehicle Sharing Is Shaping Sustainable Mobility in Chinese Cities

Tiansheng Yang [1], Ken Peattie [2,*], Jean-Paul Skeete [2] and Nicole Koenig-Lewis [2]

1 South Wales Business School, University of South Wales, Pontypridd CF37 1DL, UK; tiansheng.yang1@southwales.ac.uk
2 Cardiff Business School, Cardiff University, Cardiff CF10 3EU, UK; skeetej@cardiff.ac.uk (J.-P.S.); koenig-lewisn@cardiff.ac.uk (N.K.-L.)
* Correspondence: peattie@cardiff.ac.uk

Abstract: Urban mobility has a relatively high potential for radical change and plays an important role in building more sustainable cities. This paper investigates the role of business models and local conditions in the transitions towards sustainable urban mobility through a study set in the context of Chinese cities that focuses on the emergence of electric vehicle-sharing services (EVSSs) as a sustainable mobility innovation. Transitions theory and its multi-level perspective has been adopted as a theoretical framework for this research. A case study methodology was employed comprising semi-structured interviews with 26 respondents. These comprised EVSS providers, other mobility service providers, and other stakeholders including local and national governments bodies. It is based in the Yangtze River Delta Economic Zone (YRDEZ), which includes the major cities of Shanghai, Hangzhou, and Suzhou that have been at the forefront of EVSS adoption and innovation. The findings highlight the dynamic interplay between business models, regulatory environments, and urban settings, providing a comprehensive framework for understanding the socio-technical shifts necessary for fostering more sustainable urban mobility. The study also demonstrates the importance of a range of research disciplines for understanding the processes of sustainability transitions, whilst also revealing some limitations of transitions theory and the multi-level perspective for analysing and understanding transitions.

Keywords: urban mobility; vehicle sharing services; business models; transitions theory

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1. Introduction

Sustainability transitions represent fundamental, long-term, and multi-dimensional transformation processes through which our existing socio-technical systems can shift to more sustainable modes of production and consumption [1]. Amongst the socio-technical systems that meet the daily needs of citizens, mobility is responsible for almost one quarter of global carbon emissions along with other significant health and environmental impacts from pollutants and accidents [2,3], with private cars being the most dominant contributor [4]. It also has a relatively high potential for radical change, especially in urban areas, compared to other key systems facing more intractable barriers to change: the food system due to the globalised and diffuse nature of its supply chains, and the housing system due to the constraints of the legacy housing stock. In addition to the potential for relatively radical change, urban mobility transitions provide opportunities given that 80% of the population in most modern countries are concentrated in urban areas [5]. Although mobility impacts encompass everything from international holiday travel to movements between rural villages, the field of urban mobility represents the most coherent and impactful system scale to address.

Urban mobility plays an important role in building more sustainable cities and meeting travel needs within them [6,7]. As Berkhout, et al. [8] note, we have lived through an era of "automobility", in which the dominant transport mode has been private internal combustion engine driven automobiles supported by urban investments and policies that have shaped the spatial organisation of cities and generated particular travel behaviour patterns. The resulting socio-technical regime includes an array of supporting technologies, producer firms, markets, regulations, infrastructure, and cultural values [8].

Reducing private urban car use is one of the critical challenges in promoting sustainable mobility to create a better balance between economy, environment, and wellbeing [9]. There is a growing consensus that a transition is needed towards sustainable mobility in cities [10,11] to improve the quality of travel experiences, reduce the negative impacts of congestion on the environment and economy, stimulate innovation in mobility solutions, and better involve multiple actors across society [9,12]. However, the emergence of a new technology, in the form of electric vehicles, may offer the prospect of a transformational shift in at least the carbon emissions implications of urban mobility, but only if other elements of the regime are also capable of change (including power generation). One way to increase the potential for electric vehicles to contribute to more sustainable mobility is if they are accessed and used, not through conventional private ownership approaches, but through electric vehicle sharing services (EVSS) [13,14]. Businesses based on shared vehicle access have become widespread, with a global market worth over USD 60 billion (CNY 437.4 billion) and with predictions that they have the potential to fundamentally disrupt mobility systems in the near future [15].

Affolderbach and Schulz [16] highlight the importance of transitions theory and its multi-level perspective in understanding progress towards sustainable urban mobility, but also note that: "While the multi-level perspective offers a strong and structured analytical tool and heuristic framework to (re) construct socio-technical transitions towards low-carbon futures, it suffers from a number of limitations" (p. 1953). These limitations include a level of abstraction that under-appreciates the impact that location-specific factors can have on the transition process [16] and the role that individual firms can play through innovations in their business models [15], along with a tendency for studies to focus on a narrow range of (particularly European) geographical contexts [1].

Therefore, this paper aims to contribute to our understanding of transitions towards sustainable urban mobility through a study grounded in the context of Chinese cities that focuses on the emergence of EVSS as a sustainable mobility innovation. It seeks to address two main research questions:

(1) What role do the business models and strategies of EVSS providers play in the evolution of the vehicle sharing sector and its potential contribution towards more sustainable urban mobility?

(2) How do local factors impact providers' business models and the transition process?

The paper progresses, first via a literature review encompassing the role of transitions theory in sustainable mobility, the context of urban mobility in China, the challenges of mobility transitions, and the potential contributions of a business models perspective in Section 2, followed by a description of the case study methodology employed in Section 3. Section 4 presents and discusses our key findings, before a discussion of the implications of the research in Section 5 and our conclusions in Section 6 that lay out the contributions and limitations of this study.

2. Literature Review

2.1. Transitions Theory

Transitions theory is arguably the most influential branch of scholarship when it comes to understanding the prospects for, and the barriers to, transformational progress towards sustainability. It has been previously applied to better understand prospects for progress towards more sustainability urban mobility systems [17–20]. Its value lies in providing an understanding of the significant interactions between technological innovation and path dependencies, lifestyles, organisations, institutions, policies and value chains that a focus on individual policies, technologies, or practices will likely overlook [1]. A key strength of transitions theory is that this holistic focus on an entire socio-technical system moves the discussion about progress towards sustainability beyond the responsibilities of individual consumers or businesses, the doctrines surrounding freedom of choice, and the efficiency of markets that are central to neo-liberal policy approaches. An emphasis on individual choice risks marooning progress towards sustainability in market niches and, by providing specialised products and services targeted at the most motivated consumers, potentially depriving any market transition process of the momentum necessary to shift the mass market [21]. Transitions theory's focus on entire socio-technical systems escapes this particular trap but arguably has then shifted the focus beyond the perspective of individual businesses or the behaviour of individuals to an extent that risks under-appreciating the roles they can play in the evolution of those systems [14,22–25].

Another criticism made about the transitions theory field is that, although power and politics have been addressed within it [26], its relatively abstract nature has led to the realities of power and politics being under-appreciated [27,28]. In practice, key systems (such as for urban mobility) operate in specific places in which localised actors and factors, such as topography, local regulations, events, and socio-cultural practices, may exert specific influences on how the system operates and the prospects for changing it [16,19,29]. Such geographical factors may also significantly influence the prospects for replicating or translating successful sustainability innovations or "experiments" from one urban context to another [29]. Nykvist and Whitmarsh [30], in considering mobility transitions across countries, found that different novel transport technologies may succeed in different countries. Similarly, Markard, Raven, and Truffer [1] note that the application of transition theory and its multi-level perspective has primarily been applied in research using European scenarios (such as Nykvist and Whitmarsh's), with a lack of regional and national diversity adding to the lack of consideration of individual firms' strategies as a shortcoming.

2.2. Urban Mobility in China

The scale of China's population, its economy, and its rapid urbanization makes Chinese cities an important element in any future development strategies aimed at sustainability. Although overall private car ownership levels in China are low compared to America, it represents the world's largest car producer and consumer [4] and ten of the world's twenty-five most congested cities are located in China [31]. As well as the environmental damage and health impacts of high densities of conventional vehicles in cities, congestion creates considerable economic inefficiency. In 2017, the average Beijing car commuter's journey of 17.4 km took 52.9 min, while in Shenzhen an average 16.8 km journey took 47 min [31]. The development of more sustainable urban mobility systems in Chinese cities is therefore in line with Chinese government policy across a number of spheres including dematerialisation, resource efficiency, carbon reduction and the development of eco-cities [29].

The policies of the Chinese government have been strongly geared towards supporting the production and adoption of electric vehicles [32] so that China now has the highest proportion of electric vehicles globally [4]. There is also policy support for vehicle sharing-based approaches, which are perceived as having the potential to prevent growth in private car ownership from overwhelming Chinese cities in future and may be commercially and technically feasible since: "As a digitally advanced nation, with deeply evolved eco systems of information and communication technologies, China is an obvious candidate to spearhead smart and potentially sustainable mobility solutions" [12] (p. 375).

2.3. Transitions to Sustainable Urban Mobility

Transition theory and the multi-level perspective (MLP) has been widely used to address and assess sustainable mobility systems [33,34]. Figure 1 presents Geels's [35] overview of how urban mobility patterns operate from an MLP perspective.

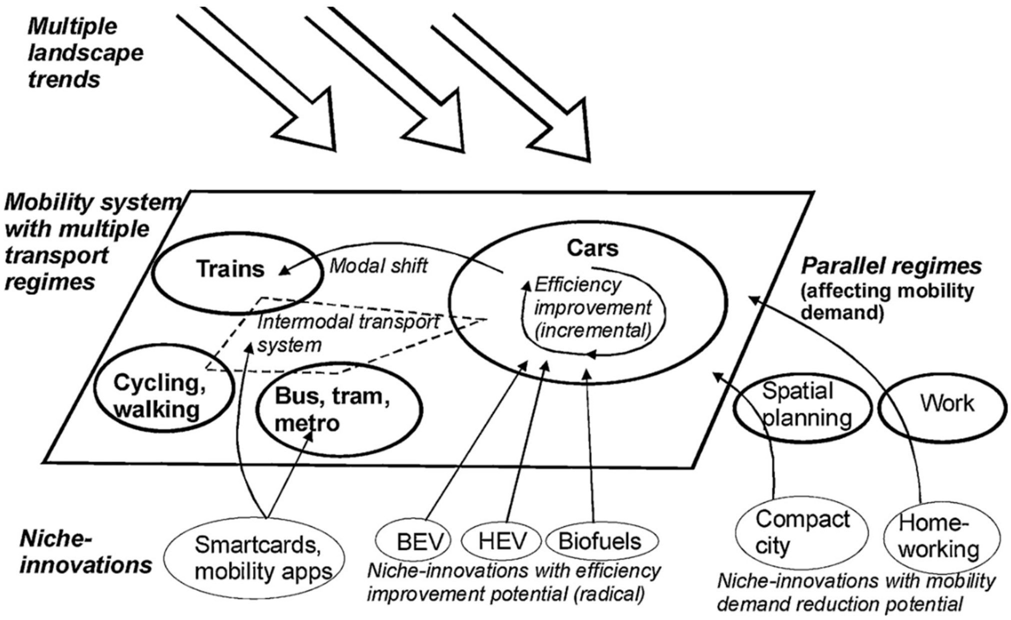

Figure 1. Integrative MLP-conceptualisation of passenger mobility system reconfiguration (source: [33] (p. 88)).

At the landscape level, a range of factors in the external environment (particularly government policy, but also including the economy, culture, climate change, and events like a global pandemic) can directly impact mobility patterns. However, supportive external landscape pressure does not guarantee progress towards more sustainable mobility [35], and the dominant automobility regime has proved remarkably resistant to change [33]. For example, one proposed solution to reduce Chinese urban automobility and promote more active travel is bike-sharing schemes where, despite a supportive policy environment, many initiatives failed due to bike over-production, consumer misuse, and poorly operated schemes [36]. This demonstrates that even with the emergence of promising niches amidst a supportive policy landscape, the emergence of a new regime may fail due to the (aggregate) actions of individual consumers and the actions of individual firms. This case demonstrated, at the micro level, the risks that the lack of a viable business model among innovating firms, and misbehaviour amongst consumers, may create barriers to success [37].

The regime level in the model is presented as a mobility system connecting different regimes each representing competing modes of transport for particular journeys. Greater sustainability is generated in two ways. Firstly, by incrementally making the existing and dominant automobility regime more efficient and sustainable through technological innovation involving new types of vehicles (particularly electric vehicles) or by adapting existing vehicles to use alternative fuels (such as biofuels). Secondly, sustainability can be promoted through modal shifts away from automobility and towards active travel solutions of walking and cycling, or public transport solutions of trains, buses, trams, or metros. Discussion about how to achieve transitions towards sustainable urban mobility have mostly been dominated by studies focusing on promoting public transport systems [38].

Geels's [35] model follows the tradition of relatively abstract transition theory models that consider how the physical impacts of the system might be influenced by the emergence of specific technologies or the application of landscape pressures such as changes to regulation, but without illuminating the commercial practices operating within the regimes and niches, or the influence of ways in which people may access and use particular transport modes. So, although innovative technologies in the form of electric vehicles are represented in the model, innovative ways of accessing and using them are not represented.

2.4. Sustainable Mobility Business Models

Business sustainability studies have evolved from an emphasis on specific products, technologies or business functions to an increasing focus on the roles played by entire firms or value chains by exploring new sustainability-oriented business models [39]. There is no single universally accepted definition of a business model [40], but from the perspective of an individual firm it can be understood as:

> "The design or architecture of the value creation, delivery and capture mechanisms. The essence of a business model is that it crystallises customer needs and ability to pay, defines how the business enterprise responds to and delivers value to customers, entices customers to pay for value, and converts those payments to profit through the proper design and operation of the various elements of the value chain". [41] (p. 179)

An understanding of business models can be important due to their influence in either opening up or constraining strategic choices for companies [42], and because their entrenchment can represent a barrier to sustainability transitions, while innovation within them can represent a pathway towards it [15,43,44].

Business model innovation is an important pathway towards more sustainable production and consumption systems [45]. It is a key element in the promotion of resource-efficient "Circular Economy" (CE) principles viewed as crucial in achieving progress towards sustainability in contexts such as Chinese cities [46] and that are central to Chinese government policy. Five types of more sustainable and circular business models have been identified [46], four of which—refurbishment/remanufacture, repair/reuse, sustainable materials management, and industrial symbiosis—are primarily focused on production issues and materiality. They may require changes from consumers (e.g., accepting recycled products or returning used products), but consumption-orientated changes within the business models are often minimal. The fifth type, product service systems (PSSs) in which consumers forego purchase and ownership of a product in favour of accessing its benefits via a service (such as rental), requires a more fundamental change to all elements of the business model.

PSS business models in urban mobility are often referred to as "Mobility as a Service" (MaaS) and have a long-standing presence in the form of taxi use or occasional car rental as an alternative to car ownership. A more contemporary form has arisen in the form of app-based ride-hailing services including Uber and China's Didi, whose business models and services offer an alternative to private car ownership and promote shared rides. Despite their potential contribution to more sustainable mobility, it is worth noting that such services have generated an ongoing academic debate regarding their actual impact on traffic congestion, public transport use, and carbon emissions [47].

Another innovative form of mobility business model comes in the form of vehicle-sharing schemes in which customers access not a ride via a taxi or an Uber/Didi, but a vehicle to drive temporarily [15,48]. Such schemes have emerged in multiple cities across the world, with varying levels of success. This has raised questions about the potential to establish them as profitable businesses that can balance the costs of offering widespread vehicle availability with the high utilization rates necessary for efficiency and profitability, without ongoing support from government subsidies [49]. There have been success stories, such as Mobility Carsharing in Switzerland, who struck a successful vehicle availability/utilisation balance to meet user needs through a scheme that was well integrated with the public transport system [50]. By contrast, Autolib in Paris represented a high-profile sharing service failure brought down by high operational costs and low utilisation, a lack of regulatory support, an overly competitive charging market, and a failure to keep up with shifting user preferences [49,51]. Success in promoting car sharing will thus depend upon developing an effective business model. The different types of car-sharing business models are summarised in Table 1 [40,52].

Table 1. Overview of car-sharing models' key characteristics and impacts.

Car-Sharing Model	Key Characteristics	Impact on Car Ownership and Environment	Sources
Conventional Car-Sharing	Access to a fleet of vehicles with designated parking spots Vehicles can be reserved for hours to days, then returned to parking spot	Reduced/delayed car ownership Fewer vehicles on roads Enhanced fuel efficiency Decreased emissions Altered travel behaviours	[53]
Point-to-Point (Free-Floating)	Vehicles picked up at one location and dropped off at another Vehicles parked on streets with permits or in designated zones	Unclear impact on energy consumption and vehicle miles travelled May promote car-free lifestyles May substitute eco-friendly transportation options	[54]
Peer-to-Peer Car-Sharing	Members lend or rent personal vehicles to other drivers Enhances vehicle utilisation Better suited for areas with lower population density	Ambiguous energy and environmental effects Increases vehicle utilisation Vehicles involved may be older and less efficient	[55,56]
European Conventional Car-Sharing	Emerging markets in 14 countries, with over 1% of Switzerland's population participating Predominantly serves private clients, with a majority of male members aged 26–49 Members more inclined to own public transportation passes	Displaces 4–8 personal vehicles per car-sharing vehicle Members possess fewer cars Compact vehicles dominating fleets	[57]

The sustainability benefits of sharing services are typically framed in terms of a greater efficiency of vehicle use and a potential to replace private ownership [2]. Estimates of the impact of sharing schemes on car ownership levels vary and include 9–13 vehicles being replaced by each shared one in a North American context [52] and 20 per shared vehicle in a European context [58]. The potential benefits can be enhanced by also adopting low-emissions electric vehicles [59] that can include light city EVs, e-bikes, and scooters [35,60]. Such electric vehicle sharing services (EVSS) represent a type of eMaaS scheme with the potential to reduce environmental impacts via greenhouse gas (GHG) emissions and alleviate urban traffic congestion [13,14,61,62]. They can also contribute to more sustainable mobility indirectly [61] via the heterogeneous data generated by EVSS users and other stakeholders (service providers, traffic departments, and charging stations). These data can be used to analyse consumer behaviour, service quality, vehicle utilisation, traffic status, air quality, the efficiency of a smart city or urban transport network, as well as ensuring users' safety [63]. This can potentially assist service providers in improving efficiency, providing value-added services, extending business opportunities, and improving citizens' quality of life.

Despite the apparent potential of such business model innovation to contribute to more sustainable urban mobility, within the literature there has been a lack of focus on understanding the specific factors involved in integrating innovative and sustainable business models into the broader mobility paradigm [9,64].

From a transition theory perspective, although e-mobility initiatives and car sharing schemes have previously been treated as separate niches within mobility transitions [65], with the emergence of EVSS schemes, these two niches have merged to become one. This is in line with the prediction of Nykvist and Whitmarsh [30], who saw hybridization and co-evolution of niches as central to future innovations for sustainable mobility.

The prospects for EVSS schemes to contribute to a sustainable urban mobility transition will depend on the ability of service providers to succeed, and success will be determined by the interplay between the business models of the providers, the regimes and regulatory pressures within the socio-technical landscape, and also with the user behaviours and local urban contexts of the cities in which they operate.

3. Methodology

Case studies are a popular methodology, particularly for exploratory research into emerging real-world phenomena [66] and cases where the boundaries between the research subject and its context are indistinct [67]. This study applies a case study methodology to understand EVSS in the Chinese context of the Yangtze River Delta Economic Zone (YRDEZ). Since this encompasses multiple cities in which EVSS schemes are operating, it can be more accurately described as a multi-site network-based case. Such studies involve a practical exploration of a specific contemporary phenomenon within its real-world context involving multiple sites [68]. They have been most widely used in education, health, and IT research rather than in business contexts, but can be valuable for understanding operational management in practice by revealing variables, patterns, themes, and relationships that determine success beyond the boundaries of the individual firm [69]. Although EVSSs can encompass a variety of vehicle types, this study is specifically on electric car sharing as the most significant one for potential reduction in conventional car use.

The YRDEZ includes the major cities of Shanghai, Hangzhou, and Suzhou, which are broadly representative of contemporary Chinese cityscapes and are cities that have been at the forefront of EVSS adoption and innovation (including the first self-driving experimental city) and/or are centres for the internet industry, which represents a significant influence on future urban EVSS development. Including analyses across multiple cities assists in understanding how heterogeneous place-based influences (such as local government or urban topography) can influence the sustainability outcomes of socio-technical systems.

Although transitions theory and the MLP is theoretically an actor-based approach [19], in practice understanding the potential for "real-world" success amongst mobility innovations based on electric vehicles and sharing requires a shift away from more abstract applications of transitions theory perspectives towards more stakeholder-centric research [2,15]. The primary data collection technique used for this study was therefore semi-structured interviews involving key stakeholders. This method is well-suited to exploring phenomena to achieve new insights, while offering opportunities to adapt and deepen an investigation as the research context evolves [66]. Although face-to-face interviews are often viewed as the "gold standard" for qualitative research, online interviews can also provide rich data and work better in specific situations [70], while overcoming some of the inherent drawbacks of in-person interviews of time, cost, and scheduling challenges [71]. This research was conducted in spring/summer of 2022 at a time when COVID-19 lockdowns were in force in the research locations. This made the use of Zoom for online interviews a necessity rather than a choice, but also created opportunities due to the unusual availability of otherwise habitually busy respondents. The interviews were undertaken in Mandarin by a native speaker (with fluent English) who also manually checked the subsequent interview recording transcriptions and translation into English.

The study employed purposive sampling to focus on participants with the greatest perceived potential to address the research questions [66,71] using existing contacts as the basis for snowball sampling. The sample comprised three groups of interviewees: (1) senior decision-makers (founder, general manager, or marketing manager) from ten EVSS providers within the YRDEZ; (2) decision-makers from nine other mobility service providers, including both online-hailing services and public transport providers; and (3) seven policymakers from local and national governmental bodies and other institutions with an interest in EVSS. Further details of the respondents are included in Tables 2 and 3.

Table 2. EVSS and representative details.

Rep	Company Type	OEM Link	Vehicle Ownership Model	Platform Type	User Base	Employee/Car Ratio
R-1	Private	No	Providers and other collaborations	Flexible service-driven EVSS	B&C-side	300/500
R-2	Private	No	Providers	User-focused vehicle resource allocation	B&C-side	260/600
R-3	Private	No	Providers and other collaborations	Decentralised collaborative marketplace	B&C-side	9/2000
R-4	Gov. led	ShouQi	OEM	Manufacturer-driven ecosystem	C-side	1200/ 30,000
R-5	Gov. led	Guanzhi	OEM	Manufacturer-driven ecosystem	C-side	1000/ 30,500
R-6	Gov. led	Guanzhi	OEM	Manufacturer-driven ecosystem	C-side	2084/ 30,000
R-7	Mixed	No	Providers	User-focused vehicle resource allocation	B&C-side	2084/ 30,600
R-8	Gov. led	SAIC	OEM	Manufacturer-driven ecosystem	C-side	100/5000
R-9	Gov. led	SAIC	OEM	Manufacturer-driven ecosystem	C-side	365/5000
R-10	Mixed	No	Providers and other collaborations	User-focused vehicle resource allocation/ Peer to peer	C-side	1000/ 100,000

Table 3. Other interviewee details.

Inter-views	Name of the Organisation	Type
I-1	Public Transport Department	Local provider of bus, taxi, tube, and tram services
I-2	Baishi Shunxin	Car
I-3	Baidu (Jidu automotive)	Car
I-4	Xiaopeng Car	Car
I-5	ShouQi	Car hailing service
I-6	Che Xiaodong	Car hailing service
I-7	Tubu	Car
I-8	DIDI	Car hailing service
I-9	T3 mobility repair garage	Collaboration
I-10	Traffic and Roads Department	Local government dept.
I-11	New Energy Vehicles (NEV) Association	Industry association
I-12	Traffic Police	Local government dept.
I-13	EV Association	Industry association
I-14	Deputy-Mayor	Local government office
I-15	Public Transport Department	Local government dept.
I-16	National Development and Reform Commission (NDRC)	Local government dept.

The interviews generated 131,904 words of data from the three respondent groups, which were analysed both using the MAXQDA 2022 software [72] and through manual thematic analysis [71], which enabled the research team to be fully immersed in the data and identify key themes that emerged. The analysis was developed through open codes, which were then generated into focused codes, and finally integrated into themes.

4. Findings and Discussion

Six themes emerged as key findings from the analysis and are discussed in the following subsections. As is not uncommon in qualitative research, we have opted to combine the presentation and discussion of findings as this can reduce the risk of repetition and be useful in helping readers to interpret the results [73], including by relating findings to prior research [74].

4.1. Business Model Diversity

Within the YRDEZ, five distinct business models emerged amongst the EVSS firms, and we have labelled them as follows:

- Manufacturer-Driven Ecosystem
- Decentralised Collaborative Marketplace
- Comprehensive Integrated Mobility System
- User-Focused Vehicle Resource Allocation
- Flexible Service-Driven EVSS

These business models vary in whether they focus on the individual consumer (C-side), business customers (B-side), or both; by levels of investment in assets (ownership of vehicles); and by rental durations. We have summarised the respondent descriptions of the different business models employed by the companies operating in the region in Table 4. The differences in business models employed partly reflects the origins of the company behind it. The "Manufacturer-Driven Ecosystem" models, for example, belonged to EV manufacturers who moved into EVSS as a market development strategy and as a way to reduce accumulated vehicle stocks. In contrast, the "Comprehensive Integrated Mobility System" models were rooted in internet economy firms extending their e-commerce capabilities into EVSS. All the firms' business models involved both vehicles and online systems in delivering the mobility service but varied in the balance of emphasis between the two within their strategies, skillsets, cultures, and business models.

Table 4. Five business models for EVSS in YRDEZ.

Business Model Type	Required Investment	Vehicle Ownership	Rental Duration	Target Market	Additional Objectives
Manufacturer-Driven Ecosystem	Heavy Assets [1]	Manufacturer	Short-term	C-Side [2]	Brand value enhancement and inventory management
Decentralised Collaborative Marketplace	Mixed	Independent Owners	Long-term and Short-term	C-Side and B-Side [3]	Exploiting the synergies of Internet of Vehicles
Comprehensive Integrated Mobility System	Light Assets [4]	Pure Platform Operator	Long-term and Short-term	C-Side	Streamlining data and financial value chains
User-Focused Vehicle Resource Allocation	Mixed	Independent Owners	Long-term and Short-term	C-Side and B-Side	Maximising underutilised vehicle assets
Flexible Service-Driven EVSS	Light Assets	Platform Operator	Long-term and Short-term	C-Side and B-Side	Adapting and tailoring services to cater to varied customer demands

[1] Heavy assets: The EVSS providers own its SEVs; capital-intensive, the original equipment manufacturer (OEM) needs to finance the vehicles in the market and does not receive the cash flow benefit of selling the car outright (e.g., EVCARD). [2] Individual customers. [3] Corporate customers. [4] Light assets: The EVSS providers partially owns its SEVs (e.g., Baishi EVSS).

The varied and evolving nature of business models amongst EVSS providers is attributable to several factors, including market demand, policy interventions, and the involvement of diverse stakeholders. Factors such as evolving customer preferences, innovative promotional strategies, local government attitudes, insurance company policies, urban infrastructures, innovative technologies, and other stakeholders contribute to the dynamic adaptation of these business models. Respondents viewed EVSS providers' business models as evolving rapidly, but likely to become less diverse as the industry consolidated from a range of new providers across multiple cities, for example:

> "In the future, the automotive industry may eventually be dominated by only two or three companies nationwide. However, I anticipate that these companies will undergo significant changes in their business models to adapt to new technologies and consumer demands. Despite these adaptations, one aspect that will remain unchanged is their commitment to exclusivity arrangements established with key suppliers from the previous era, ensuring a continued partnership that has been important to their success". (R-8)

In relation to the reconfiguration of the local passenger mobility system, the business models employed have two implications. Firstly, whilst Geels's [35] original model includes information systems niche innovation in the form of "apps" supporting public transport use, EVSS represents the application of information systems to impact car use. EVSS also represent the merging of niches as predicted by Nykvist and Whitmarsh [30], in this case the merging of "soft" app-based services with the "hard" innovations in electric vehicles.

4.2. Business Model Evolution

The merging of app-based services with vehicle technologies was viewed by respondents as being on the verge of reshaping the EVSS market and urban mobility more generally through the emergence of autonomous driving technologies [13,14]. Autonomous driving technologies are still embryonic but have become a focus of ambitious visions for more collaborative, connected, and sustainable mobility systems [14,75]. They also represent a potentially disruptive technology [14], or as one interviewee (I-12, Traffic Police) expressed it: "Autonomous driving is not just an incremental improvement, it's a complete overhaul of our transport paradigm". For EVSS providers, autonomous driving may allow them to escape the vehicle distribution versus utilisation trade-offs that hamper their business models [49], allowing for much greater efficiency. Other stakeholders also highlighted the environmental benefits of integrating autonomous vehicles into EVSS. One official (I-13, EV Association) noted, "The impact on reducing urban pollution could be substantial, aligning with our goals for sustainable urban environments".

The sustainability contribution of autonomous vehicle-based EVSS services may depend on the extent to which their use replaces private car journeys rather than allowing those unable to drive (due to issues of age, health, or license-holding) access to shared vehicle use. This may provide a social sustainability benefit of further democratising mobility, but also risks further individualising urban mobility [75] and increasing users' feelings of isolation, vulnerability, and loss of agency [2]. The environmental sustainability contribution will depend on whether additional journeys are created and/or the substitutions involved between active travel public transport and other travel services. As has been noted [75], early adoption plans for autonomous vehicles (in European cities) have typically failed to integrate sufficiently with public modes of transport or the generation of renewable energy to ensure they make a positive contribution to sustainability.

There was an expectation amongst respondents that autonomous driving would lead to a change in the business models of ride-hailing services and taxi services to embrace the new technology and effectively align these services with EVSS provision. The analysis of mobility sharing services in Chinese cities by Hu and Creutzig [12] presents ride-hailing and -sharing services as very distinct mobility subsectors (or regimes). This is in line with Geels's [35] model if we further subdivide his car-based transport regime into established regimes based around private cars, taxis, hailing services, and sharing services. However, the technical innovation of autonomous driving looks set to merge the three alternatives to private cars:

> "In the future, (shared) EVs will play a crucial role in urban transportation and long-distance travel, as they can not only meet individual travel needs but also partially replace traditional transportation methods such as taxis, buses, and rental cars. As a car manufacturer with expertise in human–machine interaction technology and ride-hailing services, I believe EVs will become a single category that combines our own products and ride-hailing services". (I-3, Baidu, Jidu automotive)
>
> This goes beyond the merging of mobility niches predicted by Nykvist and Whitmarsh [30] to represent more of a merging of regimes. The path to successfully implementing autonomous driving technology will depend on meeting technological challenges, a supportive policy environment, consumer expectations, consumer behaviour and market acceptance. A ride-hailing service provider highlighted the role of their services in familiarising the public with autonomous mobility, stating: "Our platform can accelerate public acceptance and trust in autonomous vehicles". (I-3, Baidu, Jidu Automotive)

The growth in access to autonomous vehicles via eMaaS services may also provide an opportunity for the perceived "tech savviness" involved in accessing an autonomous ride via an app-based service to supplant the symbolic and social signalling value of private vehicle ownership that has previously acted as a barrier to sustainable mobility transitions [2].

4.3. Impact of Local Factors

National Chinese government policy is explicit in its promotion of sharing services as part of a more circular economy, and policies and regulations promoting the development and adoption of EVSS include subsidies, tax incentives, and other support mechanisms [12,76,77]. However, local government policy may differ from central government policies, leading to potential inconsistencies in the overall regulatory landscape [78,79]. This may include local preferences for specific EV technologies, infrastructure development, or differing levels of support for EVSS. At a more prosaic level, manufacturer-based diversity in charging interfaces and inconsistency in local implementation of vehicle-charging infrastructure could both inhibit the growth of EVSS and threaten the profitability of firms providing charging services [12]. Another important consideration can be the practicalities of EV charging infrastructure. The availability and location of charging stations may directly impact the operational efficiency and scalability of EVSS providers' business models. Without well-planned charging infrastructure, similar challenges to those faced by the Autolib scheme in Paris [49] may arise, affecting both service profitability and user satisfaction. Operators are increasingly adopting sophisticated scheduling algorithms to tackle charging infrastructure management and vehicle disposition and relocation to improve operational efficiency and user experience [13,14].

Shanghai is one of relatively few Chinese cities with clear policies aimed at supporting EVSSs via dedicated parking spaces, charging infrastructure provision, and traffic management [12,13]. Such support has allowed local EVSS providers to experience rapid growth:

> "In Shanghai, the local government allocates a certain number of parking spaces in designated areas specifically for shared vehicles. As a result, private vehicles generally do not occupy these parking spots. The parking situation in Shanghai is undoubtedly more strained than in Suzhou, with vehicle costs possibly far exceeding those in Suzhou. However, Shanghai's government has been more effective in addressing this issue, mainly due to their clear and strong support for the shared vehicle initiative, including support from local communities". (R-9)

Beyond local government, grassroots community support for local EVSS providers was also credited with helping to develop its reputation among the citizens of Shanghai and allowing it to emerge as a major local EVSS brand:

> "Even at the grassroots level, community support for this initiative is substantial. The approach in Shanghai, from top to bottom, is more supportive and cooperative, which contributes to a better outcome". (R-9)

One EVSS firm manager highlighted the important role of government incentives and regulations in fostering EVSS adoption: "Local government policies have been a game-changer. Subsidies and regulatory support have directly influenced our strategic decisions and growth". (R-5) This sentiment was echoed by another interviewee from the ride-hailing sector, who noted the importance of policy in creating a conducive environment for innovation and user acceptance.

A government official emphasises the potential of local policy to address environmental and mobility challenges: "Our aim is to use policy tools to reduce carbon emissions and improve urban mobility. By supporting EVSS, we're not just looking at environmental benefits but also at enhancing the quality of urban life". (I-10, Traffic and Roads Department). This view aligns with the growing recognition of the need for comprehensive policy frameworks that encompass environmental, social, and economic dimensions of sustainability.

Despite the central government maintaining a favourable and supportive stance towards low-carbon, and sharing-oriented products, attitudes towards EVSS differ among cities [78,79]. For instance, Suzhou, a city near Shanghai, with its industrial background, places greater emphasis on the manufacturing sector, while Hangzhou is more receptive to the internet economy. Furthermore, the development of EVSS relies on support from the internet economy:

> "Moreover, the city's attitude towards and support for internet products also plays a role, such as Hangzhou's emphasis on the tertiary industry". (I-12, Traffic Police)

> "With regard to policy push, although national-level policy orientations serve as strategic guidelines, local policies at the city level can differ significantly. In cities like Hangzhou, the tertiary sector, such as the internet industry, strongly supports the EVSS market, and this support is reinforced by local policies. We can also observe the emergence of other markets, such as bike-sharing and various sharing initiatives, as well as live streaming with goods. Policies can be categorised into landscape and niche levels. Consequently, we can witness the rapid popularity of EVSS in Hangzhou within a short period". Corbin (I-16, National Development and Reform Commission)

4.4. Impact of Stakeholder (Mis)behaviour

Users of any service are clearly a vital aspect of any business model and their behaviour will be key to its success or failure The role of users in mobility transitions and vehicle sharing has been explored in a review of papers on the topic by Axsen and Sovacool [2] and other authors such as Yao et al. [13], Sarasini and Langeland [15], and Uteng, et al. [80]. What is notable in such contributions, and across the sustainable transitions literature more widely, is that the consumer role is almost exclusively framed in terms of intended service adoption and the extent of use, but not its nature. Therefore, a good deal is known about the type of consumer who uses these services and how their use is influenced by attitudes relating to novelty, convenience, cost, and environmental consciousness [2,13,80]. Previous research has also revealed that consumers' use of such services can be inconsistent and strongly influenced by particular life events [2] or by the nature of a specific journey (e.g., the relationship between destinations and parking availability or other transport modes) [2,13,77]. Sarasini and Langeland [15] highlight the importance of user competencies related to driving, digital media use, and trip planning as relevant factors for shared mobility, whilst also observing that user practices are under-researched in relation to business model innovation. Axsen and Sovacool [2] (p. 18) ask in relation to automated EVs:

"How will these innovations be used or even mis-used?" as an issue for future research to address.

Consumer misbehaviour negatively impacts the quality and profitability of shared mobility services as this can lead to usage reduction, but also higher maintenance, repair, and cleaning costs, issues around improper parking, and contagion effects [81,82]. EVSSs provide temporary access to cars without the transfer of ownership, which might lead users to disengage from their responsibility towards the accessed objects [83] and consequently misbehave. In the context of shared mobility services, perceived anonymity due to a low degree of provider control has been identified as a major cause for consumer misconduct [81].

What was revealing in our interviews was the extent to which respondents were also preoccupied with the "style" of service use and, following problems experienced in bike-sharing services, the extent to which consumer misbehaviour could negatively impact EVSS provision:

> "However, Suzhou adopts a conservative attitude towards new products like EVSS or sharing bikes in order to avoid causing urban chaos. For instance, in the past, there were issues with disorderly parking of shared bicycles in other cities. As a result, shared cars have not experienced rapid development in Suzhou within a short period". (I-16, National Development and Reform Commission)

All the EVSS service-based respondents mentioned consumer misbehaviour as a potential problem for their business. Although the majority of providers use integrated GPS systems that potentially reduced the chance of vehicles being stolen, there was still a risk of parts and accessories being stolen:

> "Owners have their private cars, and sometimes, for certain parts, they might dismantle parts from your vehicle. Interestingly, for electric vehicles, the issue of parts theft is somewhat less severe than for fuel cars because electric vehicles primarily use integrated components. Besides, in recent years, particularly in the last year or two, the fuel vehicle industry has been greatly impacted by the theft of catalytic converters". (R-6)

Beyond improper parking, there had also been incidents of concern in terms of the purposes behind vehicle use:

> "Many incidents involve renting vehicles for illegal activities". (R-7)

Misbehaviour impacting the services was also not restricted to users, and the Representative (R-6) reported issues of malicious vandalism of parked cars. A more unexpected stakeholder misbehaviour was noted by one provider who had encountered the providers of vehicle repair services deliberately damaging vehicles to generate business:

> "The repair garage damaged vehicles at night or at some other time. When the damage is discovered by employees the next day or the day after, they would report it for repair". (R-10)

Such incidents led to another provider, LD Go, building their own repair garage, but this also increased the operational cost and complexity of the business. Other steps that providers had taken to mitigate user misbehaviour, included emphasising terms of use, imposing penalties for misuse or damage, using digital tracking systems, implementing educational campaigns to promote responsible behaviour, and using social media channels to promote responsible shared vehicle usage and foster a culture of accountability among users.

4.5. Regime Intersection

The conventional mobility transitions approach stresses the potential for changes in "parallel" regimes (like homeworking) to impact mobility demand within the overall system [35]. The experience of the EVSS providers demonstrated that other "intersecting" regimes could influence their prospects directly by impacting the viability of their business models. For example, companies within the insurance industry could impact EVSS schemes by determining whether the vehicles involved are classified as commercial vehicles or private cars, impacting costs, risks, and business model viability:

> "Depending on the risk associated with car-sharing services, the insurance premium for a non-commercial vehicle might be USD 411 (CNY 3000), while that of a commercial vehicle could be USD 1370 (CNY 10,000). How would they handle this situation for a fleet of commercial vehicles, where the difference in premiums is significant?" (R-4)

> "From the perspective of insurance companies, they may be unwilling to settle claims for car-sharing services, and this issue becomes difficult to resolve, leading to a series of problems. For instance, what would happen in the case of a severe traffic accident? Insurance companies could potentially refuse to pay out". (R-2)

This conflict can surface when accidents occur, with insurance companies interpreting shared EVs as commercial vehicles, thus denying coverage or disputing claims based on the belief that the vehicles should have been insured under a commercial policy.

Similarly, the regulatory landscape concerning EVSS schemes is still in its nascent stage, without mature laws and regulations to address challenges and opportunities presented by this emerging industry:

> "The true essence of car-sharing lies in utilising idle vehicles. However, in this regard, many laws and regulations are not well-developed. If you try to operate a car-sharing service legitimately, you might be considered as operating illegally. In reality, it is difficult to share a vehicle because, from a legal perspective, it is classified as a non-commercial vehicle". (I-2, Baishi Shunxin)

This conflict between EVSS providers' expectations and insurance companies' practices may require further investigation to better understand the underlying factors. Clearer insurance policies, their classification criteria, and the legal framework governing vehicle insurance could help identify potential areas for improvement, ensuring fair and sustainable practices that benefit both EVSS providers and insurance companies. Other significant regimes include energy generation, since the source of the electricity powering shared vehicles will have a major influence on their sustainability [48,84], or the provision of charging infrastructure [13,14].

4.6. Shifting Dynamics: "Baiduisation"

The most significant regime intersection affecting the EVSS market perceived by respondents was the entry of leading internet services companies. Most prominent among these was Baidu. Although its roots are as an internet search engine company, Baidu has diversified rapidly into a range of digital services including AI, mapping, ride-hailing services, travel services, speech recognition, data analytics, cloud computing, and marketing services. Building on these capabilities, it has now identified "intelligent driving" as a key growth area for the business including self-driving services, high-definition mapping, automated valet parking and autonomous navigation pilot, intelligent electric vehicles, and robotaxi fleets [83,85]. Its influence on the future development of EVSS was sufficient for respondents to begin talking about the "Baiduisation" of the market.

Baidu was not the only company with an internet and digital background entering and reshaping the market, with others including JD and Xiaomi:

> "As JD.com is a future shareholder, the aim is to achieve autonomous delivery; the intelligent system employed is by Xiaomi. For instance, the navigation, air conditioning, and music sound system within this ideal future car, they will all be Xiaomi, akin to a Xiaomi tablet embedded in the vehicle". (R-3)

Increasingly the contribution of these internet companies to the market was not purely informational, but also involved hardware. This began with AI chip development for vehicles, but as one representative (R-2) noted, Baidu had become a stakeholder in car manufacturers (such as electric vehicle manufacturer NIO) and was also developing its own car manufacturing systems.

> "At Baidu, we are also developing the 'Kunlun' chip (Shanghai) and 'Honghu' chip to address the challenge of creating our own ECU for autonomous driving, having already achieved Level 4 autonomy. Moreover, to facilitate a better human-machine interaction model, we at Baidu have improved upon existing human-machine interaction technologies for vehicle connectivity. Similar to the widely used Baidu Maps navigation that will be integrated into the autonomous driving system, our familiar 'Xiaodu Xiaodu' voice and video interaction system will also be incorporated into the JiDu car". (I-3)

5. Implications

Markard, Raven, and Truffer [1] argue persuasively that the field of sustainability transition studies needs to develop by building bridges with other fields including: economic geography, to better appreciate the spatial and institutional contexts of innovation; management studies, to better understand the role of business strategies and capabilities; sociology, to understand the actors and human dimensions involved in transitions including the social norms and practices that shape consumer and citizen behaviour; and policy studies, to understand the power balances and institutional structures that will influence success. The experience and perceptions of the EVSS managers and stakeholders interviewed here reflected the importance of each of these and was also confirmatory of much previous research considering sustainable mobility transitions, vehicle-sharing schemes and the business models within them including: the difficulties of achieving change to entrenched mobility cultures and systems [33,48]; challenges related to over-capacity or a lag in the provision of supporting infrastructure [12]; and the importance of connections with other transport modes and across different types of user behaviour [13,15,48].

The insights gathered from this research highlight the importance of a range of research disciplines for understanding the processes of sustainability transitions, whilst also revealing some limitations of transitions theory and the MLP. As a model, the MLP is essentially two-dimensional, linear, and hierarchical in expressing the direct relationships between niches, regimes and the wider socio-technical landscape. In this respect, it is similar to a model of a food chain that might be used to capture and express aspects of a particular ecological system. The experience of the EVSS providers in contributing to a sustainable mobility transition within the Chinese cities studied seemed more representative of a form of "ecosystem" in which success or failure was determined by the complex interplay between multiple types of entity.

Returning to our research question of how local factors impact EVSS providers' business models and the wider transition process, for the firms studied, a supportive national policy landscape and access to promising emerging technologies was no guarantee of success. This needed to be complemented by local policy support on parking and traffic management, insurance industry cooperation, charging infrastructure policy support and commercial provision, and appropriate behaviour from consumers and other stakeholders. The findings reinforce, in the context of sustainable mobility, Williams's [29] emphasis on the importance of local context and the local embeddedness of initiatives (and their potential for replication in other places) because: "Local, socio-technical innovation shapes local contexts, and local contexts shape local socio-technical innovations" [29] (p. 192). They also demonstrate the importance of local actors and practices that go beyond the obvious ones of local government support and charging infrastructure provision, to include less obvious aspects of local contexts relating to consumer misbehaviour and grassroots community support.

In terms of the role that the business models and strategies of EVSS providers play in the evolution of the vehicle-sharing sector and its potential contribution towards more sustainable urban mobility, in relation to the reconfiguration of the local passenger mobility system, the business models we saw employed have two obvious implications. Firstly, whilst Geels's [35] original model includes information systems niche innovation in the form of "apps" supporting public transport use, EVSSs represent the application of information systems to impact car use. Secondly, EVSSs also represent the merging of niches as predicted by Nykvist and Whitmarsh [30], in this case the merging of "soft" app-based services with the "hard" innovations in electric vehicles.

The potential of autonomous vehicles for the future development of EVSS companies' markets, business models, and relationships to other forms of MaaS (like ride hailing and taxis) also potentially masked a more fundamental evolution in their market and businesses. That is, the transformation from a physical orientation around vehicles and journeys to an informational orientation around data, software systems, and mapping. The use of mobile phones to access mobility services is generating "big data" sets that can be analysed to improve both "real time" traffic management and long-term policy planning for transport systems and land use [86]. Such data also create commercial opportunities for EVSS providers and beyond. This was captured in one interviewee's statement that: "All is (becoming) more information-oriented and less vehicle-centred" (R4). This reflects the type of mobility systems/ICT convergence that Köhler et al. [17] frame as creating challenges for the companies involved, and for researchers seeking to understand the implications for sustainability from a transitions theory perspective.

The entry of digital giants such as Baidu into the EVSS arena suggests something that goes beyond either the niche-based innovations or the influence of parallel regimes encapsulated within Geels's [35] model. The intersection of the mobility regime with the "informational" regime seems more profoundly transformational and represents an influence pervading the mobility system "horizontally" in addition to the major changes in mobility landscape experienced by EVSS providers "from above" or the influence of niches emerging "from below". This "digitization" of the mobility system may have benefits in terms of efficiency and environmental sustainability but may pose societal risks of exclusion for anyone unable to use the technology and from the power of the companies that accumulate the information from the operation of the market. It is access to that information that makes the market attractive to digital market players such as Baidu and creates an interesting situation in which the information that is a by-product of EVSS (and other transport systems) use becomes a valuable "raw material" for companies such as Baidu. This is arguably an alternative form of industrial symbiosis, but unlike the usual symbiosis based on physical resources, this transcends the boundaries of the physical and digital worlds.

6. Conclusions

Although discussion on transitions to sustainable urban mobility frequently focus on the promotion of active travel and public transport use [38,48], there is increasing recognition that cars can play a potentially valuable role through their use within EVSS businesses [13–15,48]. The type of EVSSs investigated here embody five of the six key developing trends in mobility identified by Mounce and Nelson [14]: shifts away from private car ownership and use; widespread adoption of EVs; the rapid emergence of "cars on demand"; the emergence of autonomous vehicles; and the potential for the shift towards mobility as a service. Their ability to contribute to a transition towards sustainable urban mobility will depend on the ability of providers to both develop and efficiently operate appropriate business models and to integrate effectively with other elements of urban mobility systems (such as public transport) [48].

In their review of the sustainable transitions literature with an emphasis on sustainability "experiments", Sengers et al. [87] set out five key priorities for future research. One of these concerns creating a better understanding of the geographies of transition and the role of local contexts such as cities and regions in how innovations and transitions are sparked and governed, while another concerns the role and contribution of business and innovative business models in developing innovative forms of shared and more sustainable value. This study contributes to both of these by considering Chinese cities, a comparatively under-studied context in relation to electric and shared mobility transitions [2], and by focusing on EVSS providers and their business models.

This paper adds to our understanding of the potential for transitions towards sustainable mobility by demonstrating the complex dynamics at play at different levels. At a micro level, the business models adopted by individual businesses can influence how, how far, and how fast the market for shared mobility develops, and how the (mis)behaviour of individual stakeholders can shape and determine the success of those business models. At a meso level, a focus on mobility systems understood as physical systems (concerned with moving people around and the physical and social consequences of doing so) risks under-appreciating, from a business model perspective, the extent to which urban mobility is transforming into a sub-system of an informational/ICT regime. In this scenario, novel players (and their technologies) are emerging with different priorities and strategies and are creating mergers between niches and intersections between regimes that may have significant implications for the future of mobility. At a macro level, the impact that localised factors in specific places (such as local government policy) have on the success of pro-sustainable mobility landscape level pressures were very visible. This reinforces the need for good local and national policy coordination as well as for policy consistency across parallel regimes and other influences on prospects for shared mobility, encompassing insurance industry regulation, urban planning, infrastructure management, parking provision, and traffic planning and management [14].

This study also contributes through its focus on contemporary progress towards sustainability, which is in contrast to a dominant focus in mobility transitions studies on the promotion of public transport use [38], and on either past transformations or forecast future developments [11]. It also contributes by focusing on better understanding how EVSS providers' business models operate and the impact the style of use can have on their success. This both answers the call of Sarasini and Langeland [15] for more research on how these services are used and misused and is in contrast with the majority of research in the field that tackles influences on supply and demand at a more abstract level [13]. Finally, this study contributes through the focus on a Chinese context that is important due to its scale, but has often been neglected in discussions related to sustainable mobility developments [2].

Whether EVSS use, and its evolution via the use of autonomous vehicles, will make a substantial contribution to sustainability and a transition towards sustainable mobility is contentious on a number of bases. Junnila et al. [88] have challenged the sustainability benefits of PSS use; the risks of rebound effects are raised by Wells et al. [89] and Wang and Yang [90] whereby savings are spent on carbon-intensive services such as holidays; the potential social justice implications of the commodity supply chain impacts that support the shift towards EVs are highlighted by Prause and Dietz [91]; and autonomous vehicles have been critiqued for the risks of "empty" journeys and as the latest distraction from promoting more active travel, better use of public transport, and the promotion of more localised lifestyles within cities [75]. Autonomous vehicles were widely seen by respondents as "the future" of urban mobility, with the ability to bring transformative change via reduced costs and increased convenience, but signs of a "push-back" over concerns about safety and employment impacts are already emerging in places where they are being trialled [92].

This study has limitations, partly because it is location specific. The three cities involved are among the 17 Chinese "megacities" of over 10 million people. This raises the possibility that the findings may not be generalisable to smaller city contexts, although none of the key findings are obviously scale-dependent. The sample cities also share a common national policy context, which may limit generalisability to other countries. This study also has limitations because the range of social, technological, policy, and business issues relevant to the future development of EVSS services makes it a highly complex topic in which all relevant factors cannot be accommodated in a single article. In particular, we do not directly consider the perspectives of EVSS users; however, the role of users in mobility transitions and vehicle sharing has already been explored in contributions such as those by Axsen and Sovacool [2] and Sarasini and Langeland [15]. We also have not attempted to address all the uncertainties of the net long-term impacts of electric vehicles or sharing services linked to relevant issues of data quality, population and regional heterogeneity, future levels of vehicle automation, temporal dynamics, behaviour chain reactions, and societal/demographic issues like aging or fertility rates [90].

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