Mapping Key Drivers for Carsharing in London Through a Systems Thinking Approach

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Abstract

The development of urban transport and private cars has provided many benefits to society. However, this comes with a price and brings a lot of challenges. A change towards a sustainable transport system is imperative, where diminishing the dominance of private cars and fostering a transition towards other transport modes plays a significant role. In this context, carsharing serves as an alternative to private cars. Despite considerable advancements in technology and economics, at the heart of this systemic change lies people. It is crucial to design engineering solutions with a human-centric approach, ensuring they are shaped by a deep understanding of people's needs and behaviour. This research recruited 30 participants in focus groups and conducted an analysis based on a systems thinking approach, with an emphasis on understanding complex interactions within the context of London. Ultimately, the study presents a causal loop diagram that illustrates the factors driving individuals' decisions to adopt private car ownership and carsharing services, as well as their relationships with societal and commercial (operator) influences. It provides insights into the key drivers and relations that enable a transformation of the transport system.

Keywords: Carsharing, Adoption Intention, System Dynamics, System Thinking, Focus Group.

Introduction

Transport is a vital component of modern society, impacting all aspects of daily life. The development of transport, especially the increase in private cars, has brought benefits but also poses several challenges such as congestion, emissions, and limited urban space. These increasing challenges within metropolis, like London, necessitate the launch of solutions to foster a sustainable transport system.

To address those challenges, there has been a strategic emphasis placed on developing new transport technologies and shifting in travel modes. In recent years, numerous progresses have been made. There has been strong support for electric car technologies and their infrastructure development, which aims to reduce greenhouse gas and pollutant emissions, like CO_2, NOx, PM etc., associated with internal combustion engine cars [1]. In addition, the congestion zone and low-emission zone schemes have been implemented in London to curb the use of private cars [2].

With the rise of sharing business models, many innovative shared mobility services have also emerged in London, such as carpooling, micro-mobility, and carsharing. Carsharing is known as “car clubs” in the United Kingdom. It is a mobility service that allows users to access and use cars without the responsibilities of ownership. Users only pay for their usage based on the hour and distance. Currently, there are many carsharing operators servicing individual customers in London, for example, Zipcar, Enterprise Car Club, Co-wheels, and Hiyacar, etc.

Substituting private cars with shared cars is a crucial move towards a sustainable transport system. Carsharing has been considered as a more sustainable transport mode compared with private cars. It has the potential to bring many benefits, for example, Martin and Shaheen [3] proved that shared cars can lead to a reduction in CO_2 emissions by substituting private cars. Furthermore, Ye et al.’s research [4] showed that having access to carsharing services can dampen people’s desire to purchase private cars. Through a lifecycle assessment, Chen and Kockelman [5] found that carsharing has both lower energy consumption and CO_2 emissions compared to traditional private car ownership.

There are ongoing calls for a transition towards a more sustainable transport system. Although carsharing has been promoted as a sustainable alternative, it has not fully achieved its intended impact. At the core of this complex transition is people, and the factors that influence their transport mode choices need to be understood [6]. But a shift in people’s travel behaviours does not occur in isolation. It is shaped by various interacting factors. Therefore, we need to look at this in a systematic way. A

system dynamics (SD) approach is inherently adaptable, enabling both qualitative and quantitative analysis to understand the intricate dynamics and behaviour of complex systems. On the quantitative side, it may create SD simulation models to simulate different scenarios and policies to assess trends and impact in a system over time; On the qualitative side, it is a systems thinking approach, where causal loop diagrams (CLDs) may be created to understand the system's structure and its internal cause-and-effect relationships [7].

In this study, set in London, the United Kingdom, focus groups were conducted and data were analysed by using a systems thinking approach. The aim is to promote a more sustainable transport system by understanding the systemic shifts in people's adoption intention between private cars and carsharing. Correspondingly, in this research, a CLD focused on individual adoption intention between private cars and shared cars was created. Additionally, this CLD also incorporates factors related to societal and commercial (operator) aspects. It allows a more comprehensive understanding of the dynamics influencing adoption, encompassing both behaviour and the strategic actions of operators within the system.

Literature review

Many researchers have focused on understanding travel behaviour and the influencing factors for the adoption of carsharing. They have explained the associated impact of sociodemographic variables on carsharing adoption, for example, gender, age, education, living location, income and household status [8], [9], [10], [11], [12], [13]. The adoption of carsharing is influenced by various attributes, most notably its cost-saving [14], [15], as the ownership expenses are distributed among numerous users. While some research highlights environmental benefits as an influencing factor for its adoption, while, there remains debate regarding its effectiveness [16], [17].

In addition to the aforementioned factors, researchers have identified various further factors. For instance, convenience [18], [19], [20], availability [21], [22], ease of use [23], security and safety [24]. Researchers are collaboratively striving to uncover the factors influencing changes in people's travel behaviour choices. They recognise that these changes are complex and may lead to a multifaceted transition in the transport system.

These complex interactions between people, transport modes, and their impact make the transformation of the transport system challenging. In view of this, the SD approach is helpful in

explaining the topic. This approach is widely applied in social, economic, ecological, and engineering fields to help understand the system behaviour. It can be used to explore user adoption of a product or service to aid diffusion. For example, Kreng and Wang [25] developed a SD simulation model to explore the adoption of Nike golf products; Abbasi et al. [26] revealed the complex behaviour changes of users adopting mobile banking through a SD simulation model; Baur and Uriona-M [27] modelled the adoption of photovoltaic panels among house owners.

Prior literature reviews [28], [29] have emphasised the suitability of a SD approach in the transport field, including logistics and supply chain [30], [31], highway infrastructure development [32], [33], airline and airport management [34], as well as urban, regional and national transportation policy [35], [36]. Researchers have adopted a SD approach to investigate the shared mobility as it becomes more important in the sustainable transport system [37]. Carsharing has also undergone thorough research. Nevertheless, there is a scarcity of studies using the SD approach in this field. Esfandabadi et al. [38] highlighted the need for a systemic approach for understanding carsharing systems. They established a framework for carsharing, environment, population, car manufacturing, and regulation and administration aspects through the system thinking approach. Later, they extended their findings to develop CLDs for each of the aforementioned aspects [39]. Additionally, Jittrapirom et al. [40] recruited stakeholders in Bangkok, Thailand, including policy makers, users, experts, etc., to conduct remote focus groups to develop a conceptual model for carsharing. Their model explained how increasing investment in quality of service can enhance its attractiveness to users, whereas the price of the service can control the number of users.

There are also researchers who have performed SD simulations. Luna et al. [41] explored long-term CO_2 emissions by people using electric shared cars under different government policies in Fortaleza, Brazil. Their results indicate that carsharing is a driving force for the adoption of electric cars. Zhou et al. [42] evaluated the impact of different subsidy policies on the adoption of time-sharing electric cars in Shanghai, China. Their simulation results showed that appropriate subsidy policies can make the service attractive to private car users.

The above literature contributes valuable insights into carsharing systems both theoretically and practically. However, the literature is still lacking studies that reveal adoption intention and carsharing systems through the SD approach.

Method

The SD approach was pioneered by Jay Forrester at MIT in the late 1950s. It employs feedback loops to understand the intricate dynamics and behaviour of systems in the actual world [43], [44], [45]. Through the application of mathematical equations and models, it captures the interconnections and reciprocal influences among various factors within a system. Additionally, it highlights the importance of qualitative data as a fundamental source for comprehending the dynamic interplay between influencing factors.

We conducted a qualitative analysis using data collected through focus groups, aimed at identifying key factors driving the adoption of private car ownership and carsharing services. First, we conducted a preliminary survey to collect data on participants' private car ownership, carsharing membership, usage and frequency, demographic variables, and their availability for focus group sessions. Then, based on the information collected, 30 participants were ultimately selected to form the focus groups, all of whom were holding a valid driver's license, residing in London, and possessing a level of familiarity with the carsharing concept. We numbered the participants from Participant 1 (P1) to 30 (P30). The demographic characteristics of the sample are detailed in Table 1.

Table 1 Sample characteristic

Characteristic		Number
Carsharing membership	Current member	11
	Former member	10
	Non member	9
Private car ownership	Private car owner	15
	Former private car owner	9
	Non private car owner	6
Gender	Female	16
	Male	14
Age group	17-24 years old	11
	25-34 years old	15
	35-44 years old	3
	45-54 years old	1

We organised a series of six focus groups, with half of the focus groups held in-person and the remaining via Microsoft Teams. The focus groups were structured around four themes, adopting a semi-structured format. The initial theme facilitated a general discourse on transport and shared mobility, serving as an icebreaker to a more targeted discussion. The second theme was dedicated to exploring the factors influencing individuals' intention to adopt private car ownership. The third theme shifted the target to the determinants affecting the adoption of carsharing services. Lastly, the fourth theme contemplated the introduction of autonomous driving and its impact on the preference between these two transport modes. However, the last theme was excluded from the analysis of this paper.

Each focus group was moderated by a researcher and spanned an approximate duration of one hour and forty-five minutes. The focus groups were audio recorded with the consent of the participants, and then the audio recordings were transcribed into textual format for further analysis.

Employing a grounded theory approach [46], we delineated the key influencing factors and the relationships by using Nvivo 14, which is a qualitative data analysis software. In synergy with previous literature, these were then utilized to develop a CLD by using Vensim, a software used for creating CLDs and analysing dynamic feedback models. This CLD aimed to elucidate the dynamics and interrelated nature of the factors involved within the system. This approach was instrumental in synthesizing a deeper understanding of the interplay of the shift from adopting private car ownership to carsharing services.

Results and discussion

In this section, the complete CLD derived from qualitative analysis is presented and explained, enriched by illustrative examples from focus groups and insights from prior literature. The complete CLD is decomposed into multiple sub-CLDs to articulate the focus on different thematic areas: (I) urban population and society, (II) private car adoption, (III) carsharing adoption, and (IV) operator. The complete CLD is shown in Figure 5 and serves as a visual map that illustrates the systemic interactions and mechanisms within individuals as well as transport paradigm, specifically focusing on private cars and carsharing.

Urban population and society

Figure 1 illustrates the factors that influence the adoption of private car ownership and carsharing within urban population and societal behaviour. And it shows the influence of high-quality wellbeing and living standards provided by the city on the population dynamics.

The urban population boosts private car demand, where the relationship between family size, lifestyle practices, public transport availability, and practicality benefits of private cars are brought to the fore. The practical benefits of private cars refer to the utility and autonomy that private cars can offer, allowing drivers control over their trips and the freedom of use [47]. In the focus groups, participants commented on this aspect:

> "If I'm going somewhere, I can leave anytime … playing my music when I'm driving alone … I can stop to get snacks at the shop, and I can go anywhere at any time." (P5)

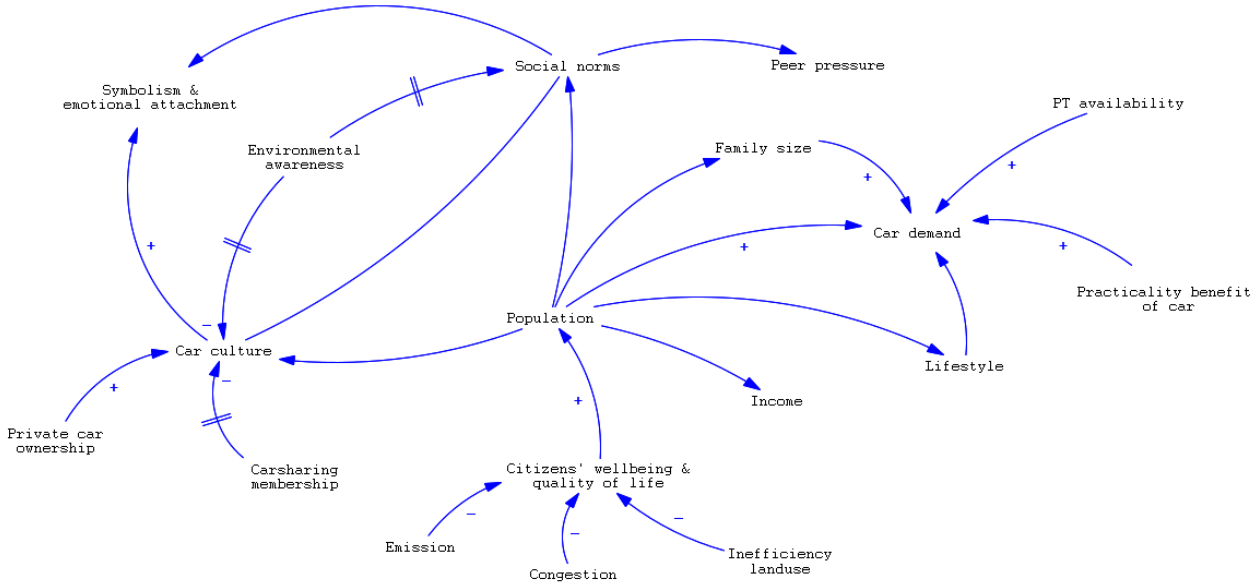

Figure 1 CLD for urban population and society

The population has gradually shaped the city's unique sociocultural landscape, giving rise to factors such as car culture and social norms. Soza-Parra and Cats [48] have stated that they are interdependent, endowing private cars with symbolic and emotional attachments, as well as engendering peer pressure. They are closely connected to people's intention to adopt the private car ownership.

> "It means that we have the wealth, we are ready for our life, we are ready to set up everything for our children and family." (P21)

These above factors contribute a reinforcing loop, the massive diffusion and adoption of private cars increase the influence of those sociocultural factors, in turn, driving the growth of intention to adopt.

However, as environmental awareness grows and sustainable transport options become more popular, there might be a slow changing in people's attitudes and priorities. These changes have the potential to reduce the inclination towards owning private cars. Some participants expressed that their pro-environmental thoughts have impacted their choice, they had started to reflect, and they believe that carsharing is a more eco-friendly transport mode compared to private cars.

> "After a bit research, I found that private car is one of the major issues. This triggered me to actually think to change my travel mode." (P24)

Although Hartl et al. [17] indicated that the sustainability of carsharing is not the primary reason people choose it, it still plays a role in stimulating people to shift. Especially as a delayed impact on sociocultural aspects and gradually intensifies, people will pay more attention to the sustainability of their transport modes. Therefore, the sustainability of carsharing remains an indispensable factor influencing people's adoption intention.

Private car adoption

The variable "intention to own a private car" is one of the central nodes within the system, promoted by the aforementioned sociocultural aspects. Furthermore, as shown in Figure 2, this central variable is directly influenced by several economic factors including purchase costs, maintenance costs, insurance costs, operational costs, and income. With the increase of income, people's intention to own private cars increases.

> "Before you consider buying a private car, you have to consider maintaining the car. The maintaining cost is so high, you probably can't get your coffee." (P25)

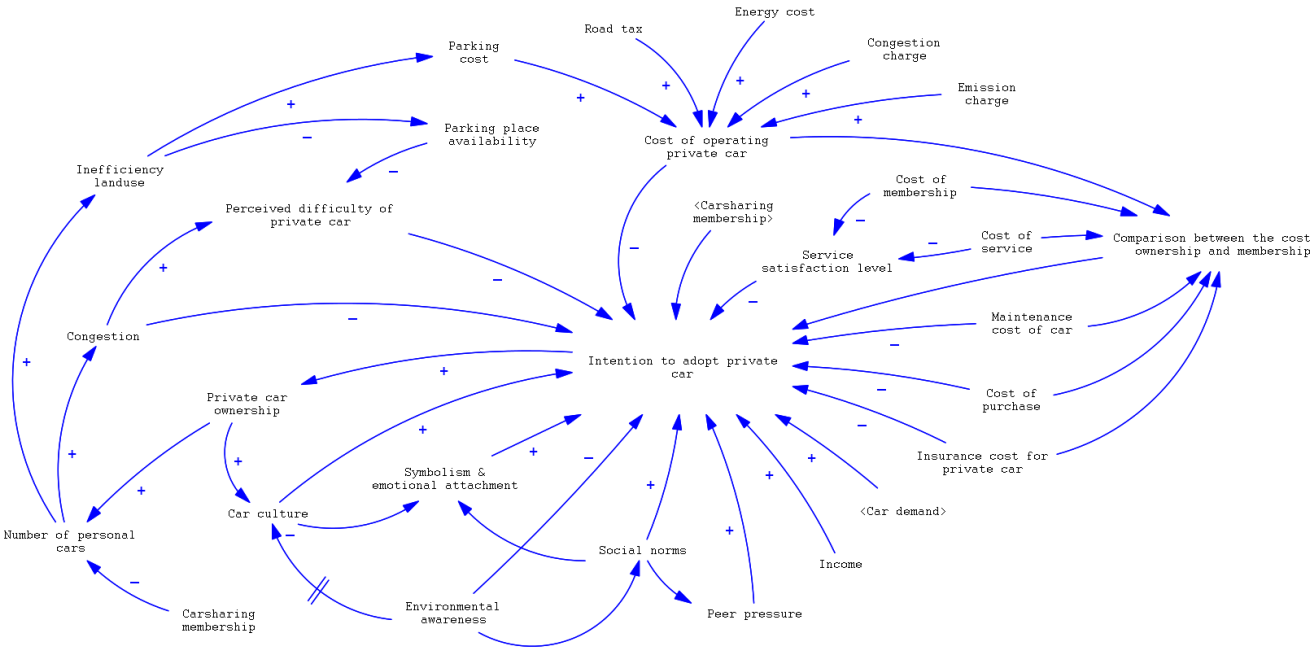

Figure 2 CLD for private car adoption

While, the high costs discourage people from owning cars, creating a balancing loop where increased expenses act as a barrier. For instance, increases in parking fee, emission and congestion charges are interlinked with it.

> "Now, obviously, if it's an old car, you pay even more, because it's polluting. My old car was one of those old diesel ones that have been banned a little earlier last year." (P10)

Policies such as emission and congestion zones play a role in modulating the attractiveness of private cars in London [49]. On one hand, by heightening the direct costs associated with private cars, they can inhibit demand. On the other hand, those costs may incite a modal shift toward alternative transport modes such as carsharing.

The perceived difficulty of owning and using private cars acts as a moderating factor. As identified in the focus groups, this perception arises from different sources: complex policy regulations (such as car registration procedures), limited parking spaces, and the challenges of driving, especially through traffic congestion. These factors increase the psychological and practical burdens of private car ownership.

> "Technically my dad takes care of the paperwork. So, the fact that I had to do it all by myself made me just forget about it." (P20)
>
> "The private car becomes a burden when you have to think about where I should leave my car, where should I park." (P21)

The increasing challenges may reduce the intention to own a private car. This describes a balancing feedback loop: as the number of cars in London increases, the associated difficulty of ownership and using a private car are magnified in people's minds, consequently, reducing the intention to own private cars. These dynamics also contribute to the rationale behind individuals considering joining carsharing, as it offers an alternative to circumvent the perceived escalating difficulty of private car ownership, e.g., car registration procedures and documents.

Carsharing adoption

Figure 3 demonstrates another central node – "intention to adopt carsharing", it is influenced by its cost-saving benefits over private car ownership expenses [50]. In the focus group, cost comparison is a prominent topic in the juxtaposition of private car ownership versus carsharing membership. Economic factors influence the attractiveness of carsharing services. Participants emphasised the cost-saving incentives of carsharing. However, this intention is directly moderated by service pricing structure (membership fees and usage charges).

> "While you are going a holiday … and you need the car for 3 to 4 days. It's not feasible to pay for 3 to 4 days. It will be expensive for one-time experience." (P4)
>
> "It's been charged hourly, so you realize that you will be paying more." (P9)

That membership schemes and pay-per-use methods are not ideal for long-term or frequent use of carsharing services. Consequently, individuals may rely on alternative ways, like public transport systems, positioning carsharing as a supplementary mode to be used when needed for car travel.

> "It (carsharing service) provides an opportunity for travelling long distance due to sometimes lack of public transport." (P5)

As previous researchers have noted, carsharing and public transport have the capacity to complement each other [51], [52]. This emphasises the crucial role of public transport in the transition towards

reduced car dependency and highlights the significance of the partnership between the public transport system and carsharing deployment.

> "They were covering some other area but not ours. And they moved in our borough. It seemed quite convenient way of having access to a car without owning one, and the car we had was becoming a bit too expensive to keep for no reason." (P10)

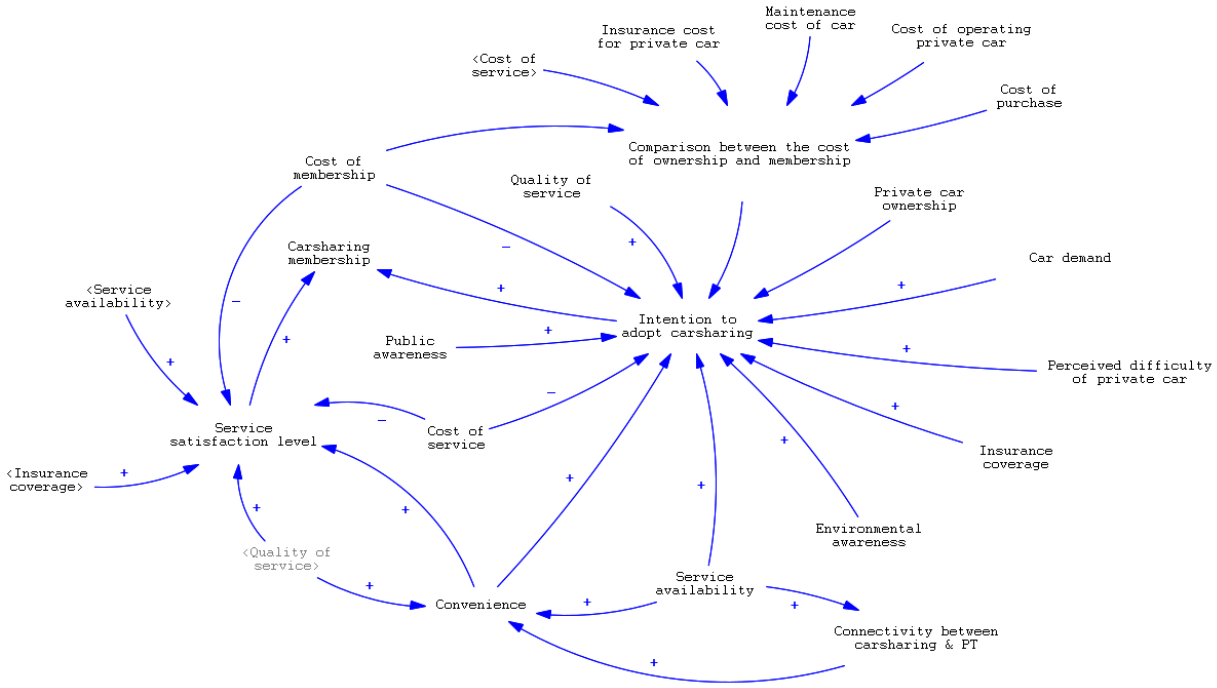

Figure 3 CLD for carsharing adoption

Another factor identified in the focus group discussions is the convenience of the service, a term encompassing various aspects as described by participants. This includes the availability of complementary transport modes, the availability of the service ("It depends on whether it's easy for me to find a shared car when I need one." (P15)), and the quality of the service. Regarding the quality of service, participants' statements aligned with the classification by Jittrapirom et al. [40], and they also demonstrated the association with convenience. Furthermore, in contrast to the difficulty associated with parking private cars in central London, carsharing provides designated parking bays. This allocation of fixed parking spaces is a motivation for some individuals to adopt carsharing.

Moreover, the improving service attributes exert a positive impact on the intention to adopt carsharing, such as availability, quality, and insurance coverage, which are closely associated with service operations. Additionally, the development of supportive infrastructure, such as dedicated parking space for shared cars, boosts the attractiveness of carsharing, as highlighted by many participants.

> "If you go to a supermarket, it's quite tricky if you have a private car, it takes you time to find a parking space. Even if you find one, it might be a quite far away … But shared cars have an allocated parking space." (P7)

To maintain or enhance positive effect of substituting private cars through carsharing, it needs to closely monitor user satisfaction [53], [54]. In our CLD, this is influenced by several factors. Positive factors include insurance coverage, quality of service, convenience, and service availability, while negative factors include membership fees and usage costs. These factors collectively impact the satisfaction level, which in turn affects users' intention to own private cars and to adopt shared cars, as it is shown in Figure 2 and 3. High satisfaction may prompt users to be more inclined to adopt shared cars as an alternative to private cars, thus reducing their dependence on private cars. On the contrary, if the user satisfaction is low, it may enhance the user's intention to keep or purchase a private car.

Operator

In the previous sub-section, it is shown that many aspects that influence the adoption of carsharing are impacted by the operations. Descriptions from these stakeholder map onto focal points that carsharing operators can attend to, which are shown in Figure 4.

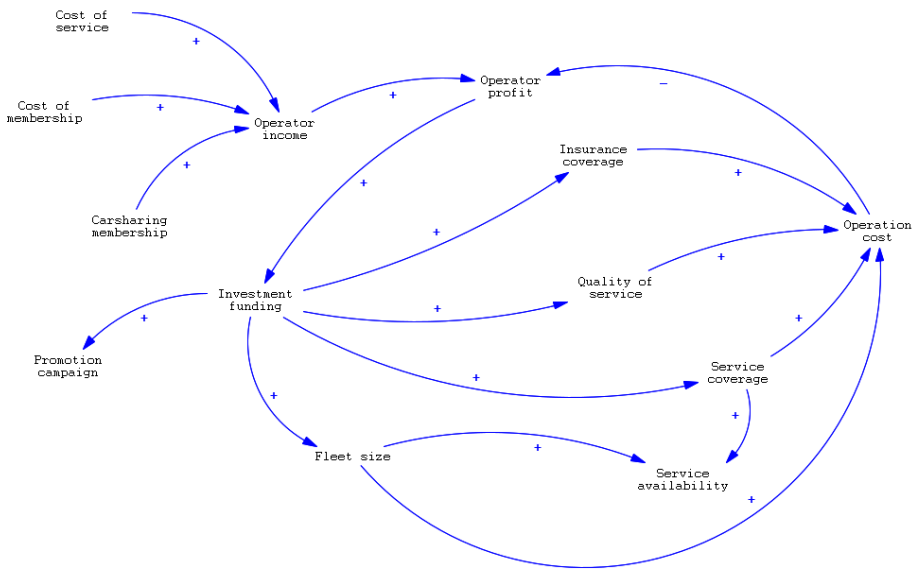

Figure 4 CLD for carsharing operators

Operators' business models directly affect the service attributes that are important to users, such as availability, reliability, and convenience of the service. Among these, how to expand and deploy service range and fleet is one of the keys. Our focus groups and prior studies collectively highlight the importance of integrating carsharing with multiple transport modes, especially public transport, which

should be considered in strategic planning. Another point that requires attention is the development of systems and platforms to support the user service experience. Here, the pricing structure acts as a regulatory factor. As stated by Yao et al. [55], the continuous optimisation of pricing, fleet, deployment locations, and service-related technology are important.

Investment in enhancing the quality of service may make carsharing services more attractive [40]. Such sustained investment has the potential to bring the adoption of the service to a 'tipping point'. The resulting increase in membership and usage frequency may positively impact the operator's revenue, thereby creating a sustainable cycle. The synergistic effect of the development forms a reinforcing loop, strengthening the intention to adopt carsharing. The increased investment can also enable more promotion campaigns to raise public awareness of the service.

> "I think what should be done more is to enlighten the public, make them know this service, understand the importance of sharing, and the importance to the environment." (P26)

Meanwhile, this 'tipping point' also reflects a delicate balance. The service development and maintenance can lead to increased costs for operation. It may affect the net profits of operators and their further development. Therefore, implementing a viable development strategy is crucial for the sustainability of carsharing operations.

The above corresponding explanations and the complete CLD shown in Figure 5, they indicate that this transition is a complex systemic change with multiple factors and feedback loops. As these interrelated factors continue to evolve, carsharing can play a key role in shaping the future of sustainable transport.

Previous studies have provided evidence that carsharing can effectively remove cars from roads in cities [4], [56]. London is no exception, the deployment of one shared car can replace 24 private cars [57]. It reduces the number of private cars by suppressing people from purchasing cars (including the purchase of a second car) and causing private car owners to abandon their private cars [58]. In turn, it brings many additional benefits, particularly in mitigating greenhouse gas emissions, traffic congestion and improving land efficiency within cities [59], [60]. Consequently, it provides a more liveable urban environment for the city population.

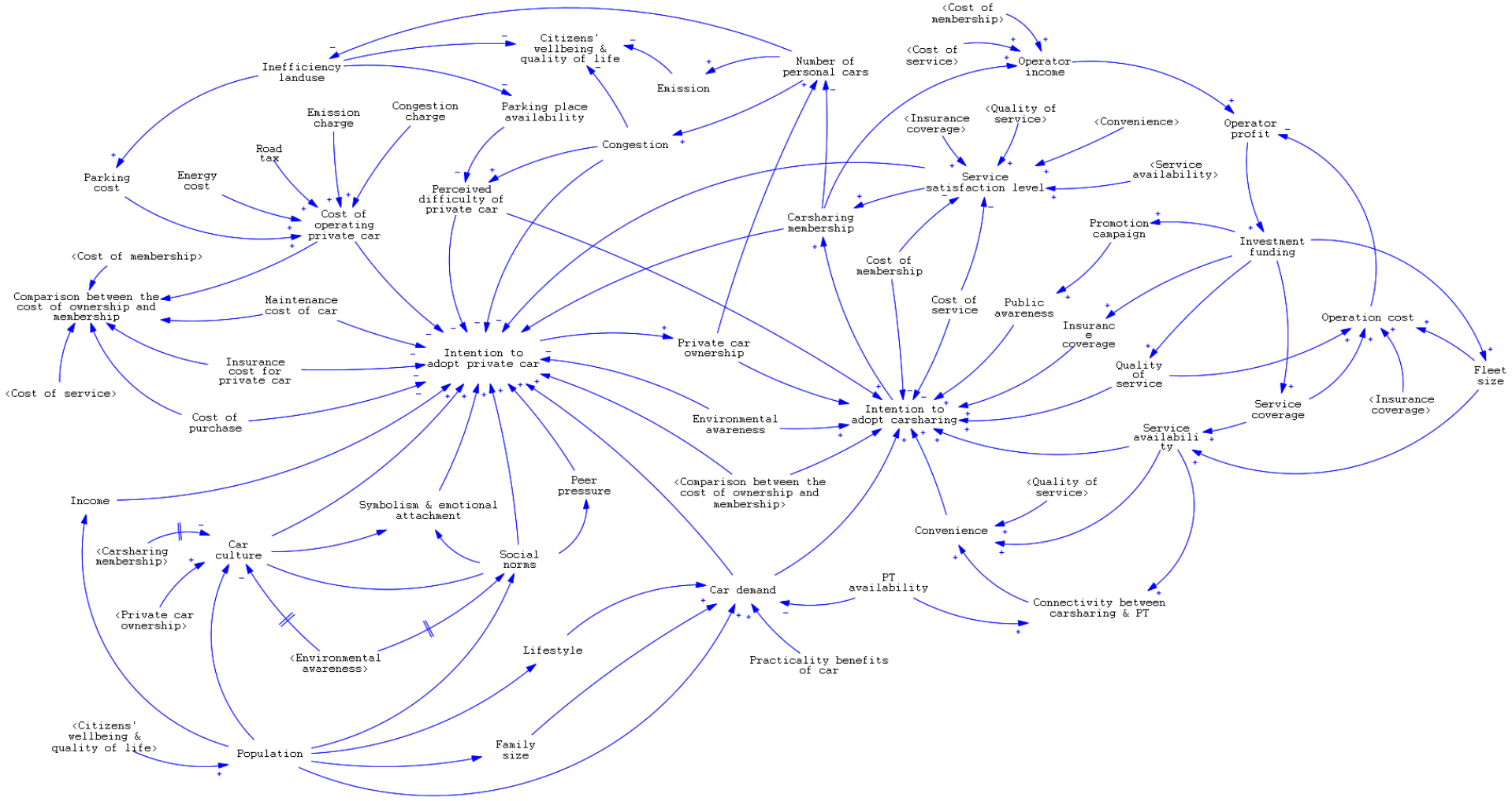

Figure 5 The complete CLD

Conclusion

In this study, based on focus groups and data analysis performed in London, the United Kingdom, by using a systems thinking approach, we demonstrated the factors that influence the intention to adopt private cars and carsharing. It is important to recognise that these intentions are a complex construct. Although we acknowledge the intention-behaviour gap [61], [62], our CLD nevertheless emphasises an explication of the driving factors behind this transition.

Directly imposing restrictions to control private car ownership may have negative consequences for the mobility of some citizens [63]. Therefore, it is crucial to promote a gradual transition of both people and transport. The successful transition is the result of an interplay of various factors, not only involving the efforts in economic and practical aspects, but also including the consideration of sociocultural aspects and changes in environmental awareness. In this process, people are the key, and their travel behaviour and demand need to be paid close attention. Therefore, stakeholders need to focus on meeting user needs, promote the shift from private cars to shared cars, and support the long-term goal of sustainable transport.

Our result provides a focused reflection and interpretation of the factors influencing individual transport mode choices. It offers insights into the transition towards carsharing as a step towards sustainable transport by reducing dependency on private cars. It sheds light on the dynamics of sociocultural influences, environmental awareness, and their delayed impact on people's travel mode choices. We also emphasize the importance of economic considerations in shaping the propensity towards the adoption of private cars. Moreover, the current complexities associated with car ownership and related documentation have been identified as deterrents for a segment of the population contemplating private car ownership. However, it is imperative to recognise the possibility of a resurgence in private car ownership upon the improvement of these conditions. In the context of carsharing adoption, economic factors continue to play a critical role. This aspect is crucial for operators, who can use pricing structures as a strategic mechanism to regulate the adoption. While the continual enhancement of service can bolster carsharing's attractiveness. Our findings also support the claim that carsharing serves as a complementary mode to other transport modes, with the potential synergy between carsharing and public transport poised to fortify the inclination towards its adoption.

However, it is important to note that the composition of the focus group in this study, primarily based in London, may influence the generalisability of the results due to geographical location and socio-

demographic variables. Thus, the transferability of findings to regions outside of London or those with different socio-economic landscapes should be approached with caution. Positively, the factors influencing adoption identified in this study show strong similarities to those found in research conducted in Melbourne, Australia [23]. Nevertheless, corroborative evidence from a broader range of regions is still required.

This study was developed as a qualitative evaluation. The influencing factors and their internal relationships explain the drivers for people to shift between transport modes, which also provided a basis for a subsequent SD simulation. They can complement each other to obtain more robust insights. However, a quantitative approach was not implemented in this research. Therefore, future research may consider acquiring relevant empirical data and developing SD simulation models for this shift to further understand and explain the transformation of the transport system.

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