GAMES
GRID AWARE MOBILITY AND ENERGY SHARING

# SHARED MOBILITY, USER CHARACTERISTICS AND TRANSPORT MODE DECISION MAKING

VERSION 1.0

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Co-creating with partners that help to understand the needs of relevant stakeholders, we team up with intermediaries to provide an innovation eco-system supporting consortia for research, innovation, technical development, piloting and demonstration activities. These co-operations pave the way towards implementation in real-life environments and market introduction.

Beyond that, ERA-Net SES provides a Knowledge Community, involving key demo projects and experts from all over Europe, to facilitate learning between projects and programs from the local level up to the European level.

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# 1 INTRODUCTION

The transport sector is one of the main consumers of fossil fuel and is the only sector that continues emitting increasing rates of GHG [1]. In 2022, passenger vehicles (including cars and vans) accounted for 48% of emissions within the transportation sector and 10% of global emissions.[1] Nevertheless, the prevalence of privately-owned internal combustion engine (ICE) vehicles as the primary means of passenger transportation is steadily growing [2], contributing to traffic congestion, air pollution, and increased CO2 emissions [3] while presenting a challenge to the transition toward sustainable mobility [4].

More than half of the world's population are predicted to live in urban areas by 2050 [5]. The energy transition must address urban car ownership if we were to live in sustainable and live-able cities [6,7]. The high motorization rate that countries have been facing throughout the 20th and 21st centuries has led to adverse unpredicted effects, resulting in inadequate public transport systems and increased rates of greenhouse gas (GHG) emissions. Inadequate public transport systems led to a lack of user satisfaction, resulting in increased car ownership which further exacerbates the situation [8]. This cycle encouraged urban planners and policy makers to rethink existing transportation systems while looking for ways to transition to a less car-centric mobility systems and to change users' mobility habits.

The efforts to address urban mobility challenges gave rise to the concept of platform-based shared mobility services which have been introduced in many cities around the world [9]. Shared mobility services provide short-term access to shared vehicles based on the user's needs and are predicted to grow in congested areas where parking space is limited, and the cost of vehicle ownership is high. Research shows that the global market for shared mobility modes is expected to grow from US$ 1.1 billion in 2015 to US$ 6.5 billion by 2024 [8].

The GAMES (Grid Aware Mobility and Energy Sharing) project explored how digitalization could help electric vehicle fleets address user mobility needs, while creating new revenue streams by providing services for public electric grids and energy communities. The project also addresses the possible conflict between providing flexibility to the grid while meeting vehicle users' transport needs. In this context, this report provides a comprehensive literature review of the state-of-the-art on shared mobility and its potential contribution to the energy transition and sustainable transport. It comprises two main chapters: the first provides the state of the art of shared mobility and the second explores the acceptance level of the new concept of building-based shared car services. It presents the results of a focus groups conducted in Israel followed by a user survey. This new concept emerged in an attempt to address some of the barriers of traditional shared car services to expand their presence and increase their usage rate.

The state-of-the-art chapter will review the following topics: the overlap between the energy transition and sustainable transport; the origin of shared mobility, its various models and how it contributes to a more sustainable transport sector; the role of digitalization in providing shared mobility services; shared car services and shared electric vehicles; and finally, the

[1] Statista, Global CO2 Emissions from Cars and Vans 2022. https://www.statista.com/statistics/1388092/carbon-dioxide-emissions-cars-vans-transport/, 2023 (accessed on November 19, 2023).

acceptance of such models among users and the various positions of researchers toward shared vehicle services.

# 2 LITERATURE REVIEW

This chapter reviews the literature that explores the concept of shared mobility services and how they are predicted to transform the transport sector into a sustainable and efficient mobility system. The quest for more sustainable lifestyles drives the contemporary approach to transportation which gives rise to various shared mobility services as a sustainable alternative to vehicle ownership. This review focuses on car sharing services, which is a central component of the GAMES project. Shared cars are likely to offer a viable solution to the challenges that the transport sector is facing, namely congestion levels, air pollution and GHG emissions, all while reducing private car ownership, reducing demand for parking space and increasing occupancy rates.

## 2.1 Energy Transition and Sustainable Mobility

The manifestations of climate change and the increase of GHG emissions led to the realization that the global energy system must be transformed. This transformation, known as the "energy transition", is a shift toward low-carbon energy sources [10]. The IRENA report [11] provides a definition of the current energy transition as "a pathway toward transformation of the global energy sector from fossil-based to zero-carbon by the second half of this century". Following the 2015 Paris agreement, governments are engaged in decarbonization efforts that involve a range of cross-sector policy approaches including changing consumer behaviour and massive transport electrification.

During the last two decades, policy makers in many countries failed to design sustainable transport systems with reduced negative externalities [8], resulting in increasing rates of private car ownership which further aggravate the adverse effects [12]. In view of the complex situation of transport systems, on the one hand, and the urgent need to transition to low carbon systems, on the other, it has been recognized that a disruptive change toward sustainable mobility modes is needed [13].

According to [14] sustainable mobility must rely on three principles: satisfy human needs, ensure social justice and respect environmental limits. Subsequently, there are three criteria that must be met: providing accessibility to basic transport (needs), ensuring equal access to transport services (justice) and ensuring that impacts of transport activities do not compromise environmental sustainability (limits).

One way of reducing the adverse environmental impact of transport is to increase the penetration rate of electrified cars, which is already underway in many countries. However, the desired transformation of the transportation sector cannot be achieved by introducing zero-emissions vehicles alone. Thus, private car ownership rate has to be reduced by shifting to more efficient modes of mobility as well as reducing travel demand [15]. Therefore, existing user mobility patterns need to move toward more collective, active and affordable forms of transport, which also include the notion of shared mobility, walking and cycling.

In the following chapters, the notion of sustainable transportation modes is presented, while focusing on shared mobility. More specifically, it addresses electric car sharing services and how such sustainable modes of transport advance the energy transition.

## 2.2 The Role of Shared Mobility in the Mobility Transition

Transport systems are conceptualized as socio-technical systems made up of multiple components, including technology, policy, economy and markets, consumer behaviour, infrastructure, culture, and scientific knowledge [16].

### 2.2.1 The concept of shared mobility

Shaheen et al. [17] defined shared mobility as a short-term access to shared vehicles based on customer's needs and convenience. Shared mobility modes are an intermediate form between private car ownership and public transport with the potential to reduce CO2 emissions, traffic congestion, and reduce the demand for parking spaces which can be then repurposed and used by pedestrians and cyclists. Shared mobility is therefore a term that refers to a broad array of transportation modes with different use cases, business models and travel behaviour. It may be considered a significant component of an efficient transportation system in urban areas [18] that can provide new ways to access goods and services [19]. Therefore, its role is to provide access to a range of mobility choices while increasing multimodality and reducing costs [20].

Ruhrort [21] claims however that the term "shared mobility services" is problematic, because the notion of "sharing" implies non-profit collaborative activity while the services are predominantly commercial. Nevertheless, she agrees that the term of mobility sharing is widely in use, and therefore it makes sense to use them in the context of short-term car rental services.

Shaheen et al. [22] provides an exhaustive list of areas where shared mobility services apply. Services include carsharing, personal vehicle sharing (including peer-to-peer [P2P] carsharing and fractional ownership); scooter sharing; bike- sharing; transportation network companies (also known as ride sourcing or ride hailing); ridesharing (i.e., carpooling, vanpooling); micro-transit; and courier network services. The following figure categorizes these key areas of shared mobility: 1. Carsharing, scooter sharing, and bike sharing are services that enable vehicle sharing (left). 2. Ridesharing (carpooling and vanpooling), on-demand ride services, and micro-transit facilitate the sharing of a passenger ride (middle). Lastly, courier network services allow for the sharing of a delivery rides (right). The GAMES project focuses on the vehicle sharing category, i.e. car sharing.

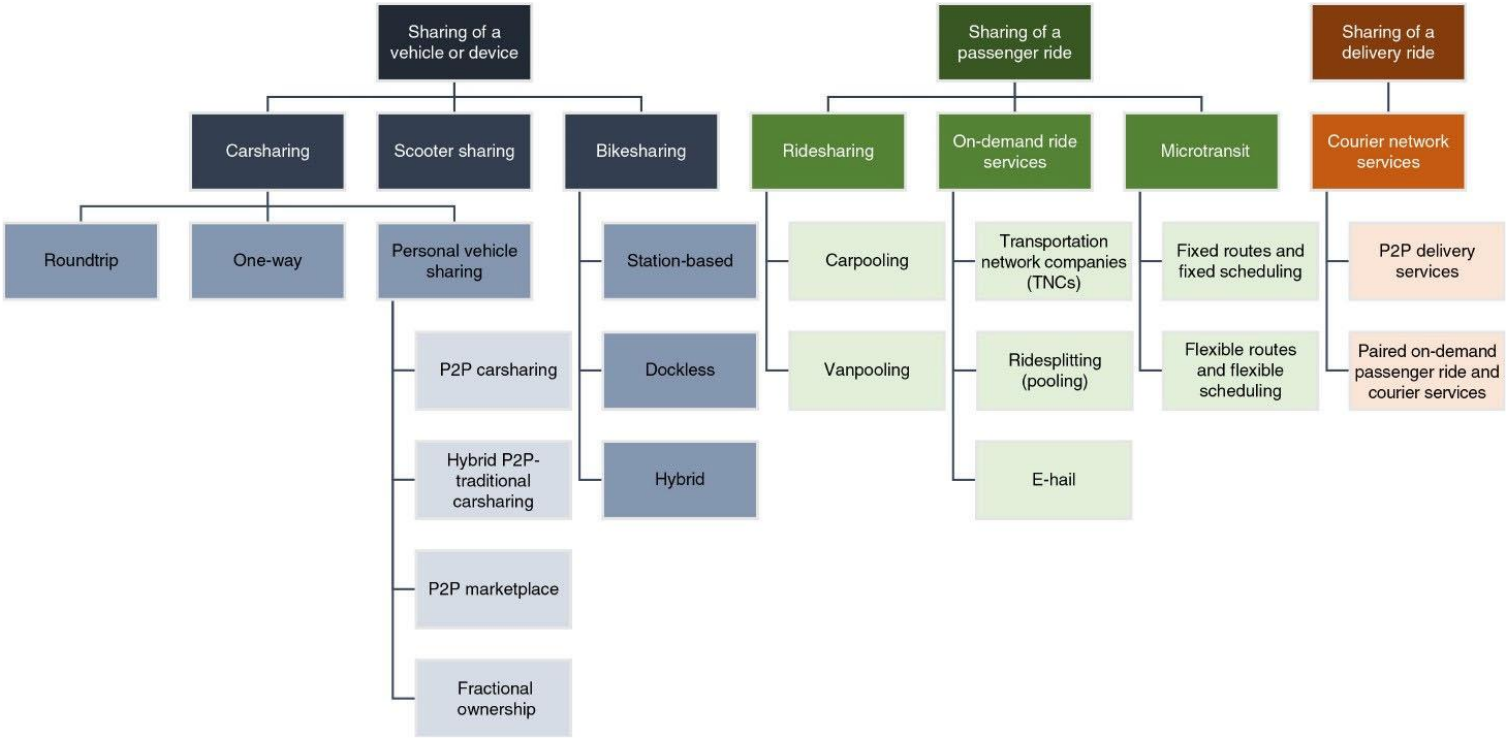


**Figure 2:** Shared Mobility and its Modalities.

Source: Shaheen et al. [22]

### 2.2.2 Controversies over Shared Mobility

While there is an agreement that sustainable mobility necessarily means reducing the modal share of private car travel, the contribution of shared mobility services to sustainable mobility is often contested [23]. Ruhrort [21] identifies three strands of the debate in the literature. One strand focuses on user groups, usage patterns and the effects of Shared Mobility Services (SMS) on the transport system and on ecological sustainability. The studies in this group typically explore the purpose and motives of users, how effective SMS are in replacing car ownership or whether SMS shifts users away from public transport. The results are mixed, but they seem to suggest that SMS have to be part of transport policy strategies in order to reduce car use and on their own they will have minor effect. The second strand focuses on the potential of SMS to become part of an integrated mobility system. A core concept in this context is Mobility-as-a-Service (MaaS) (see discussion in the next chapter), which facilitates the bundling of various transport services into monthly packages that are provided as services to users. Studies point out that offering mobility services via digital platforms may portray them in a more attractive way, but there may be negative social effects as well [24]. A third strand of research looks at the potential of SMS to foster a transition to a "multi-optional mobility culture" that would break the dominance of the private car. In this emerging regime, public transport will become the central part of a multimodal regime of mobility. It is therefore argued that SMS may lead to a cultural shift, but they need to be integrated into a regulatory framework that reduces private car travel in cities [23]. On the other hand, Groth [25] criticizes the shift to multi-optional mobility, primarily because it is coupled with technology, i.e., smart mobility. He points out that smart mobility may reproduce transport poverty under the cover of modern transport and that SMS may drive users away from public transport, walking and cycling without reducing car traffic. Canzler et al. (2016) [26] say that SMS may lead to a cultural shift, but they need to be an integral part of a wider strategy and regulatory framework aiming to reduce private car travel in cities.

In sum, the growing presence of SMS is driven by several forces. One is the environmental concern over emissions and air pollution. Another force is purely business-driven, which reflects the ongoing search of car manufacturers and fleet operators for new digitally-based business models. Yet another force is the growing awareness of urban dwellers to new lifestyles. Indeed, according to Mounce and Nelson [27], there is evidence that car ownership is declining, particularly among younger people and millennials due to changing attitudes toward mobility and lifestyles. While some studies show that SMS tend to have minor effects on car use, it may still have a role in creating an opportunity for a more sustainable transport policy and new mobility patterns are likely to continue their fast growth, as an alternative to private cars, if they are integrated in a more comprehensive urban mobility policy strategy [23].

### 2.2.3 Digitalization and shared mobility

Although shared mobility services have been operating in major cities since the early 2000s, they have evolved, with the help of digital platforms, and they now provide personalized services through smartphone applications [28]. Information systems play a crucial role in the

success of sustainable transportation in general and car sharing services in particular, by allowing users to have real time information and helping them to locate available vehicles [29]. This concept, known as Mobility-as-a-Service (MaaS) or Mobility-on-Demand, is relatively recent and rapidly shifting. It is "associated with Smart Mobility and consists of a hybrid technological innovation combining ICT with business models for delivering integrated access to transport services" [24]. The concept of MaaS aims at shifting users away from an ownership model to an access-based model in which access rights to multimodal mobility services (car, taxi, bus, rail, bike share) usually owned by corporates, are purchased via digital platforms connecting users and service operators [24].

The coupling of mobility services and technology is one of the components of energy-efficient transportation as it improves the efficiency of vehicle use by increasing its occupancy [30]. Ding et al. [31] showed that GHG emissions of urban transportation would be reduced by 4% to 20% when car sharing replaces 10% to 50% of private cars, respectively. Becker et al. (2020) found that the introduction of carsharing and bike sharing schemes may increase transport energy efficiency by up to 7%. Thus, smart shared mobility is identified as a sustainable mode of transport [32]. They found that Mobility-as-a-Service schemes together with shared mobility may allow to increase system efficiency in terms of travel time and cost.

On the downside, critics recognized that the concept of MaaS may have negative externalities from the social and governance point of view, leading to unanticipated societal implications in relation to wellbeing and social inclusion [32]. Docherty et al. [33], for example, warn that digitalizing shared mobility systems may increase the influence of large corporations on the design of mobility services platforms, therefore reducing equitable access to mobility services or denying government access to data. A study conducted by Noy and Givoni [34] substantiates the concerns raised by the critics of smart mobility. The study revealed that smart mobility innovators often do not grasp that sustainable transport requires a change of approach and that technology is the means to achieve this rather than the end. They found that there is a gap between what needs to be done and what is being advanced which does not necessarily lead to sustainable transport. They conclude by saying that if transport policy setting is driven by entrepreneurs who are concerned with profit making, then there is a reason for concern.

In conclusion, the concept of MaaS, represents a shift in the way that mobility is viewed. Instead of purchasing a physical asset (car), users purchase customised services that are available on demand, which would potentially lessen car ownership. However, the delivery of mobility services on demand depends to a large extent on well-functioning public transport and shared mobility, such as car sharing [27].

## 2.3 Car Sharing Services

Car sharing is a service that provides affordable access to a fleet of vehicles to multiple users and can be considered an intermediate form between private car ownership and mass transit [18]. Car sharing programs began in Europe in the mid-20th century. The first was introduced

in Zurich in 1948 and later expanded to other European countries [8]. The first carsharing initiatives were incorporated as cooperatives with collective ownership and were run by volunteers and were non-profit making. Similarly, in Israel, shared vehicle fleets were common for decades in rural villages known as "Kibbutzim" that operated as cooperatives[2]. The Kibbutzim residents collectively owned and operated a vehicle fleet to be used based on need and availability. This arrangement fitted well with their rather frugal lifestyle and allowed many members to use a car without bearing the burden of ownership. However, today most Kibbutzim are not communal and shared car fleets in Kibbutzim are rare. Private for-profit ownership of car sharing services for short periods of time appeared only later [35,36] and although car sharing services existed in the 1990s and in the early 2000s, their visibility increased with the introduction of mobile communications in the late 2000 [23]. Later, large car manufacturers (OEMs) introduced car sharing services, followed by bike- and later e-scooter sharing services in 2017 [23].

In recent years, car sharing has grown rapidly due the changing perception of car ownership, institutional fleet ownership and urban lifestyles [37]. In 2018, car sharing services accumulated more than 32 million members, distributed across 47 countries and six continents [22]. According to a global market report,[3] the car sharing market size surpassed USD 2 billion in 2020 and is anticipated to increase by over 20% by 2027. An industry report by Frost and Sullivan predicts that the global car sharing market will increase to "over 36 million users and 427,000 vehicles in 2025, at an annual combined growth rate of 16.4% and 14.3% respectively" [38].

### 2.3.1 Car sharing Business Models

Car sharing business models vary and can be classified based on flexibility of pick-up and return locations, the entity that provides the service, car types, pricing schemes and parking opportunities [37]. There are various forms of car sharing models:

**Station-based or roundtrip** car sharing, is a two-way service where customers pick up a vehicle at a designated location and return it to the same place, while paying for the number of hours that the vehicle was in their possession. Typically, customers would pay a per-kilometre charge [17]. The cars are parked in a pre-defined parking space owned by the service provider or leased from individuals or reserved by the local authority [8]. This type of service is typically used for short journeys with short term parking time [39].

**Station-based one way** is similar to roundtrip, only here the parking space in which the journey ends can be different from the parking space in which it started. The set of parking spaces is predefined [40].

**Free-Floating one-way** mode allows cars to be returned to a location which is not the same as the pickup location within a designated operating area [17]. There are no specific stations for

[2] Kibbutzim are a small, rural, and semi-socialist type of community unique to Israel. Many kibbutzim were established before the establishment of the state of Israel in 1948, but most were established shortly after. They were originally cooperatives. Currently, there are 274 kibbutzim across Israel, with a total population of about 140,000 residents.

[3] https://www.gminsights.com/industry-analysis/carsharing-market (accessed on February 25, 2023).

each car and the user can use the car outside the operating area as long as the car is returned to the operating zone. The cars may be parked in spaces provided by local authorities. This type of service allows users to check real-time vehicle availability and locations and book them using an application which sends the trip information automatically to the operator. This model is expanding due to available technologies, changes in local parking policies, and the freedom it offers to users [17,41]. In Germany in 2016, for example, station-based car sharing had an 18.8% increase in customers, whereas free-floating car sharing saw a 51% increase [8].

Ferrero et al. [40] found that almost half of the literature they analyzed (137 articles) refer to the one-way mode, 19% refer to free-floating mode and 19% referred to two-way mode, while they identify an increasing interest in electric car sharing. Furthermore, they noticed that throughout the period covered by the reviewed literature (2011-2016) there was a shift of focus in the literature from infrastructure design towards customer behaviour and acceptance. This change is attributed to the maturity level of car sharing systems [42].

### 2.3.2 Benefits of Car sharing

Car sharing is based on various forms of collaborative use of cars which can be considered a significant component of an efficient and sustainable mobility system in urban areas. Cars offer flexibility, comfort and availability that other shared transport options fail to provide. As a result, it is likely that shared cars can be part of the solution to the challenges that the transport sector is facing while reducing car ownership and demand for parking space, increasing occupancy rate per vehicle, decreasing congestion levels and greenhouse gas emissions [43].

On average, a privately owned car is idle for over 90% of the time and are used to transport a single person at the time, which means they are underutilized. Car sharing services increase the **utilization rate** of a car and as a result reduce the cost of travel [44]. Studies indicate that car sharing services contribute to reducing the number of cars on the road at a replacement rate of 15:1 (15 car owners can be accommodated by 1 shared vehicle), therefore reduce congestion and increase utilization rate [45].

The results of a study conducted in 247 cities throughout the OECD indicate that the widespread deployment of shared mobility services could have a significant effect on the overall emissions of urban passenger transport. The study showed 16.9% reduction in aggregate **$CO_2$ emissions** from transport by 2050 relative to 2015, concluding that the wide adoption of shared mobility can reduce congestion, reduce gasoline consumption and reduce travel times reduce congestion, gasoline consumption and travel times [46]. According to Akimoto et al. (2022), ride and e-car sharing even provide an opportunity for reducing global emissions at a low cost [47]. From the point of view of urban sustainability, the vehicles used in car sharing services are typically fuel efficient and lead to reducing urban emissions and city congestion [48].

Firnkorn and Müller (2015) discuss the entry of car makers into the shared mobility sector with the intention to target new audiences and create a new business activity [42]. As a use case, they considered the car sharing company Car2Go which was launched by Daimler in

2009. They found that the number of private vehicles were reduced as a result of using the service, resulting in reduced demand for **parking space** in cities [49]. Furthermore, since the same number of trips is facilitated by a smaller number of cars, each car will be less frequently parked therefore the demand for parking is reduced. However, this may result in a **negative feedback loop** as increased use of car sharing frees up parking space which in turn makes car ownership more viable. Therefore, the reallocation of freed-up parking spaces is important if we were to encourage the use of car sharing services and make cities more liveable [27].

Car sharing services increase the mobility of individuals and help them reach destinations otherwise inaccessible by public transit, walking or biking. As a side effect, using the service may **increase the awareness of users** to the social and environmental impact of using private cars, therefore become more prone to changing travel behaviour.

### 2.3.3 Car sharing Services Contribute to Efficient Mobility Systems

Kopp et al. [50] analysed the travel behaviour of a free-floating car-sharing service (DriveNow), and found evidence that free-floating car-sharing members are more intermodal and multimodal in their behaviour than non-members. More specifically, users of a free-floating car service tend to cycle more and use their private car less and that free floating car sharing users do more trips in the same amount of time and distance with different modes of transport [50]. This means that free-floating car sharing services has a higher potential impact on the travel behaviour of users and that locating shared mobility services near other means of public transportation would yield a higher use of public transport altogether. Therefore, car sharing services are expected to contribute significantly to the emerging flexible and sustainable urban mobility systems that are typically multimodal with public transport being the main component thereof. This shift is going to be supported by mobile technologies that help make car sharing services more commonplace. Such a concept was observed during the field research conducted in GAMES, taking the form of **mobility hubs** (in Berlin they are branded by the name Jelbi) which implements a multimodal urban mobility system that is located near a major public transport terminal.

In sum, car sharing services are most common in urban areas. If fully integrated with the public transport system and other forms of mobility, car sharing services do not necessarily have to be seen as a **substitute transportation mode but rather as having a complementary role** [27,51]. Therefore, policy makers should consider supporting such initiatives, while anticipating the potential infrastructure changes that would arise from vehicle electrification.

## 2.4 Shared Electric Vehicles

According to the International Energy Agency (IEA) the global Electric Vehicle (EV) fleet is projected to reach 230 million vehicles by 2030 [52]. In view of electric vehicles adoption rate and the expansion of Mobility-as-a-Service technologies, it is reasonable to assume that electric car fleets will play a greater role in any local energy transition policy and become one of the leading solutions for the challenges in the transportation sector. The electrification of mobility in general has multiple potential benefits, including the reduction of fossil fuel consumption in the transport sector, as well as reducing air pollution and its associated health

hazards. Consequently, shared EV fleets are predicted to grow in congested areas and become a significant component of an efficient and sustainable transportation system in urban areas [18,27]. Moreover, considering the projected number of EVs globally and governmental incentives to electrify the transport sector, using EVs in shared mobility makes economic sense on several accounts. Individuals using shared electric vehicles could benefit from saving the cost of purchasing a new electric car while enjoying the benefits of driving a new car. From the perspective of the municipality shared electric cars reduce urban pollution as it reduces the overall number of cars in the city; as a result, it may repurpose parking spaces and use them in a way that benefits the wider public. Following such reasoning, many vehicle fleet owners are contemplating on how to partially or entirely electrify their fleets.

However, the diffusion of EVs faces some challenges. One of the concerns of EV users is range anxiety. Habib et al. (2015) surveyed members of car sharing programs and looked at membership duration as well as how active members were during their membership period [53]. The results show that electric car sharing is perceived as part of an integrated transport system for short trips, therefore having low relevance to range anxiety. However, since Habib et al. (2015) published their paper, electric vehicle technologies have advanced and the range anxiety is no longer an issue in the grand majority of cases.

The expansion of car sharing services and electric vehicle adoption are synergetic and closely linked. Electric car sharing adoption will boost the electric vehicle industry since the service helps users to avoid the high purchase price of electric vehicles. In addition, better connectivity between various mobility forms (aka intramodality) will benefit electric cars because they can be used together with other transport modes, if strategically located. As car sharing services cater for the various demands of an increasing diverse customer base, the use of electric cars will also increase [27]. In addition, climate policies are prioritizing the generation of energy from renewable resources, thus advancing the expansion of electric mobility to mitigate transport emissions [54].

Ruhrort et al. [55] studied the potential of electric car sharing to become part of an integrated mobility system in Berlin. They tried to identify the target group that is likely to use this service. They found, as did other studies, that the likelihood of using the service depends on high availability of vehicles, and that **e-cars are well adapted to the typical mobility patterns found in free-floating car sharing**, i.e. short distance travel.

The needs of users vary when it comes to spontaneous access to the service and flexibility of use. Mounce and Nelson [27], for example, explore how free-floating electric car sharing has the potential to become a major component of future city transport systems. They find that the increasing road congestion in cities has reduced the appeal of the private car and a shift is observed from car ownership towards car access.

There is also a wide range of mobility preferences among users, implying that a broad range of multimodal mobility profiles have to be taken into account when designing car sharing services. The findings clearly show that **an attractive urban mobility system will be one that offers high-quality public transport and good bike mobility combined with a range of car**

**sharing services with free-floating electric car services for short range travel and station-based services for long range travel.** Equally important, car sharing users use a range of transport modes and the bulk of their everyday journeys is not made with shared cars. Therefore, when considering sustainable transport solutions, car sharing should never be regarded in isolation.

The academic literature, therefore, reflects the increased attention to environmental issues and the growing need of electrified vehicle fleets. A shift of attention towards studies related to electric car-sharing systems, mainly focusing on the propensity of users and barriers to adopt these vehicles, is observed [40]. However, many of the studies that were reviewed for this literature review were not published in the last 3-4 years. Considering the fast pace of technological improvements in the electric vehicle market, more recent research is in order.

In conclusion, the use of electric car sharing has a great potential to expand in scope, especially with regard to the free-floating scheme, which provides a high degree of flexibility to users. Using this scheme may even be profitable to fleet owners which is currently not the case. Electric car sharing has even a greater potential if connected to mobility hubs where multiple forms of mobility are present, partly because fleet sizes are currently constraint by operational costs to a bare minimum. This constraint could be partially alleviated if vehicles were to provide grid services while idle as will be explained in the next chapter.

## 2.5 Car sharing Acceptance and Consumer Preferences

Most car sharing services are in highly dense metropolitan areas, allowing users to enjoy the flexibility of private vehicles without having to pay all of the costs involved in purchasing and parking it. However, despite their increasing popularity, car sharing services are vying to achieve profitability which is dependent on the number of subscribers who are willing to frequently use the service. This chapter reviews the literature that studies user profiles and the factors that impact user acquisition and retention.

### 2.5.1 User Demographics

Over the last decade a fair number of studies investigated the behaviour of shared cars users all over the world in an attempt to find out what drives users and whether joining the service impacts users travel behaviour. Studies usually focus on socio-demographic characteristics and how they influence customer acceptance and retention. Recurring attributes include environmental consciousness, men of young age (30-39 years), medium to high income, university-level education, living in the city centre, and lower levels of travel satisfaction [56–59]. It also emerges that the majority of users live in a one- or two-person households [60] and that they are more inclined to adopt multimodal mobility pattern [61]. Another study conducted among shared mobility users in the UK, found that 37% of them do not own a vehicle as a result of using the service. The vast majority of this sub-group said that using shared mobility services resulted in a decision to not purchase a car, 11% sold their cars and 6% said they intend to do so in the next 3 months [62].

### 2.5.2 Impact of Car sharing Services on Travel Patterns

The impact of car sharing services on travel behaviour of users is another topic of great significance that is debated in the literature. Answering this question will determine whether car sharing services can reduce car ownership in the long run. Ruhrort (2020) identified two opposite trends in the literature: some studies state that car sharing could contribute to a reduction of total number of car mileage as well as a reduction of car ownership, while other studies affirm that car owners could not forego private car and those who do not own a car may use car sharing instead of other public transport [23]. However, **the impact of car sharing services on travel behaviour of users is complex and depends on multiple parameters including accessibility to the service, pricing and availability, to name a few**.

Various studies investigated the motives of users to subscribe to shared car services, while also evaluating whether shared car services are likely to replace car trips or car ownership or even replace public transport, cycling or walking. Martin and Shaheen (2011) conducted a survey among 6281 members of car sharing services organizations in North America [48]. The authors evaluated the change in annual household emissions and found that carsharing reduces GHG emissions as a whole. Moreover, among car sharing users, active transport (walking and cycling) increased significantly, as well as carpooling which led to reducing their car commuting to work. **Overall, after joining the car sharing services, users reported that they increased their use of public transit and non-motorized modals**. The study also established that the miles travelled among car sharing members decreased compared with other individuals living in the same area.

Other studies investigated the impact of car sharing services on car ownership. Martin et al. (2010) found that car sharing clearly leads to reduction in household vehicle ownership at a ratio of 9-13 vehicles removed per shared vehicle [63]. Hildebrandt et al. (2015) [29] investigated users' travel patterns in Germany and found that more than 80% of respondents agreed that a car sharing service that meets their expectations would lead them to forgo their private car. They also found that car sharing users are usually environmentally friendly, and that perceived cost saving usually leads to longer membership duration and a more frequent use. In summary, the findings showed that **the decision to become a member of such a service does not depend only on the attitude toward the concept but also based on how experienced users are with technology**.

Catulli [64] investigated customer acceptance of Product-Service Systems (PSS) which was applied to car sharing services. The PSS approach "… combines an asset (a car) and a service that gives customers access to this asset instead of ownership". The author found that consumers tend to accept PSS in principle but they are not sure whether it can meet their expectations in terms of reliability, responsiveness empathy and tangible components. Customers found PSS attractive when it was offered as a "bundle" or when the service can be modified to satisfy their needs. This finding may imply that the benefits of car sharing services should be better communicated to gain customer confidence and ultimately reach out to additional groups of users [64].

Schaefers [65] also applies the PSS approach to shared car services. Access-based services, as they are often called, allow consumers to avoid the "burden of ownership". Schaefers et al. (2016) [66] found that a higher usage of access-based services increases the likelihood of ownership reduction, which means that **the more abundant car sharing services are, the higher their potential to be more in use in the future**.

A number of other studies made an attempt to associate between the service model and car ownership reduction. They showed that **station-based car sharing services lead to a net reduction in car ownership**. However, with regard to free floating car services, some researchers found that this service is mostly used for non-regular trips and that only 6% of users forego car ownership. Other researchers found that in North America free floating services contribute to lowering the number of cars on the road. **In Germany, it was found that free-floating car sharing services could greatly encourage multimodal mobility patterns in urban areas**. Other studies found that free floating services do not have a negative effect on public transport use but also no reduction in transport related $CO_2$ emissions or car ownership. It is suggested, therefore, that free-floating car sharing in itself is not likely to reduce the number of cars on the road but rather can play a complementary role to public transport, cycling and walking [23].

### 2.5.3 Location and Accessibility

One of the factors that greatly affect user adoption is **accessibility which is determined by the location and sizing of service stations**, which is investigated by a fair number of studies across disciplines. Making cars easily and readily accessible to users and maximizing the integration with other means of mobility is highly challenging for service operators.

An important factor that plays a role in attracting users is the distance between the car sharing service stations and public transport stations. [67] tried to identify future station locations of a station-based service in Nice. They studied the drivers for demand and found that the adoption rate of the service is limited due to the fact that the users are required to return the cars to the starting point. However, since the station was near a public transport hub, it was no longer a constraint if users used also public transport. Nevertheless, the adoption rate could be improved if users could use the vehicles for one-way (free-floating) trips. In fact, there is a rapid growth in one-way car sharing which gives users the opportunity to use car sharing with other modes provided that the mobility modes are interconnected.

**Other important factors** that determine car sharing usage are the **distance between the car sharing stations and users' homes**, as well as various demographic and geographic characteristics such as **high population density, shortage of parking and the ability to live without a private vehicle**.

The planning of the optimal locations of electric car sharing stations is of primary importance when considering the challenges of free-floating electric car sharing scheme due to the need for charging infrastructure. In addition, **the need to redistribute the cars after charging adds extra costs for the operator and can hinder the profitability of the service** [27]. Sonneberg et al. (2015) for example, developed a decision support system that helps operators and policy

makers with the challenge of planning the optimal locations and sizes of electric car sharing station in San Francisco [68]. They showed that **the profitable operation of electric car sharing is possible**. Nonetheless, there is clearly a **need for an effective redistribution system**, either by the operator or by the customer, to avoid the accumulation of available cars in areas with low demand. Boldrini et al. (2017) study the spatial and temporal patterns of station utilization by users in a free-floating car sharing system to find an optimized redistribution model [69]. Redistribution by the operator is relatively expensive. However, they found that if connecting several vehicles together in road trains (one after the other) the redistribution can be done in a more economical way. The latter redistribution scheme can be achieved by incentivizing users to pick up cars from locations with lower demand and drop them off at locations with higher demand. The possibility of charging in road trains[4] means that fewer charging facilities are needed compared to conventional charging [27].

### 2.5.4 Drivers for Service Adoption

Shaheen and Cohen [36] show that the adoption rate of car sharing services is greater in high-density neighbourhoods, where public transportation is more efficient and the usage of the private car is less frequent due to city regulations and restrictions. They argue that with the support of planners, car sharing services can grow in walkable communities while accelerating the transition to a more sustainable transportation future.

Empirical studies indicate that users of new mobility modes are driven by environmental concerns and by the need for more socially and financially viable modes of transportation, which are provided by shared mobility modes [70]. Schaefers (2013) found that users adopt shared mobility services schemes for the following reasons: they save the cost of ownership of a private car (financial), they prefer flexible vehicle use, ease of use and easy access to the service (convenience), sense of engagement with a community of users and sense of belonging (lifestyle), eco-friendly service which is perceive to be important to quality-of-life [65].

Morency et al. [71] estimate the factors affecting awareness and acceptance while focusing on multimodal mobility patterns to better understand the benefits of car sharing to urban areas. The results identified two categories of users: the regulars and occasional users, with most users being the latter. These two groups have different behaviours in terms of average number of rides per day, periods of use (weekday vs. weekend) and trip length. Furthermore, the research shows that the main factors of adoption of car-sharing services are related to cost reduction and traffic congestion, and respondents are willing to pay an additional cost for the use of an electric vehicle. Some studies, including that of Schaefers (2013) [65], consider a specific age target and investigates their satisfaction about current travel patterns and to evaluate the willingness to join electric car-sharing services.

[4] The term road train designates a certain number of vehicles that are placed one after the other in a row.

Lindloff et al. (2018) studied the roles of market and non-market actors in the diffusion of car sharing in Germany while considering the perspectives of operators, customer and policy makers [72]. They found that convenience and value are more significant to users than environmental awareness and conclude that infrastructural variables are key for car sharing diffusion. Zoepf and Keith (2016) studied the decision-making process of users when they use the service [73]. Each time a vehicle is reserved the user considers the rental price, the distance from their current location to the vehicle, availability at the time they need the vehicle, and the type of vehicle. They quantified how users value each of the factors. They found that car sharing serves as a means to introduce users to a new vehicle technology such as hybrid or electric cars.

Other publications that examined mobility behaviour of car sharing users and potential users, in an attempt to identify the correlations between membership and social and demographic factors. For instance, Clewlow (2016) who conducted her research in the Bay area of San Francisco, found that users own significantly fewer vehicles than those who do not use the service [74]. However, this finding applies only to users living in urban areas. The distance travelled by members of a car sharing service in suburban areas is less than their counterpart who did not subscribe to the service. Among households that use car sharing services, those who own vehicles, a greater share of these vehicles is electric and hybrid. In short, that urban car sharing members are likely to own fewer vehicles and when they do own vehicles, they tend to be with a smaller environmental footprint.

Chen and Kockelman (2017) examined users of car sharing services in relatively dense urban neighbourhoods with good access to transportation in the US [75]. They found that car sharing users reduce their average individual transportation energy use and GHG emissions by ca. 51% when joining a car sharing service. Collectively this effect translates to roughly 5% savings in all household transport-related energy use and GHG emissions in the US. These savings are attributed to avoided travel, savings in parking infrastructure demands and fuel consumption. If taking indirect rebound effect into account, assuming savings on travel cost are spent on other goods, the net savings for all US households are expected to be 3%. This study may guide planners to educate customers to use car sharing services through increasing awareness to the potential savings due to using the service.

Another factor that greatly affect user adoption is vehicle accessibility which is determined by the location and sizing of car locations. Kumar and Bierlaire [67] found that in the case of station-based car service, the adoption rate is limited since users are required to return the cars to the starting point. However, when the return location was near a public transport hub, it was no longer a constraint if users used also public transport. Making cars easily and readily accessible to users and maximizing the integration with other means of mobility is essential but highly challenging for service operators.

The adoption rate of shared cars could be improved if users could use the vehicles for one-way (free-floating) trips. Indeed, free-floating systems provide convenience and flexibility, catering for users who seek spontaneous access and typically use the service for short distance

travel [76] and can potentially become a major component of future city transport systems as it allows spontaneity [27].

To conclude, the adoption of car sharing services by the grand public and its potential to change mobility patterns, will be determined to a large extent by factors such as the positioning and sizing of car sharing stations as well as the optimal number of vehicles in service and pricing schemes. Addressing such questions is critical for reaching out to many users and requires decision makers to address conflicting demands and goals. Such shifts have an impact on mobility patterns which might persist, and the growing uptake of shared personal mobility options as an alternative to private cars might very well continue.

# 3 CAR SHARING SERVICES IN RESIDENTIAL BUILDINGS

A report by McKinsey predicts a shift toward shared mobility and a change in consumer mobility behaviour and preferences, leading to a decline in car ownership and to the rise of on-demand fit-for-purpose mobility solutions as we approach 2030 [77]. Yet, the contribution of car sharing services to reducing car ownership rates and shifting mobility habits remains undecided and debated in the literature. Moreover, the impact of car sharing services on travel behaviour is complex and depends on multiple factors including accessibility to the service, pricing models and availability as well as user preferences and perception [21].

In an attempt to overcome some of the barriers that shared car services are currently facing, the GAMES project introduces the concept of car sharing services in multi-unit residential buildings, aiming to explore the motivations and barriers to the adoption of such services. This concept remains unexplored in existing literature although it can potentially remove some of the barriers that conventional car sharing services are facing. We explore the potential acceptance of this prospective service using the methods of focus groups and user survey. Our findings as described in this chapter offer valuable policy insights pertinent to city planners, scholars, fleet owners, and policymakers.

## 3.1 Study Objectives

Understanding the barriers to adoption of car sharing systems is essential to expanding the deployment of car sharing services. However, understanding the barriers to reducing vehicle ownership rates is equally important and requires studying the perceptions of users and the benefits associated with privately owned vehicles [4].

Along this line of thought, the present study explored the public perception and acceptance of shared car services in multi-dwelling residential buildings, offering dwellers a service tailored to their needs, while maintaining the convenience of the private car without the burdens of ownership. This service can be implemented using various ownership and operational models and is likely to be relevant to residents in urban areas, typically in city centres that experience off-street and on-street parking shortage. Moreover, building-based car sharing services may remove some of the adoption barriers that are associated with public

car sharing services as discussed earlier and can offer a solution to urban parking challenges while promoting sustainable transportation options [79].

The study focused on Israel that has some unique characteristics that influence the car ownership rates and mobility habits of its population. The number of privately owned vehicles in Israel has been steadily growing since 2015, surpassing 3 million vehicles in 2021[5]. This growth is commonly attributed to the inefficient public transport in the country and the lack of weekend public transport services[6], which drives car ownership up in Israel despite the high cost of ownership. Consequently, Israel is very car-centric and commuting by car is common in Israeli cities compared to other countries [78]. However, the operational and policy implications concerning the elimination of barriers to service adoption may have relevance in similar densely populated urban areas worldwide. This understanding is also reflected in the reviewed literature.

## 3.2 Focus groups

As a first step, three focus groups were conducted, each included 9-10 participants, who were selected based on the following screening criteria: 1) familiarity with car sharing services; 2) residence in multi-dwelling buildings (at least 30 units); 3) representing households with at least one child; 4) at least half of the households had parking shortage.

| Attributes | Group 1 | Group 2 | Group 3 |
|---|---|---|---|
| Age | 30-50 | 38-50 | 27-35 |
| Socioeconomic background | Middle to middle-high | high | Middle-low |
| Education level | 50% holding academic degrees | All holding academic degrees | Technical diplomas/high school |
| Place of residence | Tel Aviv and nearby towns | Tel Aviv | Outside the Tel Aviv metropolitan area |

The Product Service System (PSS) approach is then used to analyse the findings. PSS typically offers integrated solutions to fulfil consumer needs through a combination of products and services [80]. PSS facilitates user-oriented services, and provide community access to products while ownership remains with companies or individuals [81].

Rexfelt and Hiort af Ornas found that the two factors most affecting consumer acceptance of PSS are the perceived impact of the offering on consumers' everyday life and the uncertainties that they have about the performance of the proposed service [82]. We apply this framework

[5] Israel Central Bureau of Statistics. (2023). Number of private cars in Israel from 2013 to 2022. Statista. Statista Inc. (accessed on May 06, 2024).

[6] Israel is unique in that public transport services do not run during Shabbath (which begins upon sunset on Friday until sunset on Saturday).

to the dataset with the intention to identify the applicability of the prospective building-based car sharing service.

### 3.3 Focus Groups Results

The study evaluated the perceptions and the attitudes of users toward a hypothetical shared vehicle service within multi-dwelling residential buildings. Overall, the findings suggest that participants are receptive to the concept but are not yet ready to adopt it due to a number of perceived barriers. The acceptance and diffusion of residential car sharing are influenced by the availability of on- and off-street parking, cost of private car ownership, service quality, and trust among users and toward the service provider. Accordingly, participants weigh factors such as *availability*, *comfort*, *flexibility*, and *reliability* against car cost of ownership and the adverse effects of driving in heavy traffic. This study indicates that despite the clear drawbacks, such as parking shortages and high ownership costs, participants still prefer using their personal cars. However, the shortage of parking spaces as well as the rising costs of car ownership and the growing awareness of climate change, may result in the future in a growing number of households that forego the second car or even the primary car.

Participants identified the ownership burden as a motivation to possibly forgo the second household cars. Given the appropriate conditions and incentives, they would Favor, in principle, the financial savings and reduced commitment and responsibility that residential car sharing services offer.

To address the cost barrier, a viable and community-specific tailored price scheme, which highlights the true cost of ownership, could encourage potential users to forgo a second family car at the very least. Therefore, raising the cost of car ownership and parking fees and reducing the availability of on- and off-street parking are mandatory for wide service adoption. In addition, a simplified pricing models with clearly formulated and well-communicated terms of service could address the concerns around unexpected costs and encourage service adoption.

Participants further voiced their concerns regarding payment schemes, information sufficiency, unexpected costs, and overall service quality. For example, cleanliness and hygiene, are potential barriers for service adoption, which could be addressed by imposing a penalty for misuse. Other operational concerns that may potentially lead to disagreement among neighbours are related to the acquisition, insurance, and maintenance of fleet cars. In this context, participants strongly preferred outsourcing the management of the fleet, including vehicle procurements, maintenance, and payment collection, suggesting a desire to avoid conflicts among neighbours. Accordingly, service level issues can be resolved by establishing a service agreement with an independent fleet owner, that addresses various sensitive community-specific aspects. For example, the fleet can possibly be owned and managed by the building's management company offering the service within a comprehensive package of building services.

## 3.4 User Survey

While focus groups provide valuable insights for initial investigation, quantitative research methods could help illuminate differences among genders, socio-demographic factors, and other cultural variables. Accordingly, we conducted a user survey that sought to explore the factors that influence user acceptance and willingness to use building-based shared car services previously proposed by the project team. An online survey was conducted between April 18, 2024 and April 28, 2024 in Hebrew and was distributed to 1,277 respondents who could be the prospective adopters of the proposed service. The survey sample (N=540) included Jewish individuals, older than 25 years old, living in preselected Israeli cities (Jerusalem, Tel Aviv, Rishon LeZion, Holon, Givatayim, Ramat Gan, Herzliya, Petah Tikvah, Ramat Hasharon, Haifa, Bat Yam, Netania, Kfar Saba, Raanana). Only respondent who live in residential building of more than 6 floors were filtered out of the initial sample (N=1,277).

Two thirds of respondents live in a household of at least three members. More than 40% of respondents know most or all the other neighbours in their building. About half of respondents have one household car, 40% have two cars, 60% of respondent said they had a one private parking, while slightly more than 25% of respondents have two private parking. 13.5% of respondent have a company car.

We seek to answer two research questions: 1) What are the variables that impact the adoption of building-based shared car services; 2) how the variables correlate with demographics, lifestyle, experience with sharing practices, service quality and conditions and environmental awareness.

## 3.5 User Survey Results

In order to address our research questions, we conducted a regression with the intention to identify the variables that predict user support for a car sharing service in residential building.

Respondents reported that they use their car mostly for shopping, family visits, regular trips for personal or work purposes. The most common reasons for not forgoing the use of a private car are: lack of public transport during weekends (49%), specific needs that do not allow the use of public transport (44.4%), too long travel time in public transport (40.4%), low frequency of public transport (34.5%), location of stops are not aligned with respondents' needs (22.1%), low availability of taxi services (9.6%).

The regression that we conducted shows that the factor that most influences support for a building-based car sharing service is that vehicles are electric (26.6%). Support for the service is negatively influenced by the preference of users to use their private car over public transportation when it comes to getting to work (16.9%). Other variables that explain support for the arrangement are: having a shared vehicle service in the city of residence (16.1%), that the vehicle be large (15.7%) and an assurance for a high level of vehicle cleanliness (15.3%). Another variable that explains support for the service is high environmental awareness (9.4%).

# 4 DISCUSSION AND CONCLUSIONS

The growing presence of Shared Mobility Services (SMS) is driven by several forces, including environmental concern, the need of car manufacturers and fleet operators for new business model, and the growing awareness of urban dwellers for new lifestyles. There is evidence that car ownership is declining, particularly among younger people due to changing attitudes toward mobility and lifestyles. Although the effect of SMS on car use is debated, it may still have a role in creating an opportunity for a more sustainable transport policy and new mobility patterns in the presence of a more comprehensive urban mobility policy strategy.

The concept of Mobility as a Service (MaaS) can potentially reduce the need for car ownership by offering access to tailored services that are available on demand. However, the success of on-demand mobility services relies heavily on efficient public transportation and shared mobility options, such as car sharing.

The use of electric car sharing can potentially expand, particularly in conjunction with the free-floating scheme, which provides a high degree of flexibility to users. Using this scheme may even increase profitability for fleet owners if vehicles are connected to mobility hubs hosting diverse forms of mobility. Mass adoption of car sharing services will be determined to a large extent by factors such as the positioning and sizing of car sharing stations as well as the optimal number of vehicles in service and pricing schemes.

The GAMES project introduced the concept of building-based car services and conducted focus groups to gauge the acceptance level of this prospective service. The findings from the focus groups indicate that user acceptance of building-based shared car service is influenced by the availability of on- and off-street parking spaces. Thus, policy incentives that widen the availability of residential shared vehicle services can address this barrier, and even facilitate the implementation of controversial and unpopular local parking policies. As an example, shared vehicles services in residential buildings can help policymakers implement unpopular parking reforms, if they hold multiple co-benefits to residents such as repurposing off-street parking areas for other communal purposes, reducing air pollution, while providing good on-demand mobility services to residents.

Focus groups focused on relatively larger households, who are typically less inclined to use shared vehicle services. To cater for the needs of various consumer groups residential shared car services should include a variety of car types and sizes in their fleets. Larger household, as in the case of the present study, would probably need slightly bigger cars in certain circumstances. We then conducted a user survey to better identify which factors are most influential on users' decision to adopt the service. We found that the factor that most influences support for a building-based car sharing service is that vehicles are electric. Support for the service is negatively influenced by the preference of users to use their private car over public transportation when it comes to getting to work. Other variables that explain support for the arrangement are: having a shared vehicle service in the city of residence, that the vehicle be large and an assurance for a high level of vehicle cleanliness. Another variable that explains support for the service is high environmental awareness.

The socio-cultural context in which the Product-Service Systems (PSS) is offered is an important factor for consumer acceptance [82]. Although focus groups meetings were conducted in Israel, reflecting the Israeli cultural context, we believe that the operational and policy implications concerning the elimination of barriers to service adoption may have relevance in similarly densely populated urban areas worldwide.

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