Review

An Overview of Shared Mobility

Cláudia A. Soares Machado [1,*], Nicolas Patrick Marie de Salles Hue [1], Fernando Tobal Berssaneti [2] and José Alberto Quintanilha [1]

[1] Departamento de Engenharia de Transportes, Escola Politécnica da Universidade de São Paulo, São Paulo 05508-070, Brazil; nicolas.hue@usp.br (N.P.M.d.S.H.); jaquinta@usp.br (J.A.Q.)
[2] Departamento de Engenharia de Produção, Escola Politécnica da Universidade de São Paulo, São Paulo 05508-070, Brazil; fernando.berssaneti@usp.br
[*] Correspondence: claudia.machado@usp.br

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Abstract: In a wider understanding, shared mobility can be defined as trip alternatives that aim to maximize the utilization of the mobility resources that a society can pragmatically afford, disconnecting their usage from ownership. Then, shared mobility is the short-term access to shared vehicles according to the user's needs and convenience. The contributions and added value of this paper are to provide an up-to-date and well-structured review on the area of shared mobility to researchers and practitioners of the transport sector. Hence, this paper presents a bibliographical review of shared mobility and its diverse modalities, as an alternative to individual transportation, especially in cases of individual automobiles or short trips restricted to an urban city. The present literature review on shared modes of transportation has discovered that the introduction of these modes alone will not solve transportation problems in large cities, with elevated and growing motorization rates. However, it can among the strategies employed to help alleviate the problems caused by traffic jams and pollution by reducing the number of vehicles in circulation, congestions, and the urban emission of polluting gases. Thus, the implementation of shared mobility schemes offers the potential to enhance the efficiency, competitiveness, social equity, and quality of life in cities. This paper covers the fundamental aspects of vehicle and/or ride sharing in urban centers, and provides an overview of current shared mobility systems.

Keywords: shared mobility; carsharing; personal vehicle sharing; bikesharing; ridesharing; on-demand ride services

1. Introduction

The 21st century is increasingly concerned with the environment and with the social problems caused by the indiscriminate use of natural resources, the absence of urban planning, and the deteriorating quality of life for inhabitants of large cities. It is thus time to rethink the issue of urban mobility. Nowadays, an alternative stance is concerned with services, which can be observed in the growing popularity of short-term rental systems (based on hours, days or weeks) of vehicles (e.g., cars-Zipcar and Car2Go, bikes-Motivate), lodging and housing (cohousing–e.g., Airbnb), work spaces (coworking–e.g., Impact Hub), etc. In this context, the concept of a sharing economy emerges as a new paradigm that enables access to goods and services beyond ownership. Though the concept of "sharing" is nothing new, the sharing of services, products, personal skills, and time between strangers is seen as the essential feature of the development of sharing economy, whose popularity has grown rapidly in recent years, leading to the success of digital platforms such as Uber and Airbnb. Sharing economies have the potential to encourage the distribution and use of underutilized assets and to promote a more sustainable consumption, with economic, social, and environmental consequences [1]. Shared mobility is one of the segments of sharing economy, with the greatest

disruptive potential over urban transportation systems, which are facing significant challenges due to a rapid increase in motorization rates and the number of private vehicles [2–4]. According to the World Bank [5], by 2050, the equivalent of 2/3rds of the projected global population (about 5.4 billion people) will live in urban areas, and the number of vehicles on the road will double, to reach 2 billion. While these changes have benefitted many individuals, they have also created difficulties such as increased traffic jams and the environmental deterioration of urban areas, and have led to dispersed patterns of development in suburban and rural areas, making them increasingly difficult to serve via public transportation. According to Pojani and Stead [6], some trends in many cities around the world are: extensive urban sprawl, rapidly-growing motorization, inadequate public transport systems, chaotic traffic patterns with high use of cars and motorcycles, high environmental pollution, and poor infrastructure for pedestrians and cyclists. Thus, more people prefer to own and use private vehicles, further aggravating the problems [7]. This cycle sheds light on why the transportation sector is one of the most problematic sectors for public policy today, especially with regards to negative transport externalities (congestion, pollution, and traffic accidents) and the economic, social, and environmental repercussions of these factors. Experts on urban mobility agree that we are living in an era of shared mobility due to the advent of alternative transportation services which offer the possibility of major changes [8–10]. In this paper, the definition of shared mobility provided by Shaheen et al. [11] is adopted, which affirms that it is the short-term access to shared vehicles according to the user's needs and convenience, instead of requiring vehicle ownership. This phenomenon is occurring due to demographic and cultural shifts, new social attitudes on the ownership of goods (mainly in developed countries), and advances in mobile technology. The concept of sharing is developing rapidly and becoming more common around the world. It is enabling the number of private vehicles per family to decrease, and creating a new mentality in which users renounce ownership of a vehicle and use shared transportation services according to their convenience. Research shows that the global market for shared modes of transportation is expected to grow from US$ 1.1 billion in 2015 to US$ 6.5 billion by 2024 [12].

In the last few decades, the importance of shared mobility has grown, as well as the need to understand how to integrate it into urban transportation systems, and make it more efficient from a social, environmental, and economic perspective. However, in most studies, shared mobility has been considered as an isolated system, disregarding the complexity of its interactions with other transportation modes, which makes it extremely difficult to estimate its impact on the transportation system [13]. For this reason, this paper discusses the main aspects of manifold forms of shared mobility solutions, in order to provide a revision of them and to give a theoretical background that can be useful to promote this integration.

The objective of this paper is (1) to contribute to filling the gap of the lack of comprehensive literature reviews in structuring the theme "shared mobility" and its diverse modalities, providing to researchers an up-to-date and well-structured overview; (2) to address innovative shared mobility services, present concepts and characteristics of each one of them, and also about their users; and (3) to present a review about some modes of shared mobility that enabled users to obtain short-term access to transportation as needed, rather than requiring ownership.

After the introduction addressed in this section, the structure of the paper is given as follow. In Section 2 the research methodology adopted in this work is presented; Section 3 addresses some of the reasons why shared mobility services are spreading around the world; Section 4 presents the main outcomes obtained from a comprehensive literature review. Finally, Section 5 gives a discussion of the findings and draws some conclusions.

2. Methodology

The methodological strategy adopted was snowball research, which consists of identifying scientific papers that explore the theme "shared mobility", its variations, and related issues. Thereafter, one paper leads to another, which in turn provides a third article, and so on. In this study, the most relevant works were used to find significant papers through their citations, which show additional research also through citations, and the process continues.

This bibliographic study reviewed shared mobility systems that are present in urban centers, along with user profiles and their adaptation to new perspectives on transportation. A literature review was undertaken in academic and scientific databases, such as Web of Science, EBSCO Discovery Service (EDS), CAPES/MEC, Google Scholar, etc. Scientific sources, including the most relevant published articles in the literature over the last two decades. This, collectively, was used to compile research on shared mobility. The literature review included consultations of academic books and journals, and an online search on technical information of initiatives is currently underway across the world

3. The Spreading of Shared Mobility

The transportation sector is currently responsible for about one-third of the total energy consumption in European countries and the United States. However, the amount of travel in private cars with one occupant (Single-Occupancy Vehicle–SOV) is also high in these countries [14]. There are still many obstacles for reducing pollution (atmospheric and noise) and traffic jams, and for lowering the personal, social, and environmental costs of switching to more sustainable models. Several strategies have been proposed to promote sustainable urban mobility and more efficient modes of transportation [15–20]. These proposals focus on convincing transportation users to adopt more conscious and sustainable behavior.

Litman [21] affirms that an efficient transportation system requires a significant reduction in the use and circulation of cars, and migration towards more efficient modes of transportation such as public transit, cycling, walking, and innovative shared modes (transportation modes that share vehicles and/or rides). However, the private car presents a clear advantage over other transport options in three key attributes for its selection as mode of choice: flexibility, comfort, and availability [22]. Also, some trips will always be car-dependent due to their nature or their spatio-temporal location [23]. Hence, it is possible to affirm that shared modes could contribute to a solution because they can offer the key attributes mentioned above [24].

According to the UN Habitat III [25], private vehicles remain parked about 95% of the time, and when they are moving, their average occupancy rate is well below 2 persons per car, despite the fact that private cars in general have 4 seats for passengers and the driver. In 2007, the average occupancy rate was 1.8 persons per car in Eastern European countries and 1.54 in Western countries [26]. In 2017, in the USA the average occupancy rate was about 1.5 person per car [27].

Shared modes have the potential to reduce traffic congestion and the need for parking spaces, giving rise to a decrease in the total number of vehicles. They are intermediate modes between private modes and mass transit, and can be considered as significant components of a comprehensive and efficient transportation system in urban areas. In France, shared modes help reduce traffic congestion through higher vehicle occupancy rates. The shared mode average occupancy rate for short distance trips is 2.5 persons per car, and for long distance trips is 3.5 persons per car. This means that fewer vehicles are needed to move the same number of users [24]. According to Martinez and Viegas [22], the same happened in Lisbon, Portugal. Shared modes increase the average occupancy rate per vehicle, and decrease congestion levels and greenhouse gas emissions. Similarly, Sun [28] describes how shared mobility increases traffic efficiency and reduces unnecessary external costs, mainly caused by low average occupancy rates that leads to high congestion and pollution levels.

In most cities in China, 90% of car journeys to work have no passenger, and the average occupancy rate is around 1.4 persons per car on weekday business trips and 2.0 on weekend social trips. To overcome the low average occupancy rate, shared mobility certainly should be investigated,

because it can combine multiple similar rides to one [29]. Cruz et al. [30] claim that in Brazil there is lot of underused space in cars, and to prove this affirmation, in 2015, they applied a questionnaire to determine private vehicle occupancy rates; the results showed that 33% of the respondents use their car with no passenger, 48% with only one passenger, 10% with 2 passengers, and 9% with more than 2 passengers. So, they believe that in Brazil, mainly in large urban centers, there is a great potential for the introduction of shared modes.

In urban areas with elevated and growing motorization rates, shared modes are normally used to complement existing public transportation modes; it is not viewed as a panacea to all of society's transportation problems [31], but it can be considered to be one of the strategies that can help mitigate the effects of traffic jams and pollution by reducing the number of vehicles in circulation. Therefore, the implementation of shared mobility schemes offers the potential to enhance cities' efficiencies, competitiveness, social equity, and quality of life [32].

Shared mobility solutions have the potential to offer environmental gains and address social aspects, such as fewer trips, modal shift, distance reduction, less need for parking spaces, etc. Thus, the impact of shared mobility on transportation planning, from a sustainability perspective and urban governance, need to be properly investigated. Shared mobility has gained significant popularity and support in recent years, and there is a common understanding that shared modes can address several sustainability challenges, including atmospheric pollution, by encouraging the use of newer and cleaner vehicles, and the wider use of sustainable means of transport [2,33,34].

Innovations in mobility, such as shared modes, can be contextualized within wider socio-technical transitions, driven by the mass use of the Internet, and the emergence of smartphones, which have transformed several aspects of everyday life in less than a generation, leading to dramatic changes in the way people communicate, socialize, work, shop, travel, and so on. This behavior change has implications on economy, culture, ecology, environment, etc. Besides that, the shift from "ownership" to "usership" is a critical shared mobility innovation that impacts on how the transportation system (mass transit, individual/motorized/non-motorized modes, etc.) has to be ruled by regulatory agencies. Some important decisions have to be made by the local authorities in order to properly define the public good that shared modes, which are essentially rentier models, can provide. Examples of these decisions are: economic regulation and taxation, assurance of an appropriate degree of social equity and non-discrimination in service access, cover area regulation, and safety issues regulation [35].

Shared mobility schemes have involved a series of negotiations between public and private sectors, with implications for the decision-making process that remain unclear. The role of private companies in the mobility industry brings concerns over feasibility and acceptability of transport policies associated with shared modes. One aspect that still needs to be properly investigated is the implication of integrating shared mobility services, essentially provided by private firms, into current public transport networks, characterized by strong government regulation. It is important to identify synergies between established public transport networks and emerging shared mobility schemes, to make these services complementary, and to achieve the common objective of sustainable mobility [2,33,34].

Therefore, the future of urban mobility is the integration of on-demand multimodal services that may be enabled and accessed through digital platforms that suppress the need for multiple tickets and payments, optimize transport mode choices, and provide access to real-time journey information and weather conditions. Innovative mobility initiatives such as electromobility, autonomous and connected vehicles, and shared modes can transform the transport sector, supply the foundations for sustainable growth, and become urban travel controlled, resilient, and convenient [36].

Most of the shared mobility services are provided by private companies, some of them by community-based initiatives, and a very small number are purely public shared modes. In general, public initiatives of shared mobility fail because individuals tend to act in their own self-interest to the detriment of society and the environment [2].

Another important issue to be addressed is that, in general, to access shared mobility services, users need to have a smartphone with Internet access and a valid credit card. This may exclude a

portion of the population with low income, that can't afford this. Besides that, as the majority of the shared mobility modes operate in central zones, citizens who live in peripheral regions face difficulties to access these services. So, to ensure an effective scheme of shared mobility, the service has to be inclusive (provides access to the whole population from all socio-economic backgrounds), accessible (provides access to everybody regardless levels of ability), safe (ensures the safety of the citizens), innovative (accepts, promotes and encourages the use of new and disruptive technologies), sustainable (minimize negative environmental impacts), efficient (in terms of time and cost travel), livable (supports healthy, active and prosperous human communities), equitable (ensures that all users pay a fair share of its cost), citizen-oriented (meets the users' needs), and non-exploitative (offers and supports decent work conditions for transportation sector workers). Nevertheless, developing a transportation service that embodies all of these characteristics of effectiveness is an immense challenge, which requires building up a more forward looking and responsive regulatory framework which is able to adapt to continuous scenario changes in which technological advances are always increasing [37].

4. Shared Mobility and Its Modalities

According to Shaheen et al. [38], the market for personal mobility is being changed quickly due to structural modifications of the social and cultural trends, as well as technological advances such as smartphones, Internet of Things (IoT) [39,40], Big Data [41,42], Cloud Computing [43,44], information processing, and widespread data connectivity. Shared mobility is an innovative transportation concept, which can be considered as a set of disruptive mobility services [45,46] that enable urban trip planning and booking, real-time information, and fare payment into a single-user interface.

In terms of urban mobility, the shift from ownership to service use, often promoted in concepts of sustainability, is available in most cities around the world through the shared mobility systems. Although substantial psychological forces, rooted in the Western culture, support ownership of a vehicle, the area of individual mobility is among the first that organizations have developed that enables the shift from ownership to service use through the concept of shared mobility and the advent of vehicle-sharing organizations [47].

Shared mobility is the shared use of a vehicle (car, bicycle, scooter, van, etc.). It is an innovative transportation strategy that enables users to have short-term access to a mode of transportation when required, and can increase multimodality, reduce vehicle ownership, vehicle miles/kilometers traveled (VMT/VKT) (in some circumstances), and can provide new ways to access goods and services [10,48].

In a wider understanding, shared mobility can be defined as trip alternatives that aim to maximize the usage of mobility resources that a society can pragmatically afford, disconnecting their usage from the ownership. This concept refers to innovative initiatives based on the "access to" instead of the "ownership of", in which individuals share each other's material assets (vehicles, money, etc.), and intangible resources (personal skills, time availability, etc.) in order to provide mobility services to access places. The objective is to supply a broad set of mobility choices, increasing multimodality and reducing transportation costs [49].

The recent popularity experienced by shared mobility services is due to advances in technology (mainly smartphones, positioning systems, and mobile payment), economic changes, and social and environmental concerns related to vehicle ownership and urban living [50].

According to Shaheen et al. [50], shared mobility is an "umbrella" term that refers a broad array of innovative transportation modes with different use cases, business models, and travel behavior impacts. Figure 1 shows a scheme of shared mobility and some of its modalities, which will be addressed in this article as follows.
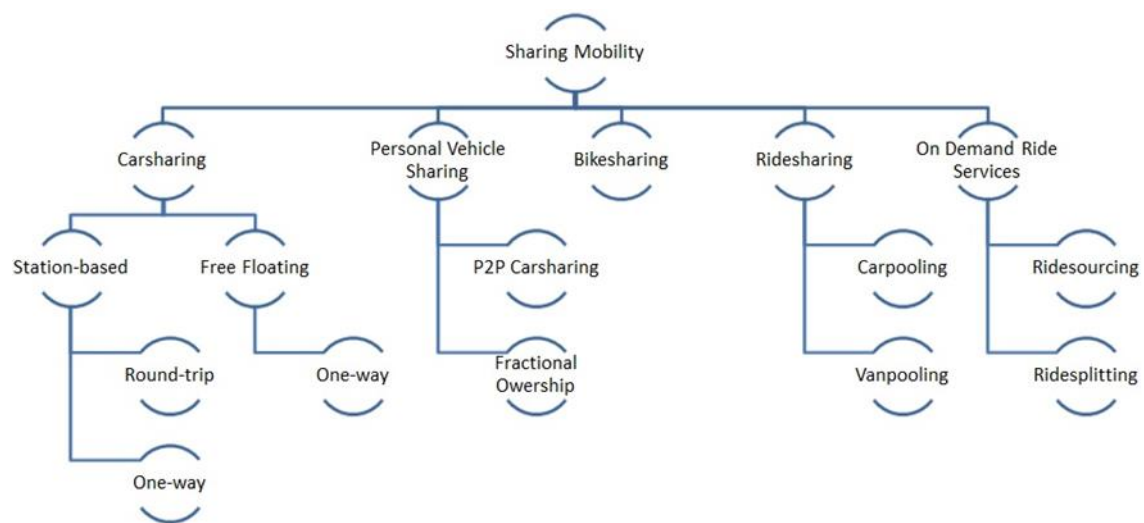
Figure 1. Shared mobility and its modalities. Source: Authors.

4.1. Carsharing

According to Shaheen et al. [11], carsharing is a mode of shared transportation in which several people use the same vehicle. It is popular for its environmental and social role. Moreover, individuals enjoy the benefits of a vehicle without the responsibilities and costs of owning one. Users typically access vehicles by joining an organization that maintains a fleet of vehicles deployed in lots located within neighborhoods and at public transit stations, employment centers, colleges and universities, and sometimes also using on-street parking. Normally, the carsharing operator provides fuel, parking, and maintenance, and participants pay a fee each time they use a vehicle [10].

Some benefits of carsharing are reduction in the frequency of car use, overall reduction in VMT/VKT, and cancellation or delay in car ownership [51]. Another advantage of carsharing is that it minimizes the total number of vehicles needed. It is estimated that a shared car can replace between 1 and 6.5 personal vehicles. It also tends to decrease the frequency of trips carried out on impulse i.e., carsharing not only makes people more aware of the cost per trip, but also demands that each trip be previously planned [52]. Namazu et al. [51] complemented this point of view by stating that the availability of a variety of vehicles, which are often newer (shared cars have much higher utilization rates, which reduces the lifecycle environmental impacts of cars) and more fuel-efficient (eventually with clean propulsion technology, in the case of electric or hybrid vehicles) when compared to typical private vehicles, can motivate the optimization of the size and characteristics of the vehicle depending on the purposes of the trip.

Carsharing programs began in Europe in the mid-20th century. The first program was introduced in 1948 in Zurich, Switzerland, and expanded over the following decades to other European countries, including France, Netherlands, Sweden, Germany, the UK, and others [53]. The earliest carsharing services were cooperatives (including the first program in Zurich that operated for 50 years 1948–1998) with collective ownership of a fleet of vehicles (run by volunteers and were non-profit making). Later, for-profit companies offered their vehicles for rent by users for short periods of time [54,55]. The USA experience with carsharing began with two projects in the 1980s: Mobility Enterprise conducted by Purdue University, and the Short-Term Auto Rental (STAR) in San Francisco, California [55].

The first carsharing systems in Asia and Australia started in the 1990s and 2003 respectively [55]. According to Yoon et al. [56], there is a rising interest in carsharing programs in Asia (particularly in China, Japan, Malaysia, and Singapore), which contains many of the fastest developing and most densely-populated cities in the world. Presently, carsharing systems are available in more than 30 countries across five continents [53,54].

According to studies conducted by Shaheen and Cohen [57–59], and Shaheen et al. [60], since the last decade, carsharing services have increased in many countries in North and South America (mainly USA, Canada, Mexico, and Brazil), Europe, and largely in Asia.

4.1.1. Carsharing Business Models

According to its type, function, and target audience, carsharing can be divided into two categories: station-based (round-trip and one-way) and free-floating (one-way).

Station-Based Round-Trip Carsharing

It is a two-way service where customers pick up a vehicle at a designated station and return it to the same place, while normally paying on an hourly basis. It can include free miles/kilometers or come with a per-mile/kilometer charge [11]. In this mode, the available vehicles are parked in pick-up stations, which are pre-defined parking spaces owned by the service provider or reserved by the local authority. This operational mode does not consider the intermediate stops that the customer may plan for personal needs. Thus, this includes both the travel to and from a destination(s), and the time spent whilst there. In general, customers need to reserve their cars in advance, though it can be possible to find an available vehicle on short notice when utilization is low [61,62]).

From the users' perspective, round-trip services may not be financially attractive if a journey requires the vehicle to spend a long time parked at a place other than its home (for e.g., while commuting). Therefore, this kind of carsharing is mostly used for short journeys when vehicles remain parked for a short duration, usually for leisure, shopping, and occasional trips [63]. Figure 2 illustrates the station-based round-trip scheme.
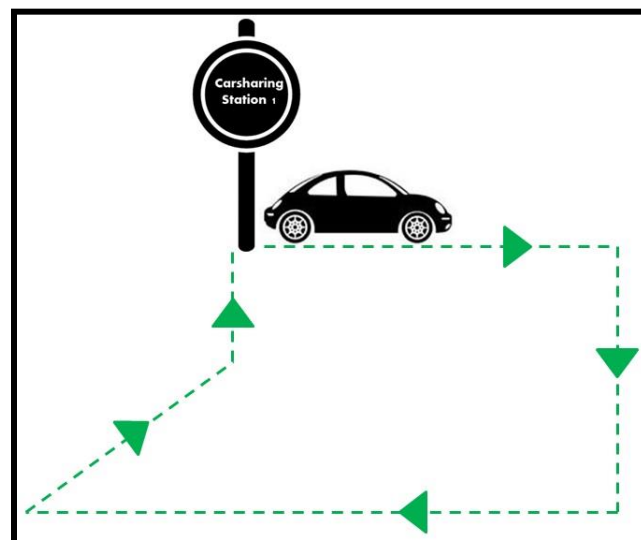

Figure 2. Station-based round-trip carsharing scheme. Source: [64]

Station-Based One-Way Carsharing

This is similar to the round-trip mode, but the individual has no obligation to return the vehicle to the same place, and can park in designated places, which may be scattered across a city or region [11]. This mode is more flexible and adaptable to customers' needs. Users typically pay by the minute (versus the hour as in the round-trip model), the trips are shorter, and do not require a reservation. Even though one-way carsharing provides a flexible service, its operational management is more complex because the operators have to guarantee a level of vehicle availability. This, coupled with an imbalance between stations, could lead to an oversized fleet and underused vehicles [65].

A study conducted in the USA, Canada, Mexico, and Brazil showed that almost 70% of round-trip carsharing operators believe that one-way sharing is a complement or evolution of the round-trip.

However, due to unequal travel demand between service stations, unidirectional vehicle-sharing systems present an operational problem of imbalances in vehicle availability across a network of stations [66]. Hence, it's necessary to develop maintenance algorithms to balance vehicles and local parking spaces at individual stations [67]. Figure 3 illustrates the station-based one-way scheme.
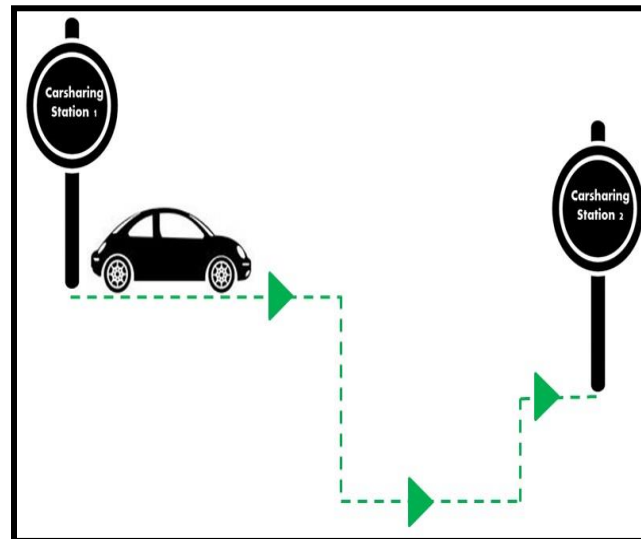

Figure 3. Station-based one-way carsharing scheme. Source: [64]

Free-Floating One Way Carsharing

This type of carsharing enables shared-use vehicles to be picked up and dropped off anywhere within a designated operating area. There are no specific stations, and while users can drive outside the operating zone, they still have to drop off cars inside the service area, often using specific carsharing roadside parking spaces provided by local authorities. In free-floating one-way carsharing services, users are able to check the real-time availability and locations of shared vehicles, and book them online (via their smartphone or computer). It is possible unlock and lock the car using a smartphone to begin and end the rental. The information of the termination of the trip is automatically sent to the operator, and the car is available again to other users.

Free-floating one-way carsharing services are expanding, largely due to advancement in technology (for instance: vehicle access technologies, smartcards, mobile applications, positioning systems such as GPS (Global Positioning System) and public policies that enable private firms to reserve on-street parking. The introduction of these services has removed some of the restrictions faced by users in conventional round-trip services. Hence, it is gradually replacing round-trip systems because of the freedom that this system offers [54,65,68]. Figure 4 illustrates the free-floating one-way scheme.

Heilig et al. [61] state that the number of carsharing users and the number of cars offered in sharing systems has increased throughout the last few years, and forecasts show that this is an ongoing trend. In Germany in 2016, for example, station-based carsharing had an 18.8% increase in customers, whereas free-floating carsharing saw a 51.0% increase.

Currently, the world's largest carsharing companies include Zipcar, founded in 2000 in the United States, with over one million members and more than 12,000 vehicles. Zipcar operates in Belgium, Canada, Costa Rica, France, Iceland, Spain, Taiwan, Turkey, the United Kingdom, and the United States [69]. Alongside Zipcar is Car2Go, which was founded in 2008 in Germany, with more than 3 million members worldwide, 14,000 vehicles, and operating in 8 countries in Europe, North America and Asia (China) [70,71]. Zipcar and Car2Go operate with their own fleet and have infrastructures that are consolidated and supported by public authorities via, for example, the allocation of public spaces for parking and vehicle reloading. Presently, 21 carsharing companies across 11 countries have formed the Car Sharing Association (CSA), which includes the company Zazcar that operates in Brazil.
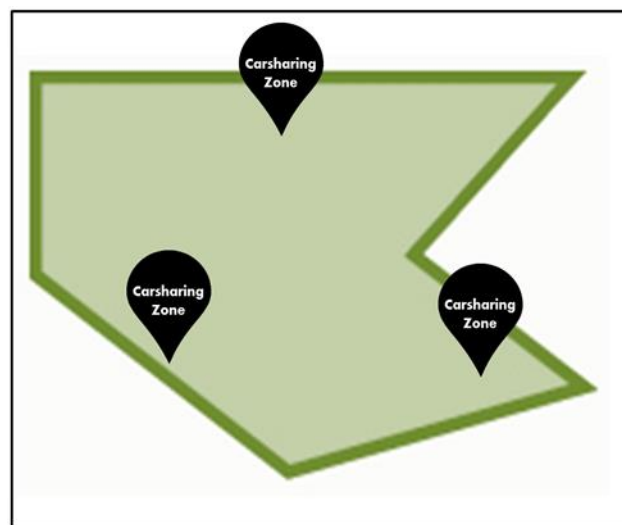
Figure 4. Free-floating one-way carsharing scheme. Source: [64]

4.2. Personal Vehicle Sharing: Peer-to-Peer Carsharing and Fractional Ownership

Personal Vehicle Sharing (PVS) is a system in which car owners convert their personal vehicles into shared cars and rent them to other drivers on a short-term basis [72]. Generally, PVS companies broker transactions between car owners and renters by providing the resources necessary to make the exchange possible, such as online platforms, customer support, auto insurance, and technology [73]. In this paper, two modalities of PVS are presented and described below.

4.2.1. Peer-to-Peer (P2P) Carsharing

Peer-to-peer (P2P) carsharing employs privately-owned vehicles that are temporarily made available for shared use by an individual or members of a P2P carsharing company (operator service). The operator intermediates the rental procedure, typically by defining schedules for when the vehicle is available, and confirming or denying member requests for access. In this modality, the pickup and drop-off locations are agreed on between the two parties (car owner and lessee), normally in a station-based round-trip scheme. Expenses, such as insurance, are generally covered by the P2P operator during the rental period. In exchange for providing the service, operators keep a portion of the usage fee. Unlike traditional carsharing companies, the vehicles constituting shared fleets within a P2P platform are generally older. On the other hand, P2P carsharing offers a greater selection of locations, vehicle types, and daily and hourly rental prices when compared to the classic carsharing model [60,74,75].

One characteristic of the P2P carsharing program is that the operator directly connects the parties involved in the negotiation (car owners and would-be renters), implying that it is a more direct manifestation of collaborative consumption than traditional carsharing systems. Apart from this, it also promotes the sharing of already owned, underused assets, in contrast to a company-maintained vehicle fleet. In addition to facilitating the sharing of existing resources, the P2P model can reduce costs (for the renter) and promote profits (for the owner), and significantly reduce operating costs for the companies, since the vehicle capital comprises almost 70% of total operating expenses for classic carsharing companies [75].

According to Shaheen et al. [75], in January 2017 in North America, there were over 2,900,000 individuals participating in P2P carsharing programs, and a shared fleet of 131,336 P2P vehicles distributed among six operators.

4.2.2. Fractional Ownership

Fractional vehicle ownership is a model of sharing the ownership of a vehicle among a small group of people, with each of these individuals taking up a portion of the expenses for access to the shared service. This share is accompanied with usage "rights" or "terms" that can vary depending on the consumer's needs and the operator's priorities or focus. This scheme can enable individuals to access vehicles that they might otherwise be unable to afford, e.g., sophisticated models, electric vehicles, etc. It can also result in income sharing when vehicles are used by non-owners [75–77].

It can be deployed in a variety of ways, for example, through a dealership and a partnership with a carsharing operator, where the car is purchased and managed by the carsharing operator that provides the vehicle to a group of people for a flat lease rate. This rate would cover fixed costs such as maintenance, depreciation, insurance, taxes, and other fixed costs. The group of people using the car would generally be restricted to a much smaller size than typically found in a carsharing system (say 10 or less). It can be thought of as a single carsharing vehicle within a closed, pre-defined user group [75,77].

This system is less flexible than other carsharing schemes because if a member of the group exits the agreement, the operator or the remaining lessees are required to pick up the remaining costs. As the shared vehicle must be located close to the collective homes of the lessees, the population available to replace the departed member is limited. On the other hand, one potential benefit of fractional ownership is that the network of vehicles expands to fit the size of demand, because the model avoids the risk faced by carsharing classic operators entering a new market, where a vehicle is placed earlier and members come later, since vehicles and members are simultaneously established [75].

According to Shaheen et al. [75], in February 2016, in Austin (TX, USA), Ford started a fractional ownership pilot program; in Stockholm (Sweden), Audi Unite is testing a fractional ownership model that allows up to five people to co-own a vehicle. Orto, a startup in London is also testing this model.

4.3. Bikesharing

The Bikesharing system is very similar to carsharing models. Users are able to access bicycles for use when required. Bikesharing stations are typically unattended, concentrated in urban settings, and offer station-based one-way access (bicycles can be returned to any station) or station-based round-trip access (bicycles must be returned to same station where they were picked-up). Free-floating one-way bikesharing offers users the ability to check-out a bicycle and return it to any location within a predefined operational area. Bikesharing provides a variety of pick-up and drop-off locations. The majority of bikesharing operators cover the costs of maintenance, storage, and parking. In general, trips of less than 30 min are included within the membership fees. Users join the bikesharing organization on an annual, monthly, daily, or per-trip basis [10].

Studies show that the benefits of bikesharing systems are numerous, such as avoiding parking and maintenance troubles with private bicycles, offering more convenient connection to public transport, reducing travel time and costs in city centers, improving body health, and opening up opportunities for more social and leisure experiences [78].

Li and Kamargianni [78] have identified some factors affecting choosing bikesharing. These factors can be classified into three categories:

✓　Natural and built environmental conditions: These include the weather (e.g., sunny, rain or snow), temperature, and air-pollution. Usually, adverse weather conditions and colder temperature would significantly discourage travelers from cycling. The topography also affects the choice of bikesharing. Steeper roads, in particular, would significantly discourage the choice of a bicycle, although the impact of hills on the choice of cycling route heavily depends on the fitness of the cyclist. Air pollution can also decrease the number of cycling commuters on the road. With regards to environmental and land use impacts, cycling-related infrastructure is an important factor that can impact bikesharing systems. An increase in the number of cycle's lanes and

  bikesharing stations can promote the use of this non-motorized mode of transportation by reducing travel time and increasing safety and convenience. Some other relevant factors such as population density in the community, the existence of university campuses, and number of parks also affect this modal choice [78].

✓ Trip and mode attributes: Trip characteristics are also important factors that determine choices of mode of transport. Cycling is associated with recreational trips, but currently, there are also a great number of cycling trips that are undertaken during peak hours for commuting, and during noon and evening for meal purposes. Non-motorized modes have a negative relationship with trip distance, so this factor will have the largest influence on modal choice when compared with other variables such as travel time, travel cost, and comfort level [78].

✓ Socio-economic characteristics: Age and gender are among the biggest influencing factors for bikesharing choice. Younger generations and males are usually more keen to cycle, whilst occupation and economic status may also play important roles in determining cycling choice. Users with lower income cycled more because those with higher incomes valued their time more highly, and chose faster modes. Other socio-economic factors related to cycling choice include health status and level of education [78].

  Bikesharing schemes in urban areas have sprawled across the world at an accelerated pace over the last few years, and could lead to unprecedented transformations in contemporary mobility and urban lives [79]. Following the success in Europe and North America, bikesharing schemes have been introduced in many cities in developing countries as well [78]. As of November 2017, 2075 bikesharing programs are in operation around the world [80].

4.4. Ridesharing

  According to Chen et al. [8], Di et al. [81], and Fagnant and Kockelman [82], ridesharing pools multiple travelers with similar or overlapping paths (origins/destinations) and departure times in the same vehicle (generally a car or a van). It has become a powerful strategy to reduce congestion, since it has the potential to diminish the total number of vehicles on roads by encouraging travelers to share rides.

  In recent years, the ease of ridesharing operations brought about by communications technologies, such as Internet, smartphone applications, and connected vehicles, has enabled people to manage their individual car use better, for example, through drivers sharing real-time traffic information. This new generation of ride matching platforms has seen a massive increase in ridesharing drivers and passengers. It is a new kind of point-to-point transportation network service based on a dynamic platform in which drivers offer their own vehicles to matched passengers who are looking for a similar destination [8,81].

  Shaheen et al. [10] affirm that empirical evidence indicates that ridesharing systems can provide transportation, infrastructure, and environmental benefits, although the exact magnitude of these impacts is not fully understood. Individually, ridesharing participants benefit from shared travel costs, savings in travel-time from high occupancy vehicle lanes, reduced commute stress, and often preferential parking and other incentives. The classic ridesharing systems are carpooling and vanpooling, as discussed below.

4.4.1. Carpooling

  Carpooling is an informal type of commuter ridesharing, which is comprised of at least three commuters per car. It is linked to travel sharing i.e., two or more individuals not belonging to the same family group share a trip, or part of one, and passengers contribute to the driver's expenses [83,84]. Some informal carpooling programs are community-based initiatives (cooperatives) that expand the frame of the shared mobility beyond commercial models, with non-profit mobility schemes [2].

Among carpoolers, the driver makes his/her vehicle available to other users going to the same place or whose destinations are on the same route. This mode is usually used by individuals travelling to school, university, or work, and it is often practiced informally (casual carpooling or slugging) without centralizing the market [84–86]. Incentives for this mode of transportation are plentiful, especially in the USA; for example, cities like Houston, Texas, have exclusive lanes for carpool vehicles (see details in Burris and Winn [87]). Other incentives provided by municipalities and businesses to encourage pooling are reserved parking spots and dedicated curb space for pickups and drop offs [88], tool discount, and short waits at the tool plaza [89].

One example of carpooling schemes is the Waze Carpool application, which is available in USA (California and Texas), Israel, and since August/2018, also in São Paulo, Brazil, which aims to centralize the carpool market by enabling contact between people who take similar routes in their daily lives on the same day of the week. More importantly, the application allows drivers to either drive for free, or to be algorithmically compensated based on miles/kilometers driven by GPS and the government reimbursement rate [90]. The Waze Carpool application also limits the number of rides an individual can offer or receive in one day [91]. Another example is BlaBlaCar, a form of money-based carpooling which functions as a marketplace where drivers post their routes with prices, and passengers may buy seats [90].

4.4.2. Vanpooling

Vanpools are typically composed of 7 to 15 people commuting on a regular basis using a van or similarly-sized vehicle who share the cost of the van and operating expenses, and may share the responsibility of driving. Vanpools usually have a coordinator and an alternative coordinator [10].

Ferguson et al. [92] list the benefits of vanpooling programs: reliability, social interaction, stress reduction, financial, ecological and environmental, and parking/productivity. Acquaintanceship is also an important aspect for the success of vanpooling agreements. Vanpools are comprised of relatively large numbers of customers (7 to 15) confined within small spaces for long periods of time on a regular basis. Knowing who the other vanpoolers are can increase reliability in vanpool operations, and generate a comfortable convivial social atmosphere within the van during commuting. Household connections to vanpooling are limited because of incompatible work schedules, different employment destinations, and other factors.

Another service very similar to vanpooling are collective taxis that use vans or minibuses in an on-demand service that picks up customers and drop them off where they want, maximizing the vehicle occupancy. The difference for vanpooling services is that customers can change in every journey. In general, there is no acquaintanceship among them [93].

4.5. On-Demand Ride Services

On-demand ride services are innovative means for people to access transportation options using their smartphones readily and when required, and primarily focus on the minimization of travel time and cost. The main reason behind their popularity is the convenience of a door-to-door service (ease of booking, automatic destination information, and online payment) and cost-effectiveness [94].

The largest on-demand ride services segments are the ridesourcing and ridesplitting schemes described below.

4.5.1. Ridesourcing

Ridesourcing, sometimes referred to as Transportation Network Companies (TNC) or Flexible Mobility on Demand (FMoD), is part of a new proposal for personal mobility. It is an effective solution for interactive and shared mobility systems through paid travel-sharing services, which uses private vehicles for paid on-demand rides. In such systems, a service charge covers fuel costs and vehicle depreciation, the driver's fee, remuneration for the company that linked the service provider and final consumer, and any taxes associated with the regulation of the service [10,95,96].

In ridesourcing systems, a fleet of private vehicles offers users transportation services that are uninterrupted, personalized, and highly flexible, covering individual requests from place of origin to destination, and providing door-to-door service [96–98].

For Miller and How [98], ridesourcing schemes have the potential to revolutionize transportation systems in urban environments by giving users access to vehicles without requiring private ownership. Furthermore, Carranza et al. [99] note that the great advantage of this mode of transportation is that it saves the costs of buying, operating, and maintaining a vehicle. In addition, ridesourcing schemes allow users to spend their travel time on activities apart from driving, such as reading, talking on the phone, and sending emails and messages. According to Atasoy et al. [96], Alemi et al. [95], and Speranza [100], young adults are most likely to use these new transportation options, leading them to postpone buying a car and getting a driver's license. For Alemi et al. [95], an increase in mixed land use and location centrality (geographical proximity to several activity hubs) is associated with a greater adoption of these services.

However, as Calvert and Chatterjee [101] have warned, this shared mode of transportation is extremely dependent on information and communication technologies. The management of supply and demand is performed via virtual platforms hosted primarily on smartphone applications. It is worth noting that, according to Davidson et al. [102], smartphones have become an essential tool for people to produce or achieve mobility, because they provide contextual information on routes, and enable new shared mobility services, such as ridesourcing applications.

According to Andersen et al. [103], ridesourcing has grown rapidly in recent years due to the emergence and rapid expansion of companies that operate this mode of interactive and shared transportation. Some examples are Uber, founded in 2009 in San Francisco, California, USA, Cabify, founded in 2011 in Spain, Lyft, founded in 2012 in San Francisco, California, USA; and the Brazilian 99, that was founded in São Paulo in 2012, and in January 2018 was acquired by the Chinese transportation company Didi Chuxing.

In general, ridesourcing companies, such as those mentioned above, implement a dynamic pricing mechanism in which fares increase when demand is high and then efficiently adjust to the fluctuating transportation demand throughout the day. These companies also significantly reduce transaction costs by lowering the costs of searching for a ride, since passengers can reserve a car from indoors instead of calling a dispatcher or standing in the street to hail a taxi. With regards to safety, ridesourcing increases trust between drivers and passengers (due to the drivers and passengers being required to register their information in advance), but insufficient driver training and uninsured or underinsured vehicles are still a problem [104].

Nevertheless, these companies are facing resistance from long-established modes of transportation, such as taxis, which has generated controversy about the legitimacy of paid ridesourcing services. For Wallsten [105], the rapid growth of travel-sharing services on ridesourcing systems has shaken the traditional taxi industry, which has generally been publicly regulated around the world. The development of these modes of transportation, which did not exist until recently, has increased users' options. As such, ridesourcing systems offer a benefit to society, which is amplified by the fact that existing transportation modes, such as taxis (a direct competitor of individual modes of sharing), must respond to this new competition by improving their services and/or reducing their prices. However, the reduction of prices is not a reliable countermeasure, because taxi companies cannot reduce prices by themselves due to strong regulations within the sector. They require the authorization of administrative bodies. Additionally, Carranza et al. [99] clarify that the goal of shared transportation is not to decrease the use of taxis, but to encourage users of individual and private transportation modes to switch to shared modes. Such a shift would lower the number of vehicles in circulation, especially during peak hours, and thus, reduce traffic jams and pollution in urban centers. However, even with the support of the technical and academic community of transportation studies, the controversy remains, and is not close to a resolution.

4.5.2. Ridesplitting

Ridesplitting is a variation of the ridesourcing model, in which passengers with similar or overlapping routes split a fare and ride in a ridesourcing vehicle. This product can facilitate shared rides, higher vehicle occupancies, reduce travel costs, and provide first-mile and last-mile connectivity to public transit along the routes [10,104].

Many TNCs operate both ridesourcing and ridesplitting. For example, Uber operates UberPOOL, and Lyft operates Lyft Line. These shared services allow for dynamic altering of routes as passengers request pickups in real time. Largely, these services leverage sophisticated mathematical algorithms and smartphone technology to ameliorate the operational efficiency of flexible routes and on-demand ride services [10,88].

5. Users of Shared Mobility

Currently, environmental concerns and the need for more socially- and financially-efficient modes of transportation are guiding the new generation of transportation users. In this context, shared transportation modes are improving the indicators of population mobility by complementing public transportation and by reducing the number of vehicles per capita, parking spaces, and fixed costs [106].

In general, there is no clear profile for shared transportation users. This group includes public transportation users who do not have the purchasing power to buy, operate, and maintain a vehicle, and thus, use shared mobility systems sporadically to reduce transportation costs and improve travel efficiency. Two features that seem to span all users are environmental concerns and familiarity with technological devices. According to a study by Fleury et al. [52], most trips are short, with users having an average age of 30 to 39 years, medium to high income, and a high level of education. Arcidiacono and Pais [107] affirm that the majority of shared mobility users live in single- or two-person households, and Signorile et al. [108] state that they are more inclined to experience a multimodal mobility style. In general, the trip purposes of shared transportation modes are work (e.g., one-way carsharing), leisure (e.g., ridesourcing or ridesplitting), and shopping (e.g., round-trip carsharing) [109].

Le Vine and Polack [110] conducted a survey in London to identify a user profile for shared mobility. The authors interviewed users of shared transportation modes and found that 37% of the sample indicated that vehicle sharing impacted their decision to own a private vehicle. Of these 37%, the vast majority (83%) indicated that the impact resulted in a decision not to purchase a vehicle that would otherwise have been purchased. In addition, 11% sold their private vehicles within a maximum of 3 months after starting shared transportation, and 6% said they intended to sell their vehicles in the next 3 months. The research also showed that the average income and education level of the users is higher than those of the general population.

Schaefers [111] lists the main reasons for users adopting shared mobility schemes, as given below:

- Financial reasons: The shared mobility service is more economical for users because it is less expensive than acquiring and maintaining a vehicle. Using shared transportation modes allows one to save money for other activities due to fair prices and, usually, free parking.
- Convenience: Ease of use and convenient access to the service. Services aim to facilitate daily routines and offer increased parking spaces, flexible vehicle use, reduced liability, and simplified fare models.
- Lifestyle: This service associates the inherent pleasure of using a private vehicle with the feeling of being engaged in a community with other users. Easy-to-understand symbols associated with shared modes, such as a uniform fleet of vehicles (preferably electric) identified by special paints or adhesive, can generate a sense of belonging. Thus, users want to have contact with others while simultaneously differentiating themselves.
- Sustainability: Environmental concerns (eco-friendly service) are considered to be important for improving quality of life.

According to Krueger et al. [109] little is known about potential user groups of shared mobility. Depending on the shared mode, it could attract user groups who don't have access to private vehicles (e.g., carsharing, bikesharing), and also who are unwilling or unable to drive a private vehicle (e.g., Uber, carpooling). In general, on-demand ride services and ridesharing schemes are seen as an attractive mobility option by the elderly, people who are too young to drive, people who work and/or live in central areas that are congested and parking restrictive, and people who avoid driving under the influence of alcohol.

In addition, to meet the desires of users, shared vehicles should reflect environmental and social awareness, which explains why electric and hybrid vehicles are gaining momentum in shared mobility systems. The electric vehicle is considered fundamental to sustainable development in urban mobility due to its low CO_2 emissions. However, these vehicles are not widely used by the general population because of reduced autonomy or the high cost of acquiring and maintaining an electric car, which is twice as much as that of a combustion engine vehicle on average. To change this scenario, two measures can be adopted: the use of electric vehicles in shared mobility systems and the integration of these systems into urban and interurban public transportation [112].

6. Final Considerations

This bibliographic study reviewed the shared mobility systems present in urban centers, along with user profiles and their adaptation to new perspectives on transportation. Scientific sources, including the most relevant published articles in the literature over the last two decades, were used to compile the research on shared mobility. Contemporary shifts in approaches to transportation are spreading service sharing as a viable alternative to private vehicle ownership that will lower personal, social, and environmental costs, and maximize travel efficiency in large cities.

Shared mobility is changing the traditional transportation industry, as it has the disruptive potential to create a shift towards social, environmental, and economic efficiency through the use of technology. This scenario has pressured conventional transport companies (bus operators, taxi companies, etc.) to improve and modernize their services to not lose their customers, as well as local authorities to provide a proper regulation, licensing, and taxation.

In recent years, much controversy has been generated in terms of regulating technologies and services related to shared mobility modes, in particular about transportation network companies (or on-demand ride services) that operate ridesourcing and/or ridesplitting services. Such issues emerge due to an increasing time gap between innovation development and regulatory responses, which pressure policy-makers and local authorities to find a breakeven point among the administration, regulation, and control that enable disruptive innovations in urban mobility to be integrated into transportation systems.

In turn, transportation users are increasingly demanding in terms of reliability, flexibility, availability, comfort, and cost of their transport mode choices. Besides that, environmental concerns are gaining more and more importance among the urban population, and the advent of innovative mobility solutions can meet these aspirations. The current transportation sector has to be resilient to develop the ability to reinvent its business strategies, adapt to the new circumstances, adopt new technologies, and find a way to satisfy its customers' current and future needs. Then, shared mobility services can be seen by policy-makers, transport industry, and users as a challenge as well as an opportunity to change urban life in an unprecedented way.

Despite the fact that on-demand ride services are the modality of shared mobility that generate most of the media attention, it doesn't mean that other shared modes are irrelevant. On the contrary, in large urban centers there is space for many mobility options, which can operate in a complementary way rather than as competitors, improving the transportation supply and expanding the range of users' choice.

As for future research, it would be interesting to develop some indicators to assess the effectiveness of shared modes in reducing traffic jams and air pollution levels. Also, a survey with shared mobility

users can be conducted to find spatial-temporal patterns of shared trips/rides, travel behavior patterns, and how the integration of shared modes with traditional transport options can be achieved. Finally, the contribution (added value) of this literature review paper, as mentioned in Van Wee and Banister [113], was to provide an up-to-date and well-structured overview of the field of shared mobility to researchers and practitioners of the transport sector, contributing to the overall body of knowledge.

References

1. Cherry, C.E.; Pidgeon, N.F. Is sharing the solution? Exploring public acceptability of the sharing economy. *J. Clean. Prod.* **2018**, *195*, 939–948. [CrossRef]

2. Cohen, B.; Kietzmann, J. Ride on! Mobility business models for the sharing economy. *Organ. Environ.* **2014**, *27*, 279–296. [CrossRef]

3. Ferenchak, N.N.; Katirai, M. Pedestrian crossing behavior in relation to grouping and gender in a developing country context. *J. Glob. Epidemiol. Environ. Health* **2017**, *1*, 37–45.

4. Lloyd, L.; Wallbank, C.; Broughton, J.; Cuerden, R. Estimating the potential impact of vehicle secondary safety regulations and consumer testing programs on road casualties in emerging markets. *J. Transp. Saf. Secur.* **2017**, *9*, 149–177. [CrossRef]

5. World Bank. Transport Overview. 2017. Available online: http://www.worldbank.org/en/topic/transport/overview (accessed on 19 November 2018).

6. Pojani, D.; Stead, D. The urban transport crisis in emerging economies: An Introduction. In *The Urban Transport Crisis in Emerging Economies*; Springer: Cham, Switzerland, 2017; pp. 1–10.

7. Enoch, M. *Sustainable Transport, Mobility Management and Travel Plans*; Ashgate Publishing: Farnham, UK, 2012; 225p.

8. Chen, X.; Zahiri, M.; Zhang, S. Understanding ridesplitting behavior of on-demand ride services: An ensemble learning approach. *Transp. Res. Part C Emerg. Technol.* **2017**, *76*, 51–70. [CrossRef]

9. Le Vine, S.; Adamou, O.; Polak, J. Predicting new forms of activity/mobility patterns enabled by shared-mobility services through a needs-based stated-response method: Case study of grocery shopping. *Transp. Policy* **2014**, *32*, 60–68. [CrossRef]

10. Shaheen, S.; Cohen, A.; Zohdy, I. *Shared Mobility: Current Practices and Guiding Principles*; U.S. Department of Transportation, Federal Highway Administration: Washington, DC, USA, 2016; 120p.

11. Shaheen, S.; Chan, N.; Bansal, A.; Cohen, A. *Shared Mobility: A Sustainability and Technologies Workshop—Definitions, Industry Developments, and Early Understanding*; Transportation Sustainability Research Center, University of California, Berkeley and California Department of Transportation: Richmond, CA, USA, 2015; 30p.

12. Coates, M. The Evolution of Car Sharing. Clean Fleet Report. 2016. Available online: http://www.cleanfleetreport.com/best-car-sharing/ (accessed on 19 November 2018).

13. Raubal, M.; Jonietz, D.; Ciari, F.; Boulouchos, K.; Küng, L.; Georges, G.; Hirschberg, S.; Schenler, W.; Cox, B.; Kannan, R.; et al. *Towards an Energy Efficient and Climate Compatible Future Swiss Transportation System. Swiss Competence Center for Energy Research—Efficient Technologies and Systems for Mobility*; Working Paper Version 1.2; CCER Mobility: Zürich, Switzerland, 2017; 67p.

14. Gabrielli, S.; Forbes, P.; Jylhä, A.; Wells, S.; Sirén, M.; Hemminki, S.; Nurmi, P.; Maimone, R.; Masthoff, J.; Jacucci, G. Design challenges in motivating change for sustainable urban mobility. *Comput. Hum. Behav.* **2014**, *41*, 416–423. [CrossRef]

15. Eriksson, L.; Garvill, J.; Nordlund, A.M. Acceptability of single and combined transport policy measures: The importance of environmental and policy specific beliefs. *Transp. Res. Part A Policy Pract.* **2008**, *42*, 1117–1128. [CrossRef]

16. Eriksson, L.; Garvill, J.; Nordlund, A.M. Acceptability of travel demand management measures: The importance of problem awareness, personal norm, freedom, and fairness. *J. Environ. Psychol.* **2006**, *26*, 15–26. [CrossRef]

17. Eriksson, L.; Nordlund, A.M.; Garvill, J. Expected car use reduction in response to structural travel demand management measures. *Transp. Res. Part F Traffic Psychol. Behav.* **2010**, *13*, 329–342. [CrossRef]

18. Gärling, T.; Eek, D.; Loukopoulos, P.; Fujii, S.; Johansson-Stenman, O.; Kitamura, R.; Pendyala, R.; Vilhelmson, B. A conceptual analysis of the impact of travel demand management on private car use. *Transp. Policy* **2002**, *9*, 59–70. [CrossRef]

19. Santos, G.; Behrendt, H.; Teytelboym, A. Policy instruments for sustainable road transport. *Res. Transp. Econ.* **2010**, *28*, 46–91. [CrossRef]

20. Stradling, S.G.; Meadows, M.L.; Beatty, S. Helping drivers out of their cars integrating transport policy and social psychology for sustainable change. *Transp. Policy* **2000**, *7*, 207–215. [CrossRef]

21. Litman, T. *Well Measured—Developing Indicators for Sustainable and Livable Transport Planning*; Victoria Transport Policy Institute: Victoria, BC, USA, 2011; 83p.

22. Martinez, L.M.; Viegas, J.M. Assessing the impacts of deploying a shared self-driving urban mobility system: An agent-based model applied to the city of Lisbon, Portugal. *Int. J. Transp. Sci. Technol.* **2017**, *6*, 13–27. [CrossRef]

23. Sioui, L.; Morency, C.; Trépanier, M. How carsharing affects the travel behavior of households: A case study of Montréal, Canada. *Int. J. Sustain. Transp.* **2013**, *7*, 52–69. [CrossRef]

24. Drut, M. Spatial issues revisited: The role of shared transportation modes. *Transp. Policy* **2018**, *66*, 85–95. [CrossRef]

25. UN HABITAT III. *United Nations Conference on Housing and Sustainable Urban Development*; Policy Paper 9; Urban Services and Technology: Quito, Ecuador, 2016; 35p.

26. Magliocchetti, D.; Gielow, M.; De Vigili, F.; Conti, G.; De Amicis, R. Ambient intelligence on personal mobility assistants for sustainable travel choices. *J. Ubiquitous Syst. Pervasive Netw.* **2012**, *4*, 1–7. [CrossRef]

27. Van Themsche, S. Will electric driverless cars kill bus and light train operations? *Int. J. Transp. Dev. Integr.* **2017**, *1*, 137–147. [CrossRef]

28. Sun, J. External Economic Costs of Intelligent Urban Transportation Systems: A Method to Evaluate the Externalities of Comparative Technology Adoption Pathways in the Urban Mobility Service Sector. Ph.D. Dissertations, Clemson University, Clemson, SC, USA, 2017.

29. Zhu, M.; Shen, R.; Shu, W.; Wu, M.-Y. Traffic efficiency improvement and passengers comfort in ridesharing systems in VANETs. In Proceedings of the IEEE the 4th International Conference on Connected Vehicles and Expo, Shenzhen, China, 19–23 October 2015; pp. 116–121.

30. Cruz, M.; Macedo, H.; Mendonça, E.; Guimarães, A. GO! Caronas: Fostering ridesharing with online social network, candidates clustering and ride matching. In Proceedings of the IEEE the 8th Euro American Conference on Telematics and Information Systems, Cartagena, Colombia, 28–29 April 2016; pp. 1–8.

31. Higginbotham, B.D. Carsharing: Increasing Rural Transportation Options in the Great Central Valley. A Great Valley Center Study. 2000. Available online: https://ssrn.com/abstract=2034370 (accessed on 19 November 2018).

32. Rode, P.; Floater, G.; Thomopoulos, N.; Docherty, J.; Schwinger, P.; Mahendra, A.; Fang, W. Accessibility in cities: transport and urban form. In *Disrupting Mobility*; Springer: Cham, Switzerland, 2017; pp. 239–273.

33. Akyelken, N.; Banister, D.; Givoni, M. The sustainability of shared mobility in London: The dilemma for governance. *Sustainability* **2018**, *10*, 420. [CrossRef]

34. Akyelken, N.; Givoni, M.; Salo, M.; Plepys, A.; Judl, J.; Anderton, K.; Koskela, S. The importance of institutions and policy settings for car sharing–Evidence from the UK, Israel, Sweden and Finland. *Eur. J. Trans. Infrastruct. Res.* **2018**, *18*, 340–359.

35. Docherty, I.; Marsden, G.; Anable, J. The governance of smart mobility. *Transp. Res. Part A Policy Pract.* **2018**, *115*, 114–125. [CrossRef]

36. Nikitas, A.; Kougias, I.; Alyavina, E.; Tchouamou, E.N. How can autonomous and connected vehicles, electromobility, BRT, hyperloop, shared use mobility and mobility-as-a-service shape transport futures for the context of smart cities? *Urban Sci.* **2017**, *1*, 36. [CrossRef]

37. Ditta, S.; Urban, M.C.; Johal, S. *Sharing the Road*; Mowat Centre for Policy Innovation, University of Toronto: Toronto, ON, Canada, 2016; 58p.

38. Shaheen, S.; Cohen, A.; Martin, E.U.S. *Department of Transportation's Mobility on Demand Initiative: Moving the Economy with Innovation and Understanding*; Transportation Research Circular: Washington, DC, USA, 2018.

39. Atzori, L.; Iera, A.; Morabito, G. The Internet of Things: A survey. *Comput. Netw.* **2010**, *54*, 2787–2805. [CrossRef]

40. Conti, M.; Dehghantanha, A.; Franke, K.; Watson, S. Internet of Things security and forensics: Challenges and opportunities. *Future Gener. Comput. Syst.* **2018**, *78*, 544–546. [CrossRef]

41. Manyika, J.; Chui, M.; Brown, B.; Bughin, J.; Dobbs, R.; Roxburgh, C.; Byers, A.H. *Big Data: The Next Frontier for Innovation, Competition, and Productivity*; McKinsey Global Institute: New York, NY, USA, 2011; 156p.

42. Storey, V.C.; Song, I.-Y. Big data technologies and Management: What conceptual modeling can do. *Data Knowl. Eng.* **2017**, *108*, 50–67. [CrossRef]

43. Armbrust, M.; Fox, A.; Griffith, R.; Joseph, A.D.; Katz, R.; Konwinski, A.; Lee, G.; Patterson, D.; Rabkin, A.; Stoica, I.; et al. Clearing the clouds away from the true potential and obstacles posed by this computing capability. *Commun. ACM* **2010**, *53*, 50–58. [CrossRef]

44. Buyya, R.; Yeo, C.S.; Venugopal, S.; Broberg, J.; Brandic, I. Cloud computing and emerging IT platforms: Vision, hype, and reality for delivering computing as the 5th utility. *Future Gener. Comput. Syst.* **2009**, *25*, 599–616. [CrossRef]

45. Dias, F.F.; Lavieri, P.S.; Garikapati, V.M.; Astroza, S.; Pendyala, R.M.; Bhat, C.R. A behavioral choice model of the use of car-sharing and ride-sourcing services. *Transportation* **2017**, *44*, 1307–1323. [CrossRef]

46. Millar, C.; Lockett, M.; Ladd, T. Disruption: Technology, innovation and society. *Technol. Forecast. Soc. Chang.* **2018**, *129*, 254–260. [CrossRef]

47. Prettenthaler, F.E.; Steininger, K.W. From ownership to service use lifestyle: The potential of car sharing. *Ecol. Econ.* **1999**, *28*, 443–453. [CrossRef]

48. Shaheen, S.; Cohen, A. *Shared Mobility Policy Briefs: Definitions, Impacts, and Recommendations*; Institute of Transportation Studies, University of California: Berkeley, CA, USA, 2018; 32p.

49. Vecchio, G. Producing opportunities together: Sharing-based policy approaches for marginal mobilities in Bogotá. *Urban Sci.* **2018**, *2*, 54. [CrossRef]

50. Shaheen, S.; Bell, C.; Cohen, A.; Yelchuru, B. *Travel Behavior: Shared Mobility and Transportation Equity*; U.S. Department of Transportation, Federal Highway Administration: Washington, DC, USA, 2017; No. PL-18-007; 66p.

51. Namazu, M.; Mackenzie, D.; Zerriffi, H.; Dowlatabadi, H. Is carsharing for everyone? Understanding the diffusion of carsharing services. *Transp. Policy* **2018**, *63*, 189–199. [CrossRef]

52. Fleury, S.; Tom, A.; Jamet, E.; Colas-Maheux, E. What drives corporate carsharing acceptance? A French case study. *Transp. Res. Part F Traffic Psychol. Behav.* **2017**, *45*, 218–227. [CrossRef]

53. Zhou, F.; Zheng, Z.; Whitehead, J.; Perrons, R.; Page, L.; Washington, S. Projected prevalence of car-sharing in four Asian-Pacific countries in 2030: What the experts think. *Transp. Res. Part C Emerg. Technol.* **2017**, *84*, 158–177. [CrossRef]

54. Namazu, M.; Dowlatabadi, H. Vehicle ownership reduction: A comparison of one-way and two-way carsharing systems. *Transp. Policy* **2018**, *64*, 38–50. [CrossRef]

55. Shaheen, S.A.; Cohen, A.P. Growth in Worldwide Carsharing: An International Comparison. *J. Transp. Res. Board* **2007**, *1992*, 81–89. [CrossRef]

56. Yoon, T.; Cherry, C.R.; Jones, L.R. One-way and round-trip carsharing: A stated preference experiment in Beijing. *Transp. Res. Part D Transp. Environ.* **2017**, *53*, 102–114. [CrossRef]

57. Shaheen, S.; Cohen, A. *Innovative Mobility Carsharing Outlook: Carsharing Market Overview, Analysis, and Trends*; Transportation Sustainability Research Center, University of California: Berkeley, CA, USA, 2016; 6p.

58. Shaheen, S.; Cohen, A. *Innovative Mobility Carsharing Outlook: Carsharing Market Overview, Analysis, and Trends*; Transportation Sustainability Research Center, University of California: Berkeley, CA, USA, 2015; 4p.

59. Shaheen, S.; Cohen, A. *Innovative Mobility Carsharing Outlook: Carsharing Market Overview, Analysis, and Trends*; Transportation Sustainability Research Center, University of California: Berkeley, CA, USA, 2014; Volume 3, No. 2; 4p.

60. Shaheen, S.; Cohen, A.; Mark, J. *Innovative Mobility Carsharing Outlook: Carsharing Market Overview, Analysis, and Trends*; Transportation Sustainability Research Center, University of California: Berkeley, CA, USA, 2018; 8p.

61. Heilig, M.; Mallig, N.; Schröder, O.; Kagerbauer, M.; Vortisch, P. Implementation of free-floating and station-based carsharing in an agent-based travel demand model. *Travel Behav. Soc.* **2018**, *12*, 151–158. [CrossRef]

62. Le Vine, S.; Lee-Gosselin, M.; Sivakumar, A.; Polak, J. A new approach to predict the market and impacts of round-trip and point-to-point carsharing systems: Case study of London. *Transp. Res. Part D Transp. Environ.* **2014**, *32*, 218–229. [CrossRef]

63. Jorge, D.; Barnhart, C.; Correia, G.H.A. Assessing the viability of enabling a round-trip carsharing system to accept one-way trips: Application to Logan Airport in Boston. *Transp. Res. Part C Emerg. Technol.* **2015**, *56*, 359–372. [CrossRef]

64. Lage, M.O.; Machado, C.A.S.; Berssaneti, F.; Quintanilha, J.A. A method to define the spatial stations location in a carsharing system in São Paulo–Brazil. *Int. Arch. Photogramm. Remote Sens. Spat. Inf. Sci.* **2018**, *XLII-4/W11*, 27–32. [CrossRef]

65. Shaheen, S.A.; Chan, N.D.; Micheaux, H. One-way carsharing's evolution and operator perspectives from the Americas. *Transportation* **2015**, *42*, 519–536. [CrossRef]

66. Alfian, G.; Rhee, J.; Kang, Y.-S.; Yoon, B. Performance comparison of reservation based and instant access one-way car sharing service through discrete event simulation. *Sustainability* **2015**, *7*, 12465–12489. [CrossRef]

67. Firnkorn, J. Triangulation of two methods measuring the impacts of a free-floating carsharing system in Germany. *Transp. Res. Part A Policy Pract.* **2012**, *46*, 1654–1672. [CrossRef]

68. Vasconcelos, A.S.; Martinez, L.M.; Correia, G.H.A.; Guimarães, D.C.; Farias, T.L. Environmental and financial impacts of adopting alternative vehicle technologies and relocation strategies in station-based oneway carsharing: An application in the city of Lisbon, Portugal. *Transp. Res. Part D Transp. Environ.* **2017**, *57*, 350–362. [CrossRef]

69. Zipcar. Zipcar Overview. 2018. Available online: https://www.zipcar.com/press/overview (accessed on 19 November 2018).

70. CAR2GO. Carsharing Is Growing Rapidly: Car2go Celebrates over Three Million Members. 2018. Available online: https://www.car2go.com/media/data/germany/microsite-press/files/180205_press-release_car2go-celebrates-over-three-million-members.pdf (accessed on 19 November 2018).

71. CAR2GO. Pioneer and Market Leader in Free-Floating Carsharing. 2017. Available online: https://www.car2go.com/media/data/germany/microsite-press/files/factsheet-car2go_november-2017_en.pdf (accessed on 19 November 2018).

72. Correia, G.H.A.; Jorge, D.R.; Antunes, D.M. The added value of accounting for users' flexibility and information on the potential of a station-based one-way car-sharing system: An application in Lisbon, Portugal. *J. Intell. Transp. Syst.* **2014**, *18*, 299–308. [CrossRef]

73. Shaheen, S.A.; Mallery, M.A.; Kingsley, K.J. Personal vehicle sharing services in North America. *Res. Transp. Bus. Manag.* **2012**, *3*, 71–81. [CrossRef]

74. Ballús-Armet, I.; Shaheen, S.A.; Clonts, K.; Weinzimmer, D. Peer-to-peer carsharing: Exploring public perception and market characteristics in the San Francisco Bay Area, California. *J. Transp. Res. Board* **2014**, *2416*, 27–36. [CrossRef]

75. Shaheen, S.; Cohen, A.; Bayen, A. *The Benefits of Carpooling—The Environmental and Economic Value of Sharing a Ride*; U.C. Berkeley: Berkeley, CA, USA, 2018; 34p.

76. Lanctot, R. *Accelerating the Future: The Economic Impact of the Emerging Passenger Economy*; Strategy Analytics: Boston, MA, USA, 2017; 30p.

77. Stocker, A.; Shaheen, S. *Shared Automated Vehicles: Review of Business Models*; Discussion Paper n.2017-09; International Transport Forum: Paris, France, 2017; 29p.

78. Li, W.; Kamargianni, M. Providing quantified evidence to policy makers for promoting bikesharing in heavily air-polluted cities: A mode choice model and policy simulation for Taiyuan-China. *Transp. Res. Part A Policy Pract.* **2018**, *111*, 277–291. [CrossRef]

79. Raux, C.; Zoubir, A.; Geyik, M. Who are bike sharing schemes members and do they travel differently? The case of Lyon's "Velo'v" scheme. *Transp. Res. Part A Policy Pract.* **2017**, *106*, 350–363. [CrossRef]

80. Zhang, Y.; Brussel, M.J.G.; Thomas, T.; Van Maarseveen, M.F.A.M. Mining bike-sharing travel behavior data: An investigation into trip chains and transition activities. *Comput. Environ. Urban Syst.* **2018**, *69*, 39–50. [CrossRef]

81. Di, X.; Ma, R.; Liu, H.X.; Ban, X. A link-node reformulation of ridesharing user equilibrium with network design. *Transp. Res. Part B Methodol.* **2018**, *112*, 230–255. [CrossRef]

82. Fagnant, D.J.; Kockelman, K.M. Dynamic ride-sharing and fleet sizing for a system of shared autonomous vehicles in Austin, Texas. *Transportation* **2018**, *45*, 143–158. [CrossRef]

83. Ciari, F.; Axhausen, K.W. Choosing carpooling or carsharing as a mode: Swiss stated choice experiments. In Proceedings of the Transportation Research Board 91st Annual Meeting, Washington, DC, USA, 22–26 January 2012.

84. Shaheen, S.A.; Chan, N.D.; Gaynor, T. Casual carpooling in the San Francisco Bay Area: Understanding user characteristics, behaviors, and motivations. *Transp. Policy* **2016**, *51*, 165–173. [CrossRef]

85. Chan, N.D.; Shaheen, S.A. Ridesharing in North America: Past, present, and future. *Transp. Rev.* **2012**, *32*, 93–112. [CrossRef]

86. Shaheen, S.; Cohen, A.; Zohdy, I. *Shared Mobility Resources: Helping to Understand Emerging Shifts in Transportation*; Policy Briefs: Berkeley, CA, USA, 2017; 2p.

87. Burris, M.W.; Winn, J.R. Slugging in Houston: Casual Carpool Passenger Characteristics. *J. Public Transp.* **2006**, *9*, 23–40. [CrossRef]

88. Shaheen, S.; Cohen, A. Is it time for a public transit renaissance?—Navigating travel behavior, technology, and business model shifts in a brave new world. *J. Public Transp.* **2018**, *21*, 67–81. [CrossRef]

89. Shaheen, S.; Martin, E.; Bansal, A. *Peer-to-Peer (P2P) Carsharing: Understanding Early Markets, Social Dynamics, and Behavioral Impacts*; Transportation Sustainability Research Center, University of California: Berkeley, CA, USA, 2018; 85p.

90. Klein, M.; Zhao, J.; Ni, J.; Johnson, I.; Hill, B.M.; Zhu, H. Quality Standards, Service Orientation, and Power in Airbnb and Couchsurfing. *J. Proc. ACM Hum.-Comput. Interact.* **2017**, *1*, 21. [CrossRef]

91. Jia, Y.; Xu, W.; Liu, X. An Optimization Framework For Online Ride-sharing Markets. In Proceedings of the 37th IEEE International Conference on Distributed Computing, Atlanta, GA, USA, 5–8 June 2017.

92. Ferguson, E.; Hodge, K.; Berkovsky, K. Psychological benefits from vanpooling and group composition. *Transportation* **1994**, *21*, 47–69. [CrossRef]

93. Andreasson, I.; Leurent, F.; Rossetti, R. Applications and future developments: Future developments and research topics. In *Modelling Public Transport Passenger Flows in the Era of Intelligent Transport Systems. Springer Tracts on Transportation and Traffic*; Gentile, G., Noekel, K., Eds.; Springer: Cham, Switzerland, 2016; pp. 561–641.

94. Gupta, S.; Buriro, A.; Crispo, B. DriverAuth: Behavioral biometric-based driver authentication mechanism for on-demand ride and ridesharing infrastructure. *ICT Express* **2018**. [CrossRef]

95. Alemi, F.; Circella, G.; Handy, S.; Mokhtarian, P. What influences travelers to use Uber? Exploring the factors affecting the adoption of on-demand ride services. In Proceedings of the Transportation Research Board 96th Annual Meeting, Washington, DC, USA, 8–12 January 2017.

96. Atasoy, B.; Ikeda, T.; Ben-Akiva, M.E. Optimizing a flexible mobility on demand system. *J. Transp. Res. Board* **2015**, *2536*, 76–85. [CrossRef]

97. Földes, D.; Csiszár, C. *Conception of Future Integrated Smart Mobility*; Smart Cities Symposium: Prague, Czech Republic, 2016; 6p.

98. Miller, J.; How, J.P. Predictive positioning and quality of service ridesharing for campus mobility on demand systems. In Proceedings of the IEEE International Conference on Robotics and Automation, Singapore, 29 May–3 June 2017; pp. 1402–1408.

99. Carranza, V.; Chow, K.; Pham, H.; Roswell, E.; Sun, P. Life cycle analysis: Uber vs. car ownership. *Environment* **2016**, *159*, 1–19.

100. Speranza, M.G. Trends in transportation and logistics. *Eur. J. Oper. Res.* **2018**, *264*, 830–836. [CrossRef]

101. Calvert, T.; Chatterjee, K. New models of car use. *World Transp. Policy Pract.* **2016**, *22*, 171–185.

102. Davidson, A.; Peters, J.; Brakewood, C. Interactive travel modes: Uber, transit, and mobility in New York City. In Proceedings of the Transportation Research Board 96th Annual Meeting, Washington, DC, USA, 8–12 January 2017.

103. Andersen, H.; Eng, Y.H.; Leong, W.K.; Zhang, C.; Kong, H.X.; Pendleton, S.; Ang, M.H., Jr.; Rus, D. Autonomous personal mobility scooter for multi-class mobility-on-demand service. In Proceedings of the IEEE 19th International Conference on Intelligent Transportation Systems, Rio de Janeiro, Brazil, 1–4 November 2016.

104. Jin, S.T.; Kong, H.; Wu, R.; Sui, D.Z. Ridesourcing, the sharing economy, and the future of cities. *Cities* **2018**, *76*, 96–104. [CrossRef]

105. Wallsten, S. *The Competitive Effects of the Sharing Economy: How Is Uber Changing Taxis?* Technology Policy Institute: Washington, DC, USA, 2015; Volume 22, 22p.

106. Baptista, P.; Melo, S.; Rolim, C. Energy, environmental and mobility impacts of car-sharing systems: Empirical results from Lisbon, Portugal. *Procedia Soc. Behav. Sci.* **2014**, *111*, 28–37. [CrossRef]

107. Arcidiacono, D.; Pais, I. Think mobility over: A survey on Car2go users in Milan. In *Multidisciplinary Design of Sharing Services*; Springer: Cham, Switzerland, 2018; pp. 143–159.

108. Signorile, P.; Larosa, V.; Spiru, A. Mobility as a service: A new model for sustainable mobility in tourism. *Worldw. Hosp. Tour. Themes* **2018**, *10*, 185–200. [CrossRef]

109. Krueger, R.; Rashidi, T.H.; Rose, J.M. Preferences for shared autonomous vehicles. *Transp. Res. Part C Emerg. Technol.* **2016**, *69*, 343–355. [CrossRef]

110. Le Vine, S.; Polak, J. The impact of free-floating carsharing on car ownership: Early-stage findings from London. *Transp. Policy* **2017**. [CrossRef]

111. Schaefers, T. Exploring carsharing usage motives: A hierarchical means-end chain analysis. *Transp. Res. Part A Policy Pract.* **2013**, *47*, 69–77. [CrossRef]

112. Wappelhorst, S.; Sauer, M.; Hinkeldein, D.; Bocherding, A.; Glaß, T. Potential of electric carsharing in urban and rural areas. *Transp. Res. Procedia* **2014**, *4*, 374–386. [CrossRef]

113. Van Wee, B.; Banister, D. How to Write a Literature Review Paper? *Transp. Rev.* **2016**, *36*, 278–288.