Mobility and the Sharing Economy

Industry Developments and Early Understanding of Impacts

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***Abstract*— Shared mobility—the shared use of a vehicle, bicycle, or other mode—is an innovative transportation strategy that enables users to gain short-term access to transportation modes on an "as-needed" basis. Shared mobility includes various forms of carsharing, bikesharing, ridesharing, on-demand ride services, and microtransit. Additionally, smartphone and mobile "apps" aggregate and optimize these mobility services and are critical to many shared mobility modes. Courier network services connect couriers using their personal vehicles or bicycles with freight and seek to disrupt the existing package and food delivery industry. The emergence of automated vehicles into shared mobility could further transform the passenger and freight transportation system, with greater emphasis on shared mobility. This chapter describes the different models that have emerged in the shared mobility space and reviews research that has quantified the environmental, social, and transportation-related impacts of these services. The authors also project future trends as automated vehicles begin to emerge.**

Keywords—shared mobility; sustainable transportation; sharing economy; business models; automated vehicles

I. Introduction

Shared mobility—the shared use of a vehicle, bicycle, or other mode—is a growing sector of the sharing economy. Although the concept of sharing is not new, economic models have emerged, particularly since the 1990s, that are based on peer-to-peer sharing or the collaborative consumption of resources. Other names for the sharing economy include the "collaborative economy" and "peer-to-peer (P2P) economy." Sharing among strangers has been facilitated through online social networking platforms and global positioning system (GPS[1])-enabled mobile technology. Sharing economy business models include the sharing of lodging, labor, equipment, food, and transportation. Botsman and Rogers (2010) explain that consumers are opting for accessing goods without the cost, burden, and environmental impacts commonly associated with personal ownership [1]. PricewaterhouseCoopers (PwC, 2014) estimated that five sectors of the sharing economy (e.g., equipment, housing, books, DVDs, and cars) generated US$15 billion in global revenue in 2014, and it is poised to grow to US$335 billion in 2025 [2].

A. Shared Mobility and the Sharing Economy

While the latter half of the 20th century in North America and Western Europe emphasized personal vehicle ownership, information communication technology (ICT) and new business models spawned innovative modes beyond the traditional automobile and public transit. Travelers can now hail a driver and vehicle (e.g., Lyft, Uber); rent a car or bicycle for a short trip (e.g., car2go, Vélib', Zipcar); ride a private shuttle on-demand or on a crowdsourced route (e.g., Bridj, Chariot, Via); and have groceries or takeout food delivered in someone's personal vehicle (e.g., Postmates and Tok Tok Tok)—all using Internet-enabled smartphones, tablets, and other mobile devices. Such innovative mobility services fall under the umbrella term of shared mobility.

Shared mobility is the shared use of a vehicle, bicycle, or other mode that enables users to have short-term access to transportation modes on an "as-needed" basis. It includes carsharing; personal vehicle sharing; scooter sharing; bikesharing; on-demand ride services (including taxi e-Hail and ridesourcing or transportation network companies (TNCs)); ridesharing (i.e., carpooling, vanpooling); and microtransit; and courier network services (CNS).

Fig. 13.1 categorizes these key areas of shared mobility depending on the service. Carsharing, scooter sharing, and bikesharing (Fig. 13.1, left) are services that enable the sharing of a vehicle. Ridesharing, on-demand ride services, and microtransit (Fig. 13.1, middle) facilitate passenger rides. Finally, courier network services (CNS), Fig. 13.1, right, enable the use of private vehicles for delivery trips.

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[1] Commonly referred to as Global Positioning System (GPS) in North America, Galileo in the European Union, GLONASS in Russia, BeiDou in China, and IRNSS in India.

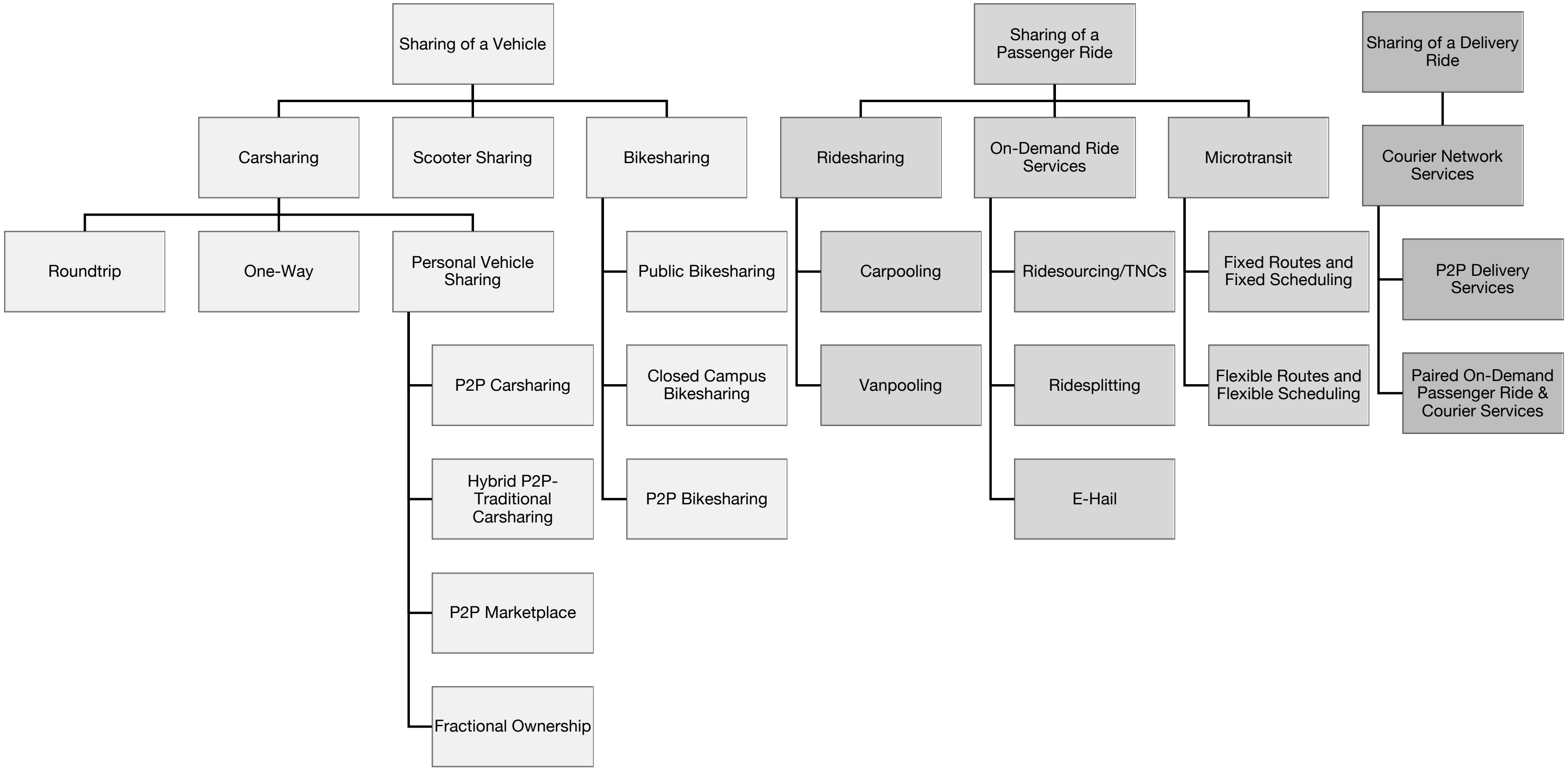

Figure 13.1 Key areas of shared mobility.

The impacts of shared mobility have been documented in cities worldwide—cost savings and convenience, reduced vehicle miles traveled (VMT)/vehicle kilometers traveled (VKT) and personal vehicle ownership, as well as decreased greenhouse gas (GHG) emissions. Moreover, there are often economic benefits to shared mobility, such as increased economic activity near multimodal hubs and commercial areas [3] [4]. However, some forms of shared mobility such as on-demand ride services, microtransit, and CNS have not been extensively studied. Many issues regarding equity, accessibility, disabled access, and the digital divide remain unaddressed. As the spectrum of shared mobility options expands in the future, public policy must evolve by enacting new or revised legislation to protect public safety, ensure equity, and provide guiding policies to harness the positive impacts of shared mobility.

This Chapter presents an overview of the key areas of shared mobility. Within each section, we present the history and current understanding of each shared mobility mode, with a focus on the energy and environmental impacts. Finally, the ~~paper~~ chapter discusses the future of urban transportation as automation and shared mobility become more integrated into a sustainable, multi-modal transportation system.

II. Carsharing

Carsharing members gain the benefits of a private vehicle user without the cost and burdens of ownership (e.g., fuel, maintenance, insurance). Instead, members are able to access a fleet of shared vehicles on an as-needed basis and pay a usage- and/or membership-based fee. The first carsharing program can be traced back to Switzerland in 1948. More popularized European programs launched in the 1980s, and since then, the industry has grown worldwide. Shaheen and Cohen (2016) documented that in October 2014, there were 4.8 million carsharing members worldwide, 2.2 million of which were in European programs, and 1.6 million in North American programs [5]. There are various carsharing business models in existence, the earliest of which is the roundtrip model. More recently, one-way carsharing and personal vehicle sharing (PVS) have emerged. The following sections discuss these business models.

A. Roundtrip Carsharing

Roundtrip carsharing provides its members access to a fleet of shared vehicles on an hourly basis, and it requires vehicles be returned to the same location from where it was accessed. Because roundtrip carsharing has the longest history, there have been several studies on its impact on VMT/VKT, vehicle ownership, GHG emissions, and individual transportation costs. Of a 2004 study of City CarShare members in the San Francisco Bay Area, 30% of members shed one or more of their personal vehicles, and two-thirds postponed purchasing a vehicle after using the service for two years [6]. Martin and Shaheen (2011) conducted a study of over 6,000 members of North American carsharing and documented the impact of roundtrip carsharing on modal shift [7]. While there was an overall decline in public transit use among carsharing members, they noted substantial increases in non-motorized and sustainable travel—walking, bicycling, and traditional carpooling. Moreover, Sioui et al. (2013) found that carsharing members in a case study in Montreal, Canada had a modal split with private car usage significantly lower than that of non-carsharing members [8].

Figure 2 provides key aggregate-level impacts of roundtrip carsharing in North America [9] [10]. It is important to note that the aggregate-level data presented are not necessarily generalizable on a municipal or regional basis (e.g., reflecting impacts of the built environment), as the analysis reflects the combined impacts across the U.S. and Canadian study populations. This was due to data agreements with participating companies that allowed for limited data disaggregation. The member survey, although imperfect in measuring changes in large numbers, is an important instrument for obtaining a before-and-after measure of carsharing impacts (n=6,281). For this reason, despite advances in technology that improve approaches to travel behavior measurement (i.e., activity data and revealed preference), surveys will likely and continue to play a fundamental role in assessing causes of change and in providing critical inputs to its measurement. A similar discussion is relevant to impact analyses of the other shared modes discussed in this chapter ~~paper~~.

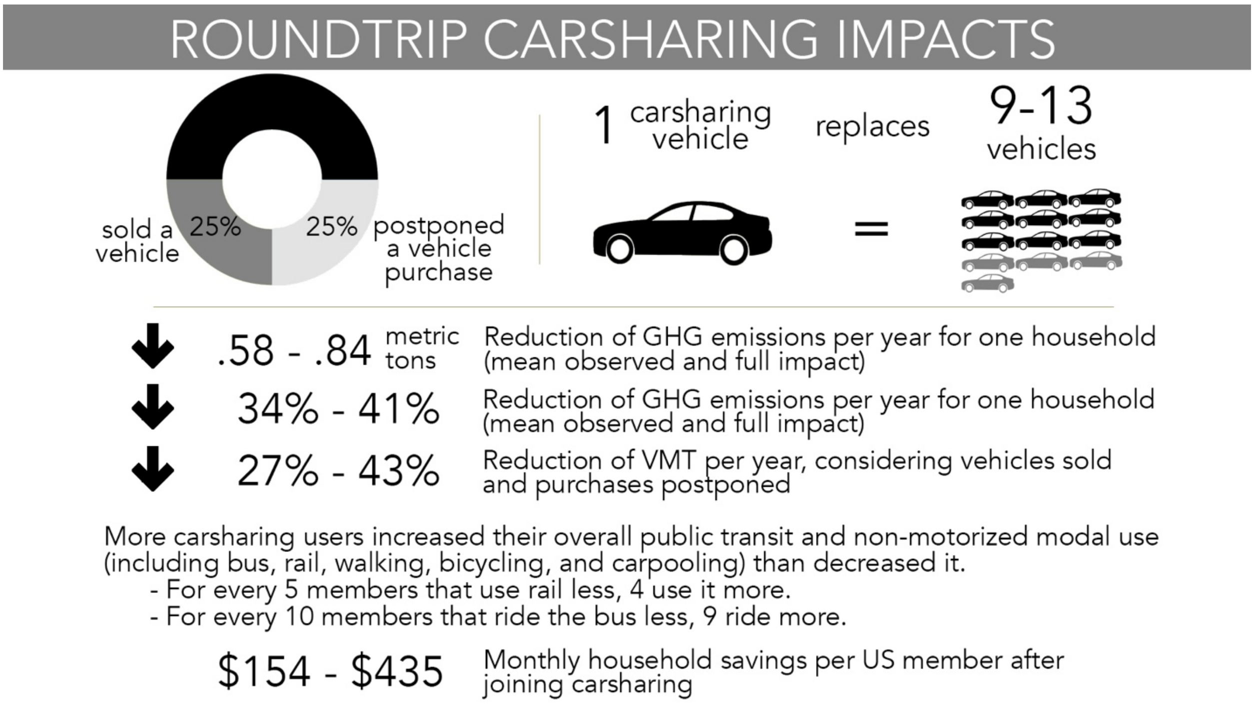

Figure 13.2 Aggregate-level impacts of roundtrip carsharing in the U.S. and Canada [10].

B. One-Way Carsharing

One-way carsharing, also known as point-to-point or free-floating carsharing, allows members to pick up a vehicle at one location and drop it off at another. In 2012, one-way carsharing began expanding rapidly to seven countries worldwide [11]. As of October 2014, there were 851,988 one-way carsharing members globally, 372,466 of which were in Europe, 445,722 were in North America, 29,600 in Asia, 3.500 in South America, and 700 in Oceania [5]. As of January 2015, 35.7% of North American fleets allowed one-way trips, and 30.8% of members had access to such fleets [12]. An advantage of one-way carsharing is its increased flexibility and potential to further enhance first- and last-mile connectivity to public transit and other modes. Moreover, as one-way trips are short city trips, electric vehicles (EVs) can be used to reduce GHG emissions. To serve these mobility opportunities, companies and cities have launched one-way carsharing programs, beginning in Europe in the 1970s, East Asia in the 1990s, and continuing in North America from the 1990s until today.

Procotip was the first recorded one-way carsharing experiment, launched in August 1971 in Montpellier, France with 35 cars and 19 stations. However, it closed in May 1973 due to technological and financial issues [13]. Liselec launched in 1993 in La Rochelle, France with 50 EVs at seven stations. Liselec was successful and still exists today as Yelómobile, and it is sponsored by Peugeot-Citroen and receives financial support from the government. Praxitèle launched in 1997 as a one-way carsharing system with connections to public transit. Fifty EVs were placed in Saint-Quentin-en-Yvelines, France, allowing its 500 members to make one-way trips between 14 stations located in neighborhoods, near offices, and at public transit stations. By March 1999, 90% of total trips were one-way trips [14]. Although Praxitèle succeeded in its technical implementation, the program struggled with costs and ended in July 1999.

In Japan, automakers have experimented with mobility services with one-way carsharing. In 1998, Honda Motor Company deployed the Intelligent Community Vehicle System, which included both roundtrip and one-way carsharing with connections to public transit [15]. Similarly, in 1999, Toyota Motor Company launched the Crayon System in Toyota City, Japan. Fifty EVs were placed at public transit stations and other locations for its 700 members. Both Honda and Toyota employed emerging technologies including smartcards, automatic vehicle location, vehicle information and communication systems, and a management system for reservations and recharging [16].

One-way carsharing began in the U.S. as pilot projects of low-emission vehicles connecting to public transit. In 1999, CarLink I launched at the Dublin/Pleasanton Bay Area Rapid Transit (BART) station in the East Bay of the San Francisco Bay Area [17] [18]. Twelve compressed natural gas (CNG) Honda Civics were available to drive between the BART station and the Lawrence Livermore National Laboratory (LLNL). Similarly, CarLink II was based at the Caltrain station in Palo Alto, California with 27 Honda Civics shared among 100 users [19]. The CarLink programs facilitated one-way trips between rail stations and home- and work-based trips. Some who lived near the transit station took BART into the central business district (CBD). Others took public transit to their suburban workplace, using CarLink as the last-mile link from the transit station to work. These commuters then returned their vehicles to the station in the evening, and home-based users picked up these vehicles after taking public transit from the CBD. At the end of the CarLink II pilot, Flexcar took over the service in 2002. However, it ceased operations in 2003 due to concerns with cost recovery and its limited scale.

The University of California (UC) piloted several one-way carsharing projects as well. UC Irvine operates the Zero Emission Vehicle Network Enabled Transport (ZEV· NET) system. Launched in 2002, ZEV· NET facilitates trips between the Irvine Transportation Center commuter rail terminal, four employers, and the UC Irvine campus. Additionally, its fleet is entirely comprised of EVs. More recently, 30 Toyota iQ EVs were added in March 2013, and the system still operates today [20]. UCR Intellishare operated around the UC Riverside campus and the Downtown Riverside Metrolink station from 1999 to 2010 [21].

Since the 1970s, despite many successful one-way carsharing projects that were well received, many ceased operations. The main reasons include economic viability (e.g., CarLink); underuse (e.g., Praxitèle); and insufficient technology (e.g., Procotip). Yet, others have succeeded and still operate today (e.g., Yélomobile). Early one-way carsharing attempts established the foundation for existing carsharing services today.

At present, one-way carsharing reflects two main models: 1) free-floating carsharing and 2) station-based carsharing. Free-floating carsharing enables shared vehicles to be picked up and dropped off anywhere within a designated geo-fenced operating area. In contrast, station-based models require users to return the vehicle to any designated station. Although this model may be perceived as less flexible, station-based carsharing limits vehicle search to select locations.

Experts in carsharing forecast one-way systems to continue to grow. Expert interviews conducted by Shaheen et al. (2015) with leaders in the carsharing industry indicated that future innovations in one-way carsharing will involve its integration with public transit and its use of low- or zero-emission vehicles [22]. Much of the recent carsharing literature has focused on vehicle rebalancing, personnel management, and the broader logistics of one-way operations (e.g. [23] [24]). More research is needed to better understand one-way carsharing's potential impact on VMT/VKT, GHG emissions, and automobile ownership [22].

C. Personal Vehicle Sharing (PVS)

Personal vehicle sharing (PVS) is another carsharing service model characterized by short-term access to privately-owned vehicles (as opposed to an operator-owned vehicle fleet). PVS companies facilitate transactions between car owners and renters by providing the infrastructure needed to make the exchange possible and seamless, such as an online platform, customer support, auto insurance, and vehicle technology. Members access vehicles either through a direct key transfer from the owner to the renter or through operator-installed in-vehicle technology that enables unattended access. There are four distinct models of personal vehicle sharing: 1) peer-to-peer (P2P) carsharing, 2) hybrid P2P-traditional carsharing, 3) P2P marketplace, and 4) fractional ownership [25].

1) Peer-to-Peer Carsharing

Peer-to-peer (P2P) carsharing employs privately-owned vehicles made temporarily available for sharing by an individual or members of a P2P company. While still heavily focused in urban areas and cities, P2P carsharing operations are not as geographically confined as other types of carsharing because the users provide the floating vehicle fleet. In addition, P2P carsharing may serve a more diverse population than traditional station-based carsharing services. In a study of P2P carsharing use in Portland, Oregon, 37% of families in poverty lived in a census block group that contained at least one P2P vehicle, while only 13% lived in a census block that had a station-based carsharing vehicle [26]. Furthermore, Fraiberger and Sundararajan (2015) projected that P2P carsharing will have more pronounced impacts on below-median income consumers than above-median income users [27]. Examples of P2P carsharing operators in the U.S. include: FlightCar, Getaround, and Turo (formerly RelayRides). Pricing and rental terms for P2P carsharing services vary, typically determined by owners listing their vehicles for rent. P2P operators generally take a portion of the rental amount in return for facilitating the exchange and providing third-party insurance. As of May 2015, there were eight active P2P operators in North America and 15 active in Europe.

2) Hybrid P2P-Roundtrip Carsharing

In the hybrid P2P-roundtrip carsharing model, individuals access vehicles by joining an organization that maintains its own fleet, but it also includes private vehicles throughout a network of locations.

3) P2P Marketplace

P2P marketplace enables direct exchanges among individuals via the Internet, including pricing agreements. Terms are generally decided among parties of a transaction, and disputes are subject to private resolution.

4) Fractional Ownership

In the fractional ownership model, individuals sublease or subscribe to a vehicle owned by a third party. These individuals have "rights" to the shared vehicle service in exchange for taking on a portion of the operating and maintenance expenses. This enables access to vehicles that individuals might otherwise be unable to afford, and it results in income sharing when the vehicle is rented to non-owners. Fractional ownership is often facilitated through a dealership or a partnership with a carsharing operator.

Fractional ownership is typically used with luxury cars and recreational vehicles. At present, this segment of the industry is small, and it remains to be seen whether or not fractional ownership can compete with existing carsharing models and personal vehicle ownership overall. Fractional ownership companies in the U.S. currently include: Curvy Road, Gotham Dream Cars, and CoachShare. In December 2014, Audi launched its "Audi Unite" fractional ownership model in Stockholm, Sweden. Audi Unite offers multi-party leases with pricing based on model, yearly mileage, and the number of drivers ranges from two to five.

III. Scooter Sharing

Scooter sharing is a recent variation on the vehicle-sharing business model. As of September 2015, there were two scooter sharing systems in Europe: Motit in Barcelona and Enjoy in Milan. Moreover, there were two systems in North America: Scoot Networks in San Francisco, California, and Scootaway in Columbia, South Carolina. All of these systems offer both one-way and roundtrip short-term scooter sharing, and include insurance and helmets. There are several other systems in Europe being tested, including CityScoot in Paris, eMio in Berlin, and Scoome in Munich and Cologne. In addition to scooters, Scoot Networks also offers electric motorcycle sharing and Scoot Quads (Renault's Twizy EV). As of October 2015, Scoot had over 400 scooters and 10 Quads in its network, and Scootaway's fleet was comprised of 350 scooters. At that time, Scoot's vehicles were being driven over 70,000 miles each month [28].

Due to the lower speed of scooters, which must remain on city streets versus highways, scooter sharing systems have remained in urban areas. Although scooter sharing has remained a smaller market relative to other shared modes, it provides urban mobility with fewer carbon emissions than automobiles. Similar to public bikesharing, scooters require less parking space at public transit stations, which could potentially increase transit ridership. Future research could test multi-modal linkages, similar to station car and one-way carsharing pilots of the past.

IV. Bikesharing

Bikesharing systems allow users to access bicycles on an as-needed basis from either a network of bikesharing stations (station-based) or free-floating within a geo-fenced area. Most operators are responsible for bicycle maintenance, storage, and parking costs. Bikesharing can also include P2P systems, where private owners lease their bicycles for short-term use through third-party hardware and applications. There are three main types of bikesharing systems: 1) public bikesharing, 2) closed campus bikesharing, and 3) P2P bikesharing [29]. The majority of bikesharing systems in the world are public, where anyone is able to access a bicycle for a nominal fee (and with a credit/debit card on file). To better serve low-income communities, some public bikesharing systems offer subsidies and cash memberships [30]. Closed-campus bikesharing systems are increasingly being deployed at university and office campuses; they are only available to the particular campus community they serve. P2P bikesharing services are available in urban areas for bike owners to rent out their idle bikes for others to use and are also growing due to companies, such as Spinlister and Bitlock.

Bikesharing has emerged as one of the fastest-growing transportation innovations in many global cities. As of April 2016, there were 1,019 cities with information technology (IT)-based public bikesharing systems in the world comprised of 1,324,530 bikes, the majority of which were in China. The U.S. had 75 programs spread over 99 cities, with approximately 32,000 bikes and 3,400 stations [31].

Bikesharing has the potential to impact public transit and other modes, serving as an effective and efficient first- and last-mile connection with no energy usage. Shaheen et al. (2012 and 2014) conducted a two-part study of public bikesharing programs in North America to determine the program impacts on modal split [30] [32]. The results suggest that public bikesharing in larger cities (e.g., Mexico City, Montreal, and Washington, D.C.) takes riders off of crowded buses, while bikesharing in smaller cities (e.g., Minneapolis-St. Paul, Minnesota) improves access to and egress from bus lines. Moreover, respondents reported that rail usage decreased in larger cities due to faster travel speeds and cost savings from bikesharing. Half of all bikesharing members reported reducing their personal automobile use [30]. Aggregate-level impacts of bikesharing are summarized in Figure 3 based on a number of cities analyzed in North America (n=6,168).

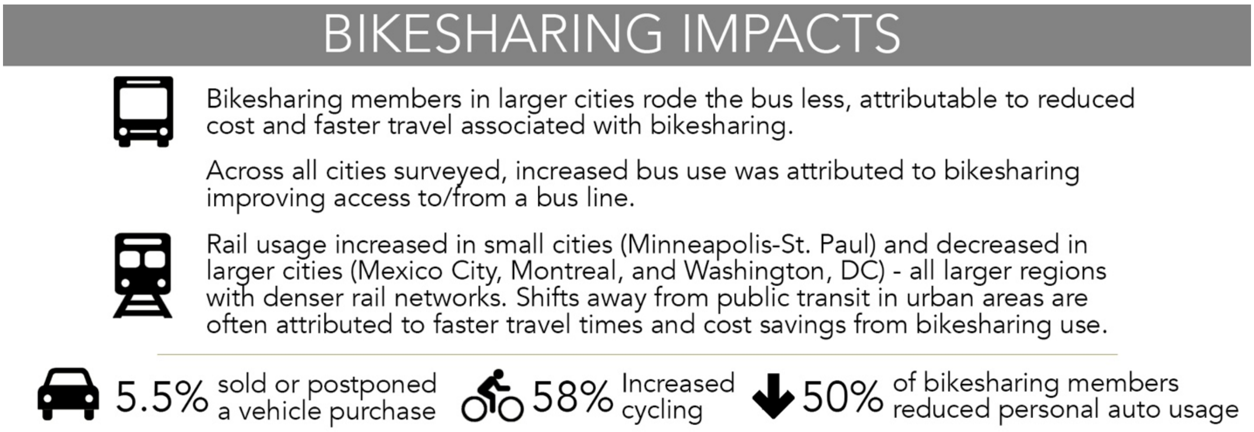

Figure 13.3 Aggregate impacts of North American public bikesharing [10].

V. Traditional Ridesharing

Traditional ridesharing facilitates shared rides among drivers and passengers with a common origin and/or destination. Traditional ridesharing includes vanpooling (the grouping of seven to 15 persons commuting together in one van) and carpooling (groups of seven or less traveling together in one car), which have been alternative transportation strategies for decades. Because innovations in the area of sharing a passenger ride have burgeoned only recently, the terminology remains unclear. To differentiate carpooling and vanpooling (ridesharing) from the emerging services, the terms "traditional ridesharing" and "on-demand ride services" are used.

Chan and Shaheen (2012) classified traditional ridesharing into the following categories: 1) acquaintance-based, 2) organization-based, and 3) ad hoc [33]. Acquaintance-based ridesharing consists of carpools that are formed by people who are already acquaintances (i.e., carpools among family ("fampools") and coworkers). Organization-based carpools require participants to join the service either through membership or by visiting a website. Ad hoc ridesharing involves more unique forms of ridesharing, including casual carpooling also known as "slugging." Although traditional ridesharing's modal share in the U.S. declined from 20.4% in 1970 to 9.3% in 2013, it remains the second largest travel mode, after driving alone [34].

Since the late-1960s, public agencies particularly in the U.S. and Canada have tried to increase traditional ridesharing's modal share through policies (e.g., transportation demand management, trip reduction ordinances); high-occupancy vehicle (HOV) infrastructure (e.g., HOV lanes, park-and-ride facilities); and technology (computerized ridematching). The combination of those strategies proved successful—as of July 2011, there were 638 ridematching services in North America, with traditional ridesharing remaining the second largest travel mode [33]. However, as mobile technology has proliferated and improved in this decade, companies have increasingly targeted the traditional ridesharing modal share. Most recently, ridesourcing companies (discussed in more detail below) have launched services to target commuters to use their apps to for facilitating more traditional ridesharing. Lyft began Driver Destination in 2014, and Uber with uberCOMMUTE in China in 2015, which targets drivers with longer commutes to pick up passengers along their commute. Lyft also partnered with the Metropolitan Transportation Commission in the San Francisco Bay Area to pilot Lyft Carpool in March 2016. Several other mobility companies have created similar platforms for traditional ridesharing including: Carma Carpooling, Carzac, and Ride.

VI. On-Demand Ride Services

On-demand ride services differ from traditional ridesharing, in that these services involve the passenger requesting a ride through a mobile device and a mobile app, and often its drivers do not have an incidental origin or destination as the passengers. On-demand ride services have experienced notable growth in the last few years in the midst of an evolving regulatory and policy climate. They include ridesourcing (also known as transportation network companies/TNCs), ridesplitting within ridesourcing services, and e-Hail services for taxis with medallions.

A. Ridesourcing

Ridesourcing (or TNC) services use mobile apps to connect community drivers with passengers. There are various terms used for this emerging transportation option—ridesourcing among transportation academics, TNCs among practitioners, and ride-hailing and ride-booking among the popular press. Examples of these services include: Lyft and Uber (specifically, uberX, uberXL, and UberSELECT), as well as specialized services for children and the older population. These services can provide various vehicle types (e.g., sedans, sports utility vehicles, vehicles with car seats, wheelchair-accessible vehicles, and vehicles where the driver can assist older or disabled passengers). While taxis are often regulated to charge static fares, ridesourcing often uses market-rate pricing, popularly known as "surge pricing" when prices usually go up during periods of high demand to incentivize more drivers to take ride requests.

Lift Hero is a specialized ridesourcing service that caters toward older adults and those with disabilities in the San Francisco Bay Area. The drivers are specially trained in caring for such riders. Similarly, Lyft has partnered with National MedTrans Network to operate Concierge, a platform to provide non-emergency medical transportation in New York City. Another specialized for-hire vehicle service is HopSkipDrive, which provides rides for children either to or from school or afterschool activities. The drivers are either mothers or those with a background in childcare. At present, HopSkipDrive is only available in the Los Angeles area. Shuddle similarly catered to children in the San Francisco Bay Area, but it ceased operations in April 2016 due to financial difficulties.

There are mixed responses from cities and public agencies regarding the popularity of ridesourcing in urban areas. While some have attempted to prohibit ridesourcing operations, others are interested in its potential to complement the existing public transit system and reduce parking demand. In March 2016, a suburb of Orlando, Florida has begun a pilot to subsidize Uber rides within its city and to and from its commuter rail station.

Since ridesourcing services began in 2012 in San Francisco, California, relatively little research, other than internal studies of companies' proprietary data, has documented their impacts. An exploratory study was conducted in 2014 of 380 ridesourcing users in San Francisco [35]. Ridesourcing users were generally younger and more highly educated than the city average (84% had a bachelor's degree or higher). UberX provided the majority of trips (53%), while other Uber services (black car, SUV, etc.) represented another eight percent. Lyft provided 30% of trips, Sidecar (now defunct) provided 7%, and the remainder of trips were provided by other services. Of respondents who owned a car, 40% stated that they had reduced their driving due to the service. A summary of the study findings is provided in Fig. 13.4.

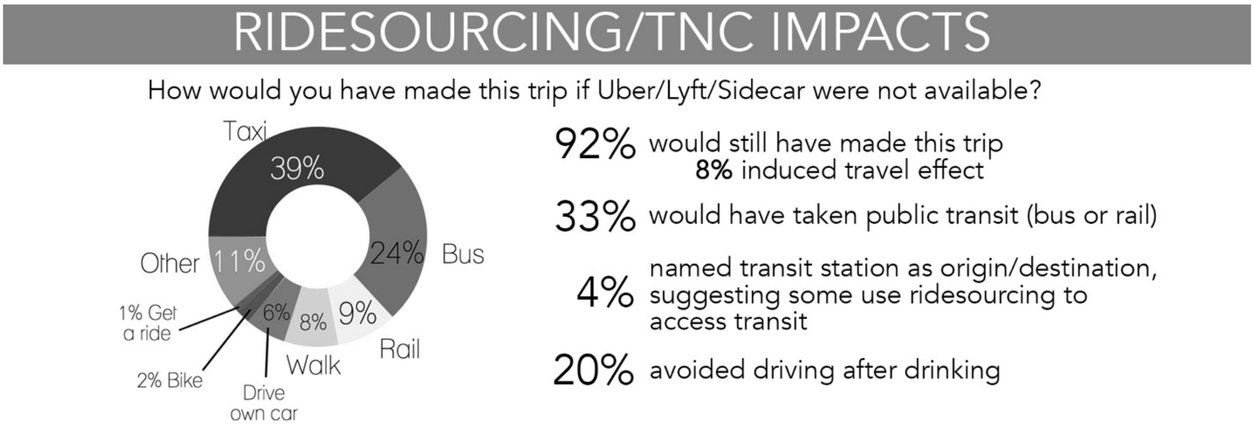

Figure 13.4 Impacts of ridesourcing/TNCs in San Francisco, California [10].

Ridesourcing may also complement public transit, serving specific times when, and areas where, public transit is sparser. A 2016 from the American Public Transportation Association found that ridesourcing is most used between the hours of 10pm and 4am, when public transit is infrequent or even unavailable. Moreover, the study found that ridesourcing appeared to substitute for private auto trips rather than trips via public transit [35].

B. Ridesplitting

A recent development ridesourcing is the introduction of ridesplitting, the splitting of a ride and its fare with someone else taking a similar route. Ridesourcing companies operate ridesplitting services, such as Lyft Line and UberPOOL, which match riders with similar origins and destinations together. These shared services enable dynamic changing of routes as passengers request pickups in real time. Lyft Line has experimented with "Hot Spots" in the San Francisco Bay Area that encourage passengers to congregate at select intersections in exchange for discounted fares as a means of consolidating operations and making them more efficient. Similarly, UberPOOL has tested "Smart Routes," where users can get a discounted fare starting at US$1 off the normal UberPOOL price in return for walking to a major arterial street. This allows drivers to make fewer turns and complete ride requests faster [37].

Uber also launched uberHOP in Seattle, Washington, and Toronto, Canada—an on-demand ridesplitting service for peak-period travel. Travelers request their ride through the app and walk to a designated pickup location and share the ride with other commuters. The uberHOP service straddles ridesplitting and on-demand microtransit (discussed below). Like microtransit, it pools more riders together and uses predetermined pickup and dropoff locations, but employs community vehicles and drivers closer to ridesplitting.

C. E-Hail Services

The taxi industry has responded to the rising popularity of ridesourcing with its own mobile device apps known as "e-Hail." Travelers can use e-Hail apps, which are maintained either by the taxi company or a third-party provider, to electronically hail a taxi. There has been a dramatic increase in use of e-Hail services, such as Arro, Bandwagon, Curb, Flywheel, Gett, Hailo, and iTaxi, in the U.S. For example, as of October 2014, Flywheel was used among 80% of San Francisco taxis (1,450 taxis), which has brought taxi wait times closely in line with those of ridesourcing [38]. Increasingly, taxi and limousine regulatory agencies are developing e-Hail pilot programs and mandating e-Hail app compatibility. In February 2015, Flywheel was operating in six cities with over 5,000 drivers, and Curb (recently acquired by Verifone) served approximately 60 U.S. cities with 35,000 cabs. The Bandwagon app combines ridesplitting with e-Hail to facilitate taxi splitting. It matches riders going a similar direction in taxis and provides a platform for splitting the fare. As of Spring 2016, Bandwagon operates at LaGuardia Airport and John F. Kennedy International Airport in New York City. In April 2016, the Gett app introduced a fare splitting feature for use in over 15,000 black cabs in London. Because regulated taxis charge static fares, e-Hail services similarly charge locally-regulated taxi rates and do not use "surge pricing" during periods of high demand as ridesourcing services often do.

Partnerships are starting to form between public agencies, taxi companies, and app developers to create a common platform for travelers to use e-Hail apps in various countries. UpTop is a global taxi network developed by a partnership of IRU and the Taxicab, Limousine and Paratransit Association. UpTop has been partnering with app companies. More recently, it added Curb, The Ride, and zTrip apps to its network, and it covers 500,000 taxis, or ten percent, of all taxis worldwide.

VII. MICROTRANSIT

Other transportation options have existed in addition to traditional, fixed-route public transit: paratransit, jitneys, dollar vans, and feeder shuttles operated by employers or public transit agencies. Recently, a form of technology-enabled transit has emerged, called microtransit, which incorporates flexible routing, flexible scheduling, or both. Microtransit services are typically operated by private companies, but public transit agencies are gaining interest in operating their own microtransit services. These services operate similarly to jitneys of the past but are enhanced with ICT [39]. Microtransit operators primarily target commuters, connecting residential areas with urban and suburban job centers. Microtransit's use of mobile technology avoids traditional and costly methods of reserving rides, such as call centers or even booking websites, thus potentially lowering operating costs for services that target special populations, such as disabled, older adults, and low-income groups. Microtransit services can be categorized into the following two models: 1) fixed route, fixed schedule and 2) flexible route with on-demand scheduling, which are discussed below.

A. Fixed Routes and Fixed Scheduling

Fixed-route and fixed-schedule microtransit operates similarly to fixed-route public transit or even vanpooling. An example of such a service is Chariot, which runs 14-seat vans along predefined routes in San Francisco, California. Chariot allows its customers to request new routes through its mobile app as a way to determine new crowdsourced routes. While these services may appear like vanpooling, microtransit drivers are employed drivers rather than vanpool participants who share driving responsibilities. To some public transit agencies, microtransit seems to directly compete with its bus routes. However, in some congested cities, microtransit can alleviate overcrowded buses or provide feeder services to transit trunk lines. Research is needed to better understand this dynamic.

B. Flexible Routes and On-Demand Scheduling

Flexible-route, on-demand microtransit operates more similarly to ridesplitting and paratransit services. An example includes Bridj in Boston, Massachusetts; Kansas City (both Missouri and Kansas); and Washington, D.C. Its app enables users to request rides in select neighborhoods. Based on the requests received, Bridj selects a central meeting spot, which passengers walk to and share a ride with other passengers traveling along a similar route. According to Bridj, the service is able to transport 22 passengers per vehicle per hour. Notably, *Ride KC: Bridj* in Kansas City is the first public-private partnership between a shared mobility company (Bridj), an automaker (Ford Motor Company), and a public transit agency (Kansas City Area Transportation Authority).

Another on-demand microtransit service is Via in New York City. Via users request rides in real-time and share a ride with passengers going a similar direction. Due to the one-way avenue design of New York City, passengers are often asked to walk to an adjacent one-way avenue to minimize route deviation and improve operational efficiency. Via has served 1.5 million rides since its launch in late-2013 and expanded to Chicago, Illinois. The public sector has also been experimenting with this model. The Santa Clara Valley Transportation Authority launched VTA FLEX in San Jose, California, which is an on-demand bus service that routes buses to pick up passengers at existing public bus stops. Similar to fixed-route microtransit, on-demand microtransit could provide first- and last-mile service for public transit, but research is needed to understand potential impacts.

VIII. COURIER NETWORK SERVICES

Courier network services (CNS) (also referred to as flexible goods delivery) provide for-hire delivery services using an online platform (such as a website or mobile app) to connect couriers using their personal vehicles, bicycles, or scooters with freight (e.g., packages, food). Although the business models in this realm are evolving, two general approaches appear to have emerged: 1) P2P delivery services and 2) paired on-demand passenger ride and courier services.

A. P2P Delivery Services

In P2P delivery services, couriers use their own vehicle, bicycle, or scooter to conduct a delivery. Within P2P delivery services, there are a variety of business models. For example, Postmates has its couriers deliver groceries, takeout food, or goods from almost any restaurant or store in a city. They charge a delivery fee in addition to a 9% service fee based on the cost of the goods being delivered. Instacart is similar to Postmates, but it is limited to grocery delivery and charges a delivery fee between US$4 to $10 depending on the time given to complete the delivery. DoorDash is a takeout food delivery service, charging a flat delivery fee of US$7. Roadie is another courier service, primarily for inter-city goods movement rather than same-day intra city deliveries. Finally, Shipbird is a shipping service that connects everyday commuters with individuals seeking couriers. Couriers provide the Shipbird app with their availability, commuting route, and the distance they are willing to deviate from their commute route to complete a delivery. Shipbird then matches these couriers with the requested delivery jobs. The proliferation of P2P delivery services, where couriers use their personal vehicles or travel modes, could reduce the need for delivery companies to maintain their own fleet for operations.

B. Paired On-Demand Passenger Ride and Courier Services

The second CNS model that has emerged is one in which for-hire ride services (e.g., ridesourcing) also conduct package deliveries. Deliveries via these modes can either be made in separate trips or in mixed-purpose trips (e.g., for-hire drivers can transport packages and passengers in the same trip). Sidecar was the only ridesourcing company that conducted mixed-purpose trips in addition to dedicated goods delivery trips, through a service called Sidecar Deliveries. In February 2015, the company claimed that 10% of its passenger rides in San Francisco included package deliveries [40]. Sidecar Deliveries also allowed couriers on foot, bicycles, and scooters into its network. The service partnered with Yelp Eat24, a food ordering service, to assist with deliveries. The company claimed to have cut estimated delivery times in half. However, Sidecar ceased operations in December 2015.

Uber has also entered the delivery services market with UberEATS (food) and UberRUSH (bike, foot, and vehicle messenger goods delivery service). UberEATS charges a US$3 flat delivery fee (US$4 in New York City) in addition to the food cost, while UberRUSH charges a 20% delivery fee in New York City and 25% in San Francisco and Chicago. Uber piloted UberRUSH in New York City in 2014, first as a bike messenger service where couriers would pick up an item from the requester and deliver it somewhere within a coverage area within the same day. This is now being expanded to merchant delivery, where items are picked up from stores and delivered either to the requester or to a third party by foot or vehicle, and it has recently expanded to San Francisco and Chicago [41]. Uber is also experimenting with UberCARGO in Hong Kong for moving and delivery needs (e.g., mattress delivery to a new house) (Russell, 2015). For one day in June 2015, Lyft ran a promotion with Starbucks where they delivered free iced coffee. Thus, the three major ridesourcing operators had in some form tried to expand their ride services to include package/item delivery, food delivery, or both. As the model is still new, this paired passenger and courier model may continue to evolve over the coming years.

IX. FUTURE OF SHARED MOBILITY

Smartphones represent one of the most important transportation innovations of the 21st century. Demographic shifts, advancements in geo-spatial routing and computing power, the use of cloud technologies, faster wireless networks capable of carrying greater bandwidth, concerns about congestion, and heightened awareness about the environment and climate change are changing the way people think about mobility. Mobility consumers are increasingly using smartphone applications, dubbed "apps" for an array of transportation functions. More people are starting their trips with smartphones, engaging in activities such as route planning, finding departure information for the next bus or railcar, or requesting a driver (e.g., Lyft, Uber, or taxi). The increasing capability, availability, and affordability of intelligent transportation systems (ITS), GPS, wireless, and cloud technologies—coupled with growing data availability, sharing, and interoperability—are causing more people to use smartphone apps to assist with their transportation needs. Time savings (e.g., high occupancy vehicle lanes available to users of dynamic ridesharing); financial savings (e.g., dynamic pricing providing discounts for peak and off-peak travel and for choosing low-volume routes); incentives (e.g., offering points, discounts, or lotteries); and gamification (e.g., use of game design elements in a non-game context) are among the key factors driving the growth of transportation apps. This section focuses on shared mobility's future including use of trip planning mobile apps and potential opportunities with automated vehicles.

A. *Mobility-Related Smartphone Apps*

Many of the shared mobility services mentioned in this chapter are only accessible by a smartphone or mobile app. Smartphone apps have helped give rise to innovative business models, services, and ways to access destinations. These are broadly summarized in the five categories below:

1) Apps that have enabled on-demand for-hire ride services (e.g., ridesourcing and e-Hail taxis);
2) Public transit-related apps that give real-time arrival information and can help plan routes and transfers;
3) Apps that enable business-to-consumer (B2C) transactions (e.g., roundtrip or one-way carsharing);
4) Apps that enable peer-to-peer (P2P) transactions, such as those with carsharing or bikesharing modes; and
5) Apps that aggregate different modes, routes, and real-time travel conditions to assist with planning trips.

The fifth category listed above, or trip-planning apps, can aid the use of the other four app services. Trip planning apps help travelers identify their preferred travel route and mode based on cost, convenience, time considerations, and environmental impact. They can also provide step-by-step assistance as users navigate their chosen route. In this way, they can act as an enabling technology for shared mobility use. Initial research indicates that 80% of such app users took modes other than their personal cars, mostly opting for public transit [42].

Trip planning apps can be grouped into two general categories: 1) single mode trip planning and 2) multi-modal trip aggregators. A survey of 82 common U.S. transportation apps, which include the ones discussed below, found that 93% were offered free of charge [43].

1) *Single-Mode Trip Planning*

Trip planning apps can be designed for a single mode, usually with public transit and driving route-assistance. Increasingly, mobility apps are using real-time information. Transit trip planning apps augment static maps and timetables with real-time information about delays. For example, the Washington D.C. Metro has its own app that provides real-time delay information about its trains. Driving-related single mode apps include Waze and Metropia. These apps use real-time traffic congestion and incident data to generate optimal travel routes, and they also give turn-by-turn assistance during the journey. The turn-by-turn guidance is similar to Google Maps and Apple Maps, although those applications also show modes other than driving when generating route options for a particular trip.

2) *Multi-Modal Trip Aggregators*

Multi-modal trip aggregators offer a single platform for planning trips involving different modes including: public transit, taxi services, carsharing, ridesharing, on-demand ride services, bicycling, walking, and personal vehicles. Travelers can quickly view the time, cost, and even calories burned while using different modes and routes. These apps also use real-time information to provide accurate departure and arrival times. For bicyclists, some apps also show the flattest route to take. These apps can also quantify carbon dioxide (CO2) emissions savings and provide a platform for integrated payments across modes. For example, the trip aggregator app RideScout (now Moovel) estimates that by 2018, they will have more than four million users, which will save 2.4 million tons of and remove the equivalent of 427,000 cars from the road each year [42]. RideScout acquired GlobeSherpa in Summer 2015, which enabled integrated mobility payment across modes for this service. In April 2016, RideScout and GlobeSherpa merged to become Moovel North America A few additional examples of trip aggregation apps include: Citymapper, Moovit, Nimbler, Swiftly (formerly Swyft), Transit App, and TripGo.

Companies are also partnering with cities to create apps specific to modes and services available in that particular city or region. One example is Go LA, a multi-modal transit app developed in collaboration between Xerox and the City of Los Angeles. This app was launched in January 2016. Xerox launched a similar app, Go Denver, for the City of Denver in February 2016 [44].

3) *Gamification*

Some mobile apps use gamification, or the use of game theory and game mechanics to incentivize positive travel behaviors. These apps achieve this by way of leaderboards, badges, levels, points, and progress bars, in addition to other tools [45]. For example, Waze gives its users points for providing traffic data and warnings of road hazards (construction, police, cameras) for other drivers. Metropia provides commuting routes, but it also offers incentives for people to take alternative routes and departure times to reduce traffic on certain routes. Incentives, provided through community sponsors, include online music, gift cards to local and online shops, etc. The app also tracks how many pounds of CO2 the user saves. A Metropia pilot study on its users in Los Angeles found that after six weeks of use, 86% of commuters reported saving time, and over 60% of users changed their regular departure time. Users who changed their departure time and route experienced between a 20 and 30% reduction in commute times [46].

4) *Impact on Travel Behavior*

The use of smartphone apps for transportation can have economic, social, and psychological impacts on its users. First and foremost, they reduce the cognitive burden of a user trying to plan a trip after considering public transit options and delays, as well as route preference and current road traffic conditions. Another often overlooked benefit of trip planning apps is giving perceived control to the user, which may make him or her more satisfied with their trip regardless of whether there was an objective improvement in their comfort [43]. For example, several studies have shown that bus riders without real-time arrival data perceived their wait time to be longer than was felt by riders with real-time data, suggesting that the presence of real-time information can increase the perceived satisfaction with the trip [45]. Further, trip aggregators, such as Swiftly, help users consider the menu of options available and can facilitate the use of nonconventional modes. Smartphones apps that match riders to each other, to drivers, or to peer-to-peer shared vehicles can also help foster a sense of trust in the network. This is done by employing a system of ratings as well as by linking social media profiles. Taking the presence of the embedded social network a step further, travel apps also leverage social dynamics to influence adjustments in behaviors. This is done by apps, such as Waze, Moovit, and GasBuddy, which use points, competition, or ratings to shape behavior. The behavioral mechanisms employed by transportation applications are worth greater study as an increasing number of users consult travel applications before starting a trip. Findings of such studies could build on anecdotal evidence that suggests such applications are successful in affecting travel behavior [43].

B. *Impact of Automated Vehicles on Shared Mobility*

Automated vehicles (AVs) are conveyances that move passengers or freight without human intervention. Research and development activities on AVs are increasing, with many high-profile companies and research institutions developing AVs or partnering to develop them. Greenblatt and Shaheen (2015) reviewed the history, developments, and trends of AVs, and predicted that AV technology will be emergent by 2020, accepted by the 2030s, and predominant by 2050. As the use of shared mobility has grown exponentially in recent years, so has the prospect of using automated vehicles in these services as shared automated vehicles (SAVs). Specifically, they forecast a potential synergy between AVs and carsharing. By 2020, several automakers are slated to release level 3 (i.e., limited self-driving) AVs. With level 3 automation, AVs could drive up to carsharing users, park, and refuel/recharge themselves, saving time and increasing user convenience. Moreover, with enhanced safety features, level 3 AVs in a shared vehicle setting may reduce an operator's insurance costs. These savings could be passed onto shared mobility consumers, Higher levels of automation will likely enhance the capabilities and convenience of savings of SAVs [48].

Still, research on SAVs is limited. Fagnant and Kockelman (2014) developed an agent-based model for SAVs to help shared mobility companies estimate optimal fleet size and environmental impacts. Initial results reveal that one SAV can replace 11 conventional vehicles. However, a system of SAVs may increase VMT by 11% due to necessary travel between users [49]. Greenblatt and Saxena (2015) postulated that small electric SAVs, when combined with a low-carbon electrical grid could reduce per-mile (km) GHG emissions by 90% compared to today's vehicles. In addition, the appropriate-sized SAV can be deployed according to passenger occupancy needs, further reducing excess GHG emissions [50]. Most recently, Wadud et al. [51] argue that AVs have the potential for significant emission and energy reductions, but those reductions are not guaranteed. Various scenarios were created to determine the net impacts of AVs on energy use, with wide variation—from halving emissions to doubling them—due to different assumptions on the social and behavioral response to this new technology [51]. Thus research, evaluation, and adaptive policies are necessary to achieve the maximum benefits of AVs.

X. CONCLUSION

Shared mobility, a subset of the larger sharing economy, enables users to gain short-term access to transportation modes on an as-needed basis. Carsharing, bikesharing, on-demand ride services, microtransit, and courier network services are changing how urban travelers access transportation, make connections to other modes, and send and receive goods. Studies have found a number of environmental, social, and transportation-related impacts of shared mobility services, such as a reduction of vehicle miles/kilometers traveled, vehicle use, and vehicle ownership. Users have often cited cost savings and convenience over private vehicle ownership as reasons of using a shared mode. This has been demonstrated for roundtrip carsharing and public bikesharing; however, more research is needed to better understand the impacts of on-demand ride services and courier network services.

Despite shared mobility's impacts and opportunities, challenges remain particularly in the area of public policy. Cities and states have confronted difficulties in enacting and/or revising policies to keep pace with shared mobility innovations while addressing issues of public safety, insurance and liability, and fair labor practices. All too often, equity considerations remain unanswered—early anecdotal evidence is emerging that suggests that lower-income populations may lack sufficient access to certain shared mobility services. Additionally, labor issues concerning for-hire vehicle drivers raise questions regarding whether or not drivers should be considered independent contractors or employees. Public-private partnerships, such as the Ride KC: Bridj pilot, which employs drivers from the Kansas City Area Transportation Authority, may offer guidance on how public agencies can address labor issues. As automated vehicles are poised to dramatically transform urban transportation, SAVs may too become a major public transportation mode, filling gaps in the existing fixed-route network and allowing first- and last-mile connectivity. Although research and development into AVs has increased, its impacts on travel and emissions remains speculation. Future research should focus efforts to better understand the longer-term impacts of this burgeoning industry on future transportation networks.

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