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Strangers On This Road We Are On: A Literature Review of Pooling in On-Demand Mobility Services

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Abstract

Ridepooling service options introduced by transportation network companies (TNCs) and microtransit companies provide opportunities to increase shared-ride trips in vehicles, thereby improving congestion and environmental factors. This paper reviews the existing literature available on ridepooling and related services, specifically focusing on pooling options available from on-demand transportation companies. The paper summarizes the existing knowledge on the use of pooled-ride services, factors in travel mode service options for customers, available policy and planning strategies to incentivize sharing vehicles, and effects of the COVID-19 pandemic on shared-ride travel. Overall, research shows that ridepooling options are more likely to be considered by public transit users who have lower household incomes, while ridesourcing users of upper-class backgrounds are less likely to consider moving to a shared-ride service. Travel time and trip cost are the most important factors for travelers determining whether to use a ridesplitting or microtransit service rather than a ride-alone ridesourced trip. Existing policy and planning tools targeting pooled travel or TNCs can be expanded on and specified for on-demand ridepooling services, such as offering better incentives to use shared vehicles and increased access to curb areas or travel lanes, but the most effective strategies will include increasing the user costs for parking or riding alone.

Keywords

planning and analysis, on-demand mobility, shared mobility, public transportation, microtransit, transportation network companies, autonomous vehicles

New mobility services have the potential to address various transportation issues, such as traffic congestion and air pollution, by reducing private-vehicle ownership and single-occupancy vehicle (SOV) use while improving personal mobility. The concept of sharing, supported by the evolution of emerging technologies, is particularly important in transforming mobility. From a societal benefit perspective, pooling more rides and attracting riders to pooled service options can help increase the average vehicle occupancy in on-demand transportation while mitigating the negative impacts of increased vehicle mileage, traffic congestion, and greenhouse gas emissions from these services (*1*). Ridepooling of shared vehicle fleets can decrease total travel distance and carbon emissions through the reduced fleet size needed to fulfill trip demands from travelers (*2*). Likewise, pooled future autonomous vehicle (AV) services with low enough fares to incentivize ridership are expected to minimize vehicle miles traveled (VMT) and vehicle miles without passengers compared to exclusive-ride AV services (*3*).

This study aims to contribute to the growing literature on new mobility services through a review of existing studies of pooled travel choices, differences between different pooled on-demand transportation options, and existing or suggested strategies for encouraging pooled rides. The study primarily focuses on ridepooling service options introduced by transportation network companies (TNCs) and microtransit companies, which provide opportunities to increase shared-ride trips in vehicles. Accrued knowledge of existing research about pooling

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rides in on-demand transportation can guide policy and planning strategies to encourage pooled travel behavior for cities, regional planning authorities, state departments of transportation, public transportation agencies, and private ridesourcing services or technology companies.

To identify relevant literature for this review, researchers used scholarly search engines, including Google Scholar, Transportation Research International Documentation, Science Direct, and Research Gate. The search focused on sources since 2013 that reflect the arrival of TNCs and the transformation of on-demand service options with ridepooling or ridesplitting features. Any resources that referred only to more traditional pooled-trip options—such as carpooling, vanpooling, or call-and-ride demand-responsive transit—were not included. Given the evolving terminology and discrepancies in definitions, researchers used a variety of search terms based on a wide range of standard terminology applied to shared-ride or pooled-ride transportation. The search process resulted in 130 total papers and resources from all over the world; the review included only peer-reviewed journal articles, conference proceedings, and technical reports written in English.

To establish a common understanding of terminology between different shared on-demand mobility services, Table 1 provides definitions that are applicable for these terms throughout the paper; the definitions are culled and summarized from other research papers that used or previously defined these terms within their studies. Some private transportation service products are mentioned to serve as common examples of the type of services; any mention of a particular company is presented as merely an example and is not meant to be interpreted as an endorsement of that product.

The rest of the paper includes a discussion of the research on the factors affecting travel choices, followed by policy and planning strategies for consideration. The paper concludes with review outcomes and recommendations for future work and implementation.

Factors Affecting the Choice of Pooling

The success of pooling in mobility options is dependent on the decisions of individuals to pool or not pool for their trips (*1*). The review identified several factors that drive the choice and adoption of pooled-ride services.

Travel-Related Characteristics

Characteristics about the costs of the travel option and reasons for making the trip are often the basis for travel mode choices. This section identifies findings from research on pooling choices with respect to the trips themselves.

Time and Price. Above other factors, time and price to complete a trip are generally the most important considerations for people's choices in mobility services. A model analysis of stated choice survey data in New York City found that preferences in in-vehicle travel time and willingness to pay can be widely variable between different populations, particularly depending on their perceptions of the level of reliability of the service (*18*). The perception of unreliability for ridesplitting services can come from both uncertain wait times for nonexclusive vehicles and additional waiting time created from new ride requests, which may occur from rerouting vehicles and finding passengers at additional pickup points (*19*).

Social Experience. The existing literature tends to be more focused on factors of cost and time compared to the social experience of sharing rides. Generally, while riders will also weigh the factors related to the social experience in their travel choices, price of service and travel time tend to outweigh factors of the social experience and environmental impacts when considering sharing rides (*18*, *20*). Morris et al. (*20*) surveyed current and former TNC users across the U.S.A. in 2019, finding that the social experiences in pooled or shared rides were very important for some users while not as important for others. The authors emphasized the importance of improving the social experience and highlighting the social positives of sharing while reducing the negatives.

Passengers choosing a pooled ride for an on-demand service typically pay a discounted fare upfront but risk having a longer trip time than they would normally have for a non-pooled ride (*21*). Riders may have greater uncertainty in estimated travel time and on-time arrival from ridesplitting services compared to exclusive services (*22*). Bailey et al. (*23*) conducted an online in 2020 survey including a stated-preference experiment to examine the value of travel time variability in exclusive versus pooled trips. The results of their descriptive analysis indicated a lower likelihood of on-time arrival for pooled trips as well as a greater perception of the uncertainty of time with pooled-ridehailing services. The results of the binary logit models of the stated-preference survey data also indicated increased sensitivity of estimated waiting time for pooled ridehailing compared to exclusive ridehailing (*23*). A 2016 survey of TNC users in U.S. metropolitan areas found that the traditional factors of time and cost were most important to mode choice, while social interactions were of secondary importance (*24*). Interestingly, the study found that "the possibility of having a negative

Table 1. Definitions of Shared- and Pooled-Ride-Related Terms

Mobility term	Definition	Reference(s)
Shared ride	A ride taken by a traveler that is shared with a stranger (or multiple strangers) rather than a companion or previously known person. Shared rides can be taken on any public or private demand-responsive service.	(*2*)
Pooled ride	A ride that is grouped with another ride based on proximity to the current travel route and common travel direction or destination between the rides. Pooled rides typically occur on shared taxicab services, taxi-like services (including TNC-based services), and microtransit services. Pooled-ride services typically use either small passenger vehicles, sport utility vehicles, or minivans to group rides together.	(*4*)
Transportation network company (TNC)	A provider of taxi-like services that offer travelers on-demand access to a ride using a digitally enabled application or platform that connects travelers to drivers using personal vehicles. TNC applications are used by the traveler for booking, making an electronic payment, and rating the driver. Service levels and availability from TNCs can vary by time of day and area depending on when and where drivers log in to the platform. Common examples include DiDi, Lyft, and Uber.	(*1*, *5*)
Ridesharing	A service that groups multiple travelers into a car or van to complete a common trip. Depending on the type of service, ridesharing will add passengers to a private trip with a shared destination with either another passenger or the driver (in the case of carpooling or vanpooling modes). Ridesharing arrangements aim to fill otherwise empty seats in vehicles with an existing travel itinerary that can be utilized by persons traveling in the same direction.	(*1*, *6*)
Ridehailing	A taxicab or taxi-like service, such as Yellow Cab. Traditionally, ridehailing was used for taxicab services only since these vehicles were hailed by pedestrians at the curb signaling to the driver. Ridehailing is sometimes likewise applied to TNCs, even though these services are arranged through a digital platform rather than hailed at the curb. Ridehailing can occur in exclusive-ride or shared-ride services; in the latter case, shared rides will define pickup and drop-off locations through the dynamic software platform.	(*7*–*9*)
Ridesourcing	A service in which ridesourcing providers connect passengers to available drivers using digitally enabled platforms and allow riders to choose between available service products/classes of vehicle, including economy versus premium services, and pooled-ride options. The term is typically applied only to TNCs or microtransit companies (although also to some taxicab services that are not hailed from the curb).	(*6*)
Ridesplitting	Shared rides from on-demand services in which passengers are matched together based on similar trip paths and time windows, and then the passengers divide the cost of the trip. Sometimes, ridesplitting services are also referred to as pooling or taxi-sharing; in all cases, the rides are paired in real time with others traveling along a similar route. Travelers choose to split the ride with the service in exchange for a discounted cost for the trip, although selecting a ridesplitting service does not guarantee that the ride will be shared (i.e., in cases when there is not a suitable match found). In the case of taxi-sharing, spontaneous groups of passengers may be formed through ridehailing and the cost split by the passengers outside of a smartphone application that determines trip rates. Common examples include UberPool, Uber Express Pool, Lyft Line, UberX Share, and Lyft Shared.	(*1*, *6*, *10*–*16*)

(continued)

Table 1. (continued)

Mobility term	Definition	Reference(s)
Microtransit	A technology-enabled demand-responsive transit service, typically using shuttles or vans with dynamic, real-time routing and scheduling. Microtransit by design includes pooling passenger trips together by using pickup and drop-off points at common destinations generated in real time for efficient routing, or sometimes at the direct curb point the passenger is traveling to or from. Early private microtransit services were aimed toward commuting trips and providing service alternatives to public transit, although microtransit has since evolved to be more complementary to public transit by filling service gaps, providing a feeder service, and increasing service quality for marginalized populations. Microtransit operational models can be completely private or use some combination of public and private roles (for vehicles, maintenance, dispatching, or drivers) in a contracted agreement. Common examples include RideCo, Via, Spare, TransLoc, Transdev, and Routematch.	(*1*, *6*, *7*, *14*, *17*)

social interaction is more of a deterrent than the potential of having a positive social interaction is an incentive to using dynamic ridesharing" (*24*).

Trip Purpose. Most of the literature on ridepooling and shared autonomous vehicles (SAVs) agrees that trip purpose is also a factor for riders choosing to pool, which can factor into decisions for commuting, leisure, and other types of trips (*7*). Some studies have found that exclusive-ride products are more popular than shared-ride products such as ridesplitting or microtransit services, particularly for commuter trips or trips with an increased perception of the importance of being on time to the destination. Khaloei et al. (*25*) developed a mixed logit model using data from a stated- and revealed-preference survey conducted in the U.S.A. and found that commuter trips in an autonomous ridehailing environment would likely result in mostly solo ridehailing trips. Abkarian et al. (*26*) studied Chicago's TNC trip data from November 2018 to December 2019 and found that shared rides amounted to 20%–30% of all ridesourcing trips throughout the day (implying that ridesplitting choice was not dependent on trip purpose). A study of Didi Chuxing data from November 2016 found that ridesplitting trips were more frequent on weekdays during the middle of the day rather than during the morning or afternoon peak commuting travel period; meanwhile, ridesplitting on weekends was more prevalent for evening trips (*27*). Conversely, in a survey of UberHop riders in Seattle in 2016, respondents revealed that most used the service as their primary commute mode (*28*). The perceived safety of certain trip purposes can also factor into decisions to pool rides; a descriptive analysis of survey data of households in four California metropolitan regions during the fall of 2018 found that survey participants were more likely to consider pooling options for a commute trip to work or travel to a bar or restaurant, while preferring to ride alone when making a trip home (*1*).

Individual-Related Characteristics

Characteristics about individuals, including their background and socioeconomic status, can be equally or more important in ride choices than trip-related factors. Much of the current research on pooling choices by population type or group of people (such as demographic factors) is focused on survey data of persons employing ridesourcing services. The review identified several factors for individual-related characteristics in decision-making for pooled rides.

Household Income. Consistently, household income is a key factor in ridepooling, with lower-income populations being more likely to choose a ridepooling option. For example, a survey questionnaire of TNC users in China found that over three-quarters of ridesplitting users were from lower household incomes (*13*). A descriptive analysis of survey data of California households in 2018 found that survey participants with incomes less than US$35,000 were more likely to choose a pooled ride (*1*). Studies of shared TNC trip data in Chicago found that census tracts with higher median incomes had lower portions of shared-ride trips (*29*, *30*), while a study of trip-level TNC data in Los Angeles during 2018 found that higher portions of shared trips occurred in dense and lower-income neighborhoods (*31*). Studies using multivariate statistical models (including multivariate integrated choice and latent variable approaches, multinomial probit models, and binary logit models) have found that populations influenced by socioeconomic factors similar to those used to measure transit

need (such as households with lower vehicle ownership, non-white populations, and lower education levels) are more likely to try pooled service products (*7*, *20*, *32*). A separate study using a cluster analysis of TNC trip data in Chicago from 2019 found census tracts with higher income levels and proximity to downtown were negatively correlated with trips selected as pooled rides, while more trips were selected as pooled rides during peak hours or for longer rides (and had higher success in pooling matches) (*33*).

Education and Employment. Research measuring education level and ridepooling is split on whether higher education levels increase or decrease pooled-ride choices. Morris et al. (*34*) developed a probit model using an online survey among TNC travelers in the U.S.A. in 2020 and reported that highly educated populations were one of the key groups deterred from using pooled services through TNCs because of experiencing greater dissatisfaction with longer travel times. Conversely, using a joint revealed-preference stated-preference (RP-SP) model of 2019 online survey data of Austin, Texas, residents, Kang et al. (*35*) found that highly educated populations had a higher propensity to choose shared rides. In the U.S.A., the employment status of travelers can also be an important indicator of whether someone chooses a pooled or exclusive-ride option (*36*). Shaheen et al. (*1*) found that unemployed/retired individuals in California in 2018 were more likely to choose a pooled ride in a discrete choice modeling of survey data. Another study in Chicago used spatial regressive models in predicting the rate of sharing in a census tract and found that census tracts with higher percentages of unemployed persons were more likely to have shared rides occur via TNCs during 2019 (*29*). Conversely, the same analysis of 2019 survey data from Austin using a joint RP-SP model found that individuals who were employed had a higher propensity to choose shared rides (*35*), suggesting that this employment status may matter more for certain cities or be less important compared to other individual factors.

Age. Generally, most research has found that younger populations are more likely to choose pooled-ride options, while older populations are less likely to do so. A review study found that in the U.S.A., younger, unmarried individuals and households that do not own a car choose pooled service products more often than other demographic groups (*36*). Survey questionnaire research from the summer of 2017 in Hangzhou, China, revealed that users of ridesplitting services from TNCs tend to be younger than overall users; three-quarters of respondents were between the ages of 18 to 40, and over one-third of respondents were between 18 and 30 (*13*, *37*). Dean and Kockelman (*29*) found that census tracts with higher percentages of younger persons had higher proportions of shared rides on TNCs in Chicago during 2019. Kang et al.'s (*35*) 2019 Austin survey analysis using a joint RP-SP model found that older adults had a lower propensity to choose pooled rides on TNC services.

Persons With Disabilities. Persons with disabilities may often be deterred from using pooled services (*34*), although choices to share a ride may be dependent on the specific type of disability. For example, survey and focus group research found that persons with disabilities or elderly persons may be deterred from pooled services because of uncertainty about traveling with strangers and lowered personal space resulting from vehicle crowding (*34*, *38*). A descriptive analysis of survey data and focus group research involving persons with visual disabilities found that pooled services from TNCs may increase feelings of safety through being accompanied by other passengers in the case of hostile driver behavior (*39*).

Race and Ethnicity. Most research looking at data on race and ethnicity in ridesourcing tends to show that non-white persons are more likely to choose a ridepool option than non-Hispanic/Latinx white populations. Studies of shared TNC trip data in Chicago from 2019 using advanced statistical models and machine learning techniques to estimate sharing decisions in TNC trips found that census tracts with higher percentages of non-white persons were positively associated with having shared rides occur in those neighborhoods and that the proportion of the white population at the drop-off area was negatively correlated with ridesplitting (*26*, *29*). Meanwhile, the 2019 Austin survey analysis using a joint RP-SP model (*35*) found that non-Hispanic/Latinx whites had a lower propensity to choose pooled rides. An analysis of commuter survey data from 2017 in Dallas, Texas, using multivariate integrated choice and latent variable approaches also found that non-Hispanic whites were less likely to have used pooled services (*7*). Collectively, these findings may indicate that non-Hispanic persons are less willing to share trips with other passengers for on-demand services.

Gender. The literature on ridepooling is not conclusive about tendencies in pooling choices by gender; however, many studies have concluded that women are less likely than men to choose pooled options with strangers for their travel. In an online survey conducted in the U.S.A., Morris et al. (*34*) found that women were one of the key population groups deterred from using pooled services on TNCs. The analysis of survey data of Austin residents

in 2019 using a joint RP-SP model found that women had a lower propensity to choose pooled rides, potentially because of perceptions of personal safety (*35*). Women may have safety concerns about sexual harassment or stalking behavior when riding in a TNC vehicle; this issue is particularly the case for survivors of intimate partner violence (*40*). Research using both descriptive and inferential statistics (including factor analysis and multinomial probit regression models) has found that women are more likely to report feeling unsafe riding with other passengers, may prefer riding with passengers of the same sex, and are more likely to stop using a pooled service after a negative experience (*20*, *24*, *41*). Conversely, Bansal et al. (*42*) developed a binary logit model using population-weighted 2017 survey data in TNC-served areas in the U.S.A. and found that young female TNC users were more likely to take pooled trips than young male users.

Attitudinal and Other Factors

Personal attitudes and behavioral tendencies of riders can also be key contributors to their willingness to share rides. The personality traits of people more open to choosing SAV options may include agreeableness with strangers and extroversion (*43*, *44*). The descriptive analysis of survey data of California households found that factors affecting perceptions of pooled rides include comfort level in sharing rides with strangers and chatting with other passengers, as well as perceptions of positive impacts on the environment (*1*). In addition, personal attitudes and their effects on ride choices can be influenced by the traveler's environment as well. Analyses of online commentary on Twitter and built environment data found factors for increased pooling behavior include feelings of safety, the presence of pedestrian infrastructure, and living in walkable neighborhoods (*29*, *43*).

Discrimination

Research on perceptions of using on-demand services also reveals how drivers or other passengers making a rider feel uncomfortable can be a factor in pooling choices; research using structural equation modeling of survey data of TNC users in the U.S.A. and employing a confirmatory factor analysis model found that discriminatory attitudes can be a strong negative predictor of how travelers choose a service option (*45*). A survey of TNC riders in the U.S.A. found that riders can be deterred from ridesplitting by the possibility of negative social interactions because of personal discriminatory attitudes toward persons from other social classes or racial backgrounds (*24*). Some features in ridesourcing apps provide actionable information about fellow passengers, such as the name of the passengers being matched to the ride on a ridesplitting product, which can then enable a rider to cancel a ride based on a discriminatory tendency (*46*). These product features and availability of information can compound the influence of personal backgrounds and attitudes of riders in making discrimination-based decisions in sharing rides.

Role of Transit

Multiple studies have looked at the correlation between other modes of travel and choices to share rides, with many finding that transit use is a major indicator of whether people are willing to share rides on on-demand services. Regular transit users may be more likely to consider all shared-ride travel options for their trip rather than switch over to exclusive-ride or ridesplitting service products. In the descriptive analysis of 2019 survey data of California metropolitan areas, those who used TNCs at least once a week reported being more likely to consider pooling options from TNCs and engage in more multimodal trips (using a combination of TNCs and public transit to complete a trip) (*1*). A descriptive analysis of survey data of DiDi ridesourcing users in three Mexican cities during 2020 found that frequent use of ridesourcing is positively associated with public transit and privately operated buses, with important factors being safety, driver experience, and estimated travel time (*47*).

Although ridepooling can be less expensive than operating fixed-route transit (particularly in less dense or rural environments) and increase access to bus or rail stations, newer on-demand services may not provide impactful benefits in significantly reducing VMT during peak travel times on a systemwide scale (*48*, *49*); Jaller et al. (*48*) conducted a simulation study for the San Francisco Bay Area, finding that overall VMT was only reduced by 0.2%–0.5% during peak hours, namely because of rideshare mileage incurred when vehicles are without passengers. Even as on-demand services offer the capability to group trips together and reduce some VMT on roadways, they may also potentially take trips away from public transit, thereby increasing overall VMT regardless.

Effects of Automation

The future promises the advent of AVs in mobility options for travelers, including vehicles for TNCs and microtransit. As AVs become a reality, the opportunity to share more trips between travelers will present some of the same, as well as brand new, challenges of overcoming barriers in choices to share rides. In a survey of Frisco, Texas, residents in 2019, most respondents asked

about ridesourcing options on AVs stated that they would prefer to travel with known companions rather than split the cost of the ride with a stranger (*50*). Ridesplitting choices in AVs may involve the same traveler priorities as non-AVs in respect of travel time and trip cost. For instance, Zhang et al. (*51*) employed a paired sample *t*-test and text mining on survey data of residents in Massachusetts and Connecticut and found that respondents were more willing to split rides with more passengers if the cost was lower and there were no large negative impacts on their travel time, regardless of whether the vehicle was automated.

Flexibility and Pricing. Conceptually, SAVs may merge characteristics of current public and private mobility options through increased flexibility in travel choices. SAVs can help facilitate ridesplitting and provide first- or last-mile connections to transit hubs (*52*). For SAVs, factors such as personal space, designated seats, and seating configurations may add complexity to individuals' decisions to take a shared ride (*53*). Automation in ridesourcing and pooling services may also lower passenger fare costs as driver roles are eliminated from the vehicles, thereby making shared rides more attractive for riders that value the price of service more highly in their travel choices (*54*, *55*). If prices for ridesourcing trips substantially drop following the introduction of automation, there may be increased use of exclusive-ridesourcing trips (rather than pooled trips) and a decrease in public transit trips, thereby increasing net VMT and emissions (*25*).

Travel Time. Several studies have examined perceptions of future travel in AVs and how riders may or may not be willing to share travel with a stranger in an AV. In a 2017 survey in the U.S.A., around 62% of Americans reported that they may be willing to share rides with strangers on AVs when no delay accrues to their trip; also, respondents were more willing to share their trip during the middle of the day or at night (essentially nonpeak travel times) (*56*). A survey of Dallas commuters using a generalized heterogeneous data model found that living in an urban area and using non-drive-alone modes for commuting are the strongest indicators of willingness to share rides on AVs (*7*). An online stated-preference study in Germany determined that 90% of travelers would prefer to share a 10-min ride if the discounted price was at least 50% less than an exclusive ride (*57*).

Comfort and Safety. Willingness to share rides in AVs will also be influenced by factors related to riders' perceptions of comfort and safety. Personal space is an important consideration for travelers in their mobility choices and needs to be considered in the discussion on emerging AVs, particularly in the U.S.A. (*58*). For a SAV-pooled service product from a TNC, companies may be less able or less incentivized to vet riders for background information to help ensure safe behavior with other riders in the vehicle (*58*). Moreover, SAVs may increase travelers' fear of other riders without a driver in the vehicle, who often acts as a passive enforcer of social norms and respectable interactions. This element may increase difficulty in establishing trust in a pooling service in an AV to provide a safe and comfortable ride with another passenger, particularly for women; a 2018 analysis using factor-based structural equation models with stated-preference survey data of TNC users in the U.S.A. found that women reported higher safety concerns in potential driverless vehicles (*46*).

Policy Strategies

Setting and implementing policies that encourage ridepooling in shared mobility services is critical for the government at all levels to help increase shared rides and reduce vehicle congestion and emissions. Policy solutions about the capacity of roadways should encourage ridepooling in all vehicles, particularly during peak travel times when transportation systems are strained. Some of these policy types can include expanding high-occupancy vehicle (HOV) and high-occupancy toll (HOT) lanes, using congestion pricing strategies, implementing flexible pricing systems based on vehicle occupancy, and allowing access for ridesplitting trips in bus lanes (*59*, *60*).

Promoting Shared Rides

When developing ridepooling programs and strategies, promotion policies that target dense urban areas, busy roads, and peak-hour travel should be implemented during the early stages (*61*). Governments can work with ridesourcing platforms to promote ridepooling services as an available travel option and adapt appropriate matching windows for riders, particularly in areas with severe traffic congestion (*21*). Points and rewards systems for frequent customers who use pooled services or preferential treatment and pickup times for pooled rides might be additional ways to entice more riders to share vehicles (*20*, *62*). Mobility as a Service (MaaS) platforms can also point out available shared-ride options to riders.

Pricing and Taxing

Because cost is a large factor in decisions about mobility choices, pricing and taxing options for on-demand services can be another key tool to encourage pooled travel. Cities can focus efforts on attracting nonusers, particularly those using SOV travel, to ridesplitting services using pricing and cost saving incentives for positive travel

choice behavior (while being careful to not take away trips from active transportation options) (*63*).

Pricing Incentives. Pricing incentives for shared-ride travel might take the form of lower prices to share a ride or higher prices to take an exclusive ride. Ride-matching platforms can differentiate pricing in matching travelers to the same vehicle by differentiating pricing between riders willing to pay more (through surge pricing) and riders willing to wait longer (in exchange for discounted fares) (*64*). These mechanisms working together can prioritize different riders' needs while encouraging more people to share rides in the same vehicle (*64*).

Restructuring the pricing system for pooled rides to provide larger discounts for rides that take longer than expected can ease rider dissatisfaction with travel delays; pricing discounts for pooled rides may be beneficial despite lower profitability if they succeed in attracting new riders (*20*). Pricing schemes to incentivize pooled travel and encourage ridesplitting in areas that generate high volumes of solo ridesourcing trips may be a better strategy for cities to consider than simple congestion pricing (*32*, *62*). Promotions that offer discounts or free rides for future trips are also incentive options for someone to choose a pooled ride on an on-demand service (*1*).

Taxes and Fees. Increasing fees for exclusive-ridesourcing trips is another option to increase the cost of travel for non-shared rides: New York State, San Francisco, and Chicago currently have surcharges for TNC trips, with differentiations made for pooled versus non-pooled trips (*1*, *62*). These changes can also be tied to time-of-day ranges for peak travel to coincide with congestion reduction goals (*62*). Cities can also lift existing restrictions against pooled rides in taxis and incentivize taxicab companies to adjust pricing for pooled trips (*62*). Even with these pricing incentives for discounted shared rides, traveler choices to choose shared-ride options may only be moderately influenced; Schaller's (*65*) review of TNC trips in New York City during February 2018 found that only 22%–23% of TNC trips were shared, while 60% of private microtransit service trips were shared.

Cities can also provide discounts on fees and taxes to ridesourcing companies that reach certain thresholds for pooled trips (*62*). Policy responses that internalize the external costs of road use into a pricing model aimed at vehicle users will be important to encourage increased ridepooling and shared rides in AVs (*66*).

Ordinances and Prioritization

Governments can implement the needed statutes and ordinances and work with private transportation providers, area employers, and other stakeholders to ensure that ridepooling service options with minimized barriers are available in the community for travelers (*61*). Cities can take steps in their transportation-related ordinances, such as opening street spaces to prioritize shared modes or eliminating minimum parking ordinances to deter SOV trips (*67*). Some studies suggest that solo ridesourcing and ridesplitting services should be treated in public policymaking as distinct services (*31*).

Travel Demand Management

Policymakers can also use tools for managing zoning designations and parking availability to encourage pooled-ride travel. Regional governments can incentivize zoning to encourage ridepooling by integrating provisions within building codes. For example, developers can be permitted to cumulatively reduce required parking in exchange for including travel demand management (TDM) measures, such as pooling parking spaces or hub areas (*68*). Ezike et al. (*59*) proposed policy solutions involving locational priorities of shared mobility vehicles and AVs, which include adapting the street design to accommodate shared modes and ensuring pooled rides benefit all communities.

TDM strategies for ridepooling include reducing the appeal of driving relative to alternative transportation options by restricting parking supply and pricing parking. Parking incentives can include marking maximums, unbundled parking, employee cash-out policies, and demand-responsive parking meters (*69*). TDM programs may also partner with TNCs to offer discounted pooled rides to employees (*68*). However, TDM techniques—aside from increased pricing for SOVs—tend to provide marginal benefits to congestion in growing metropolitan areas (*62*). Improved pricing for parking is also an important step to incentivize increased pooled travel, although it faces a tough challenge for political palatability (*69*).

Commuting Benefits

Policymakers can also consider incentivizing shared-ride options for travel through monetary incentives; implementing either a direct subsidy or pre-tax benefit as an economic incentive for riders to use pooled rides is a potential policy move to consider. Although Congress at the federal level determines which modes are eligible for commuting benefits, state and local governments can take approaches such as enacting tax advantages for participating employers or requiring participation based on the number of employees (*52*, *68*).

Pre-Tax Benefits. Pre-tax benefits are an important mechanism that cities can use to encourage pooled-ride choices. Beginning in 2016, New York City allowed

commuters to allocate pre-tax commuter benefit funds to pay for UberPool rides (*70*). Privately operated microtransit services have been deemed to conform to the Internal Revenue Service transit pass standard, thereby allowing riders to pay for fares with pre-tax commuter benefits (*71*). Increased awareness for riders to potentially apply these benefits toward ridepooling travel options may be an effective policy information measure for consideration.

Parking Cash-Out Programs. Parking cash-out strategies offering a cash allowance equivalent to the cost of parking can discourage employers from providing parking free of charge, thus encouraging other modes of travel for employees' commute to work (*68*). Conversely, employers can charge employees for the cost of providing parking; cities cannot require employers to impose this charge but can tax parking spaces or require parking cash-out programs to be available (*62*).

Partnerships and Flexible Schedules. Partnerships between transportation providers and employers or employer districts can also be a mechanism to improve rates of pooled travel (*4*). Other programs for encouraging ridepooling may include charging employers a reduced rate per ride by employees, offering employee bonuses for using non-SOV travel options, and providing guaranteed ride home programs as a backup transportation option (*72*).

Safety Concerns and Discrimination

Perceptions of safety in sharing rides with strangers present additional barriers to pooled-ride choices; some of these barriers can be overcome with additional product measures, while other types of perceptions by travelers may be too greatly influenced by the discriminatory attitudes of others.

Safety concerns in shared mobility vehicles can be addressed by providing physical barriers between passengers, increased video surveillance, and party-size rules, although these measures may have the subsequent effect of decreasing comfort levels in using ridesourcing services for some riders (*46*). Curbing discrimination based on race or class is another key concern; Middleton (*46*) proposed options such as requiring TNCs to report evidence of discrimination from drivers or other riders. Currently, the Colorado Utilities Commission requires TNCs to report data on driver refusals that occur in Colorado; similar data can be collected on rider match refusals to investigate any discriminatory behavior of riders (*46*).

TNC platforms choose which information is available to each party, including names, photographs, ratings, and vehicle information. Additional anonymity measures may involve eliminating or delaying information until needed to find the vehicle or using passcodes instead of names to confirm identification (*46*). TNCs may also consider policies that allow rating passengers, banning poorly behaving riders, and conducting background checks, although these measures will likely lead to discrimination from rider to rider (*20*, *44*). Governments could work with TNCs on implementing formal codes of conduct between passengers to help reduce friction between riders on pooled services (*44*).

Planning Strategies

Aside from public policy efforts, better transportation and infrastructure planning to encourage the pooling of rides is also suggested as a tool for cities and regional governments to utilize. Land-use policies and parking requirements that support pooled services at transit nodes and key activity centers can be accomplished through revisions of zoning ordinances, development codes, and other land-use regulations (*52*). Transportation planning can also aim to steer SOV users toward ridepooling modes rather than siphon existing public transit users; this step is a challenge given most riders' existing inclinations to share or not share rides (*62*).

Trip Planning

Improving the integration of transit and ridesharing services in common smartphone applications and online platforms, including MaaS platforms, helps give customers additional information needed to plan shared mobility trips and make decisions on pooled-ride options (*73*). Planning tools are available for making connections to high-capacity mass transit and spaces at highway systems for staging ridepool vehicles; cities and metropolitan planning organizations can create fixed pooling points on branch roads, where shared-ride travel requests will have priority over other locations to improve operational efficiency and therefore the rider experience (*61*). Public agencies can also aim to improve the visibility of ridepooling services and ease of use in trip planning and mobility smartphone applications (*22*).

Safety Planning

Some population groups have greater concerns about safety when using ridepooling services, particularly women when using ridesourcing or transit services. Transportation providers can consider allowing riders to share trips only with passengers of the same gender, although the implementation and screening process could be politically problematic. In addition, allowing riders to match to vehicles based on shared interests or ratings might be another mechanism to improve passenger comfort but may encourage rider-to-rider discrimination

(*34*). Other factors for improved safety in ridepooling include surveillance services and emergency/panic buttons to provide additional perceptions of safety and service accessibility for ridesourcing services (*42*).

Curb Management

As on-demand passenger and delivery services continue to proliferate in cities, management of curb areas at high in-demand city blocks or intersections is becoming increasingly important to control congestion and public safety. Both major TNCs in the U.S.A. have tried implementing features to make routing more efficient by directing riders to virtual stops at curb areas and presenting discounted fares for their ridesplitting products (*71*). Operational designs and incentives that encourage passengers to walk or bike to nearby major intersections to be picked up by their ridepooling vehicle can encourage timeliness/attentiveness from passengers (*74*).

Curb management can involve having designated curb areas for on-demand vehicle access, creating flexible curb zones by the time of day, monitoring real-time activity at the curb, offering variable pricing for pooled-trip vehicles, and steering parking demand to encourage pooled travel (*29*, *62*). Dedicated pickup and drop-off locations for on-demand rides in residential and commercial zones can help aggregate demand for pooled-ride services, while dynamic differentiated pricing can help incentivize the use of these designated locations (rather than door-to-door trips) (*1*). Columbus, Ohio, and Washington, DC, are two cities using dynamic curb access management to regulate price, time limits, and user types through technology and data-driven curb enforcement approaches (*75*). Cities can move to have variable pricing for curb access by mode or time of day to reach goals for increased ridepooling, such as charging less for curb access to ridepooled and microtransit vehicles; this step will require technology to confirm vehicle occupancy levels or vehicle service status.

Infrastructure Considerations

Other infrastructure measures can be used to demonstrate the operational effectiveness of ridepooling services and increase travel time reliability. The public sector could give ridepooling services with multiple passengers priority access to existing high-occupancy lanes, signal prioritization, or preferential parking schemes in dense urban areas (*61*, *68*, *74*).

COVID-19 Pandemic

With the emergence of COVID-19 in early 2020, many public transportation and private ridesourcing services reduced seating capacity in vehicles or suspended service temporarily during the initial months of the pandemic to increase protection against contracting the virus. This included the removal of ridesplitting product options by TNCs on their application platforms, thereby preventing shared rides between strangers to occur within on-demand ridehail vehicles (*76*). Some public transit agencies developed and/or partnered with microtransit services to deliver rides for essential trips and medical appointments, functionally offering direct rides for travelers in the vehicles (rather than shared rides as normal); in some cases, passenger limits, such as one or two riders, were set by the transit agency on the technology platform itself (*77*). Other measures, such as prescreening riders to ask questions about potential symptoms or using contract tracing on trips taken by ill passengers, were considered but ultimately not implemented by private mobility companies (*77*).

It is unknown how much the pandemic will decrease pooling choices for individuals over the long term as mobility services recover; some forecasts indicate lasting effects of increased individual vehicle use and lower public transit ridership (*1*). Some travelers who switched from using public transit to traveling alone in a ridehailing service were deterred from taking trips on transit because of experiences with other riders not wearing masks or sitting too close to them (within the designated 6-ft threshold) (*78*). Most ridehailing or microtransit vehicles do not allow for a 6-ft buffer distance between seated passengers, meaning that social distancing between vehicle occupants is not feasible. The inherent risk in travelers who previously chose shared-ride transportation options shifting away from these options in the short term is that they could more permanently alter their travel mode choices in the long term as the risks of COVID-19 subside. Increased telework and shifting of traditional commute patterns could also alter the kinds of trips that are shared in on-demand service options (*76*). Changing mode choices could still occur in the face of studies showing that mask-wearing compliance and high vaccination rates greatly decrease the risk of contracting the virus while sharing rides with other passengers (*78*).

Another uncertainty is to what extent private ridesourcing companies will reinstate pooling or splitting ride options on their platforms because of both safety and profitability concerns. As of July 2022, both major TNCs in the U.S.A. have reintroduced ridesplitting products (called Lyft Shared and UberX Share) on their application platforms in 14 city markets (depending on the company) (*79*, *80*); these services have some key differences to those available from the same companies before the COVID-19 pandemic. Restrictions on the new ridesplitting options include allowing no more than two

passengers per ride, limiting ride requests for a shared ride to single persons, and only pairing riders traveling in the same direction (*79*, *81*). These companies have also adjusted the parameters for pricing incentives and available vehicle supply for ridesplitting compared to before the pandemic. One company provides a discounted fare only if the rider is successfully matched with another rider (previously a discount was provided regardless of the match status) (*82*). Conversely, the other company has made participation in the ridesplitting product optional for drivers on the platform (*83*). The changes in appeal of the service from a pricing incentive standpoint, combined with any previous negative experiences with pooled rides (from either riders or drivers), may make sharing a ride on a TNC a harder sell post-pandemic (*83*, *84*). While press releases state that these ridesplitting products will be launched in additional city markets over time (*79*, *84*), any additional rollout could potentially be halted by the evolving conditions of the pandemic and reduced palatability for sharing rides with strangers (resulting in lower profit margins on ridesplitting for the companies themselves).

Conclusions and Future Directions

Ridepooling trips interest both public organizations and private companies; government agencies see ridepooling as a means to decrease roadway congestion, parking and infrastructure costs, and negative externalities to the environment, while on-demand transportation companies (as well as transit agencies) desire to serve more riders in the same number of vehicles to decrease operational costs. Making ridepooling attractive to travelers is a challenge for population groups who do not already use shared-ride transit or active transportation modes, such as walking or cycling. Some users of ridesourcing services will consider ridesplitting products if the discount is significant compared to an exclusive ride and their trip purpose is less time sensitive.

Age, household income, and racial/ethnic background can be significant indicators of whether someone will consider using a pooled service. Cost and travel time are the most important factors for travelers deciding whether to take a ridepooling service, weighted against the anticipated delay from picking up additional riders. Comfort and safety are secondary factors for choosing a ridepooling service, but may have greater importance for some population segments; some research identified troubling findings of discriminatory attitudes of travelers in sharing vehicles with other riders.

Well-designed policy and planning strategies by governmental agencies and their partners—supported by an in-depth understanding of these services and their role during the pandemic and other emergencies—are essential. Existing policy and planning strategies to encourage ridepooling are mostly focused on either traditional ridepooling options or fees for ridesourcing services in general. Some of these strategies can be updated and adjusted to apply to new on-demand pooling options; examples include differentiating fees and pricing between shared and exclusive rides on ridesourcing services, making HOV/HOT/bus-only lanes available for ridepooling trips, and prioritizing access to curb areas for ridepool and microtransit services (as opposed to exclusive TNCs or SOVs). Promoting ridepooling strategies to make them more visible and appealing in on-demand transportation platforms is an important step toward increasing awareness of shared-ride options. In addition, further study of the pandemic's effect on choices to share rides during and following the COVID-19 pandemic is needed to understand how considerations by travelers have changed as well as what adjustments in service design and incentives are needed to encourage sharing a ride.

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