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Ensuring equitable transportation for the disadvantaged: Paratransit usage by persons with disabilities during the COVID-19 pandemic

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\textbf{ABSTRACT}

Paratransit services developed under the Americans with Disabilities Act are a critical transportation means for persons with disabilities to meet their basic needs, but the COVID-19 pandemic posed an unprecedented challenge to service providers. To safeguard transportation equity, this study used complete records of service trips and riders obtained from the Access Transportation Program in the Seattle region for an empirical analysis aimed at answering two research questions. First, how did the ridership and trip purposes of paratransit change after the outbreak of COVID-19? Second, what factors explained the users’ changing levels of service usage in response to the pandemic? Statistical methods, including a Hurdle model, were employed as the analytical tools. The results show that paratransit ridership dramatically decreased during 2020 with the most substantial reductions of working and non-essential personal trips, and that most of the remaining trips were for medical purposes. The results also indicate that riders’ service usage during the pandemic was associated with their sociodemographic characteristics, disability conditions, and pre-pandemic travel demand. When controlling for other factors, riders who lived in neighborhoods with lower income and lower access to personal vehicles were more dependent on the service. Based on the empirical findings, we recommend that when developing plans for future disruptive events, public transit agencies should promptly implement safety measures, identify and prioritize neighborhoods that are most in need of mobility services, and actively pursue collaboration with other organizations for innovative service delivery options.

1. Introduction

Public transportation is essential for disadvantaged populations, especially those who are mobility challenged due to financial and/or health constraints. The passage of the Americans with Disabilities Act (ADA) by the US Congress in 1990 was the culmination of efforts to ensure a transportation service comparable to fixed-route transit for people with disabilities. Such a service, provided by transit agencies and commonly known as ADA paratransit, is an origin-to-destination service that usually takes the form of reserving a
ride at least one day in advance (Thatcher and Gaffney 1991). The service is provided within a certain distance of fixed-route transit to riders who are eligible, and is often operated by private contractors using small buses or vans (Chia 2008). As the population in the US continues to grow and age, the demand for ADA paratransit is continuously increasing (Citizens Budget Commission 2016).

For people with disabilities, ADA paratransit serves as a critical means for them to perform necessary activities, access socioeconomic opportunities, and maintain social connections (Bascom and Christensen 2017; American Association of People with Disabilities 2016). Paratransit riders are disproportionately from disadvantaged neighborhoods with low incomes and high proportions of elderly persons and African Americans (Deka and Gonzales 2014). Safeguarding the right of people with disabilities is crucial for transportation equity in society. The theoretical literature on transportation equity has applied philosophical reasoning to argue that a fair and just system should prioritize the most disadvantaged population groups by guaranteeing them a minimum standard of accessibility, while closing the mobility gaps between the best-off and worst-off populations (Martens, Golub, and Robinson 2012; Pereira, Schwanen, and Banister 2017). In practice, improving the accessibility of people with disabilities is explicitly valued by transportation planners and public transit providers as part of their social equity goals and measures (Manaugh, Badami, and El-Geneidy 2015; Citizens Budget Commission 2016).

Starting in March 2020, the COVID-19 pandemic caused major changes to the demand for and the supply of ADA paratransit service. For riders, paratransit service continued to function as a ‘safety-net’ to meet their ongoing daily needs and emergent medical needs during the pandemic. However, concerns such as getting infected on the ride prevented many of them, especially those who have chronic underlying health conditions and hence are vulnerable to the virus, from taking a ride and fulfilling their needs. The negative impacts were likely to be more severe for socioeconomically disadvantaged riders who tended to lack transportation alternatives. The demand was further reduced due to constraints such as lock-down orders, the closure of workplaces and stores, and reductions in hospitals’ capacities for regular patients.

For paratransit service providers, the pandemic and the resulting policy mandates such as social distancing and enhanced sanitation requirements, caused significant disruptions. Prior to the pandemic, ADA rides could be shared among riders depending on the vehicles capacity. For example, in King County, Washington, most Access paratransit vehicles normally have an average capacity of 11 riders. But the possibility of transmitting viruses inside the vehicles made it difficult for sharing rides among full-capacity riders, which caused King County Metro (KCM) to reduce the capacity to 3 riders per trip (Ashour et al. 2021). As the service capacity was reduced, the cost per trip increased, and the role of paratransit in safeguarding transportation equity was challenged. The plummeting demand facilitated capacity reduction but forced paratransit providers and operators to furlough and lay-off many employees. For example, KCM in the Seattle region laid off 50 part-time ADA paratransit drivers due to the pandemic (Ashour et al. 2021).

More generally, COVID-19 redefined spatial accessibility. Paratransit riders have limited spatial accessibility, and the pandemic exacerbated their disadvantages. Besides taking fewer trips, paratransit riders may adjust the destinations and travel means of some trips. For example, instead of traveling to large grocery stores, people with disabilities and/or their household members may switch to local stores and pharmacies for daily needs. If there are no stores nearby, they may turn to commercial delivery services with higher costs. Providing basic accessibility for the needs of mobility challenged populations was essential to ensure transportation equity during the COVID-19 pandemic.

For service providers, it is imperative to understand the differential impacts of the pandemic on the ADA paratransit users with varying transportation needs, sociodemographic characteristics, levels of disabilities, and neighborhood built environments. This knowledge can help transit agencies better mitigate the negative impacts of the pandemic by directing limited resources to the population most dependent on paratransit service. In the longer term, such information can support transportation policymaking and urban planning to better prepare for future pandemics and other major disruptions. This paper aims at answering the following questions through examining service provider data obtained from the KCM, the primary transit provider in the Seattle region:

1. How did the ridership and trip purposes of the ADA paratransit service change after the outbreak of the COVID-19 pandemic?
2. At the individual level of paratransit users, what factors explain their changing levels of service usage in response to the pandemic?

1.1. Literature review

Two areas of literature are most pertinent to this research: first, the characteristics of ADA paratransit service and its riders; and second, the impacts of the COVID-19 pandemic on transit agencies and paratransit services.

1.2. ADA paratransit service and its riders

ADA paratransit is an essential component of public transit in the US. People with disabilities face barriers when they travel, due to issues concerning availability and reliability, and access barriers of most transportation modes (Rosenbloom 2007; American Association of People with Disabilities 2016; Brumbaugh 2018). Elderly persons and people with disabilities are more impacted by the reliability issue of transit, because a large proportion of their trips are made for healthcare appointments (Deka 2014b). In addition, a significant portion of people with disabilities are low-income and those who lack support from household members, thus they are more likely to be dependent on public transportation and impacted by its availability, and have greater concerns about transportation costs (Deka 2014b; Friedman and Rizzolo 2016). As a result, they are more likely to be homebound, which significantly affects their quality of life, increases their dependence on others, and excludes them from community and social life (Bascom and Christensen 2017; Friedman and Rizzolo 2016; Stanley et al. 2019). People with disabilities are less likely to own or use a personal vehicle (Rosenbloom...
The COVID-19 pandemic caused severe disruptions to public transit agencies. Studies reported a higher transmission rate for infectious diseases when people are close to each other on public transit (Troko et al. 2011; Edelson and Hyphers 2011). The risk of transmitting COVID-19 is likely to be high because the virus is highly contagious and can live on hard surfaces for days (Musselwhite, Avineri, and Susilo 2020). The resulting health concerns caused many riders to stop riding public transit (Beck and Hensher 2020). Second, paratransit service is costly to operate due to unique requirements such as on-demand scheduling and routing, ADA compliant vehicles and equipment, and driver training for special assistance. The cost of providing paratransit can be as high as $70 per trip in the US, several times higher than the per trip cost of fixed-route transit (Citizens Budget Commission 2016; Goodwill and Carapella 2008; United States Government Accountability Office 2012). The cost has been increasing over the past decades and has taken a disproportionately high percentage in transit agencies’ budgets (Kane, Tomer, and Puentes 2016; Kaufman et al. 2014). Third, to facilitate mobility for persons with disabilities, there are no restrictions on paratransit trip purposes, nor should the transit agency ask about trip purposes. Consequently, the agency serves all kinds of trips but only has information about origin and destination but not explicit trip purpose (Federal Transit Administration 2018). Fourth, while there are severe financial constraints on service provision, opportunities have emerged with the rapid growth of new shared mobility options enabled by advanced mobile information and communications technology. Many agencies have started to explore these new alternatives, including efforts to build partnerships with shared mobility service providers. More research is needed to fully understand the impacts of such partnerships (Kane, Tomer, and Puentes 2016; Miah et al. 2020; Feigenbaum 2019; Mulley and Nelson 2016).

Less attention has been given to the connection between the built environment and paratransit service provision and performance. Several studies have focused on the role of population density in affecting the system performance of paratransit services. Higher density is found to have a positive association with service efficiency, likely because of the proximity effect (Fu, Yang, and Casello Feigenbaum 2019; Mulley and Nelson 2016), but density could also result in more trip delays due to higher congestion (Deka 2014a). However, few researchers have studied the impact of the built environment on riders’ usage of paratransit. Among people with disabilities, those who live in a neighborhood with more convenient access to various destinations may have a lower level of dependency on paratransit.

During the pandemic, public transit agencies faced new challenges and resource constraints. Policy recommendations derived from previous research may no longer be most applicable. Because few prior studies have examined paratransit riders’ travel behavior, it is difficult to anticipate how riders with different characteristics change their demand for paratransit in response to the pandemic.

1.3. Impacts of the pandemic on transit agencies and paratransit

The COVID-19 pandemic caused severe disruptions to public transit agencies. Studies reported a higher transmission rate for infectious diseases when people are close to each other on public transit (Troko et al. 2011; Edelson and Hyphers 2011). The risk of transmitting COVID-19 is likely to be high because the virus is highly contagious and can live on hard surfaces for days (Musselwhite, Avineri, and Susilo 2020). The resulting health concerns caused many riders to stop riding public transit (Beck and Hensher 2020). There were sharp declines in transit ridership in many parts of the world (Beck and Hensher 2020; Gao et al. 2020; Liu, Miller, and Scheff 2020; Ahammad, Chavis, and Jeliani 2020; Arellana, Márquez, and Cantillo 2020). For example, based on the National Transit Database monthly data, the ridership of bus, light rail and heavy rail of all transit agencies in the United States in April 2020 was about 70%, 75%, and 90% lower than the ridership in February 2020, respectively (Federal Transit Administration 2020b).

Additionally, as an effort to slow the transmission of the disease, many cities locked down their non-essential businesses, and many employers implemented work from home policies. The Federal Transit Administration published guidelines that recommended social distancing on public transit (Federal Transit Administration 2020a). While these measures further reduced transit ridership, riders who took public transit during the pandemic were likely performing essential activities (Liu, Miller, and Scheff 2020).

While studies have recognized that people with mobility challenges are disproportionately affected by the adverse impacts of the pandemic (Liu, Miller, and Scheff 2020; Musselwhite, Avineri, and Susilo 2020), few investigated paratransit and its riders during the pandemic. It is known that people with disabilities are at much higher risk of illness due to several factors: 1) the strong associations between disabilities and having chronic underlying conditions, lower socioeconomic status, and higher probability to live in group communities (Turk and McDermott 2020; Boyle et al. 2020); 2) the difficulties for some of them to understand and follow the new protective health routines (Turk and McDermott 2020; Courtenay and Perera 2020; Boyle et al. 2020); 3) difficulties in maintaining social distancing as they often rely on the assistance and care of others (Boyle et al. 2020). Although several reports identified various pandemic-related challenges that were unique to paratransit services and made policy recommendations (Centers for Disease Control 2020; Weiner and Armenta 2020), these recommendations were quite generic. Effective policymaking requires more in-depth research on how paratransit riders changed travel behavior in response to the pandemic and how their mobility rights can be safeguarded. From interviews of 21 people with disabilities in the Bay Area, Cochran reported the interviewees faced more mobility challenges during the pandemic, not only in accessing paratransit services but also in obtaining up-to-date service information (Cochran 2020). However, it is difficult to generalize the findings due to small sample size and potential bias in self-reported information.

1.4. Research design: data source and analytical methods

1.4.1. Access transportation program

This research employs data from Access Transportation Program, the ADA paratransit service provided by KCM in the Seattle
region. Access Transportation offers next-day, origin-to-destination rides for eligible users meeting the following criteria: 1) having disabilities that prevent them from riding the fixed-route transit services; 2) living within $\frac{3}{4}$ of a mile on either side of non-commuter fixed-route bus services; 3) being at least 6 years old (King County Metro, 2020). Eligible riders can request an Access Transportation trip online or by phone and pay the same fare as required for fixed-route transit service. The program plays a vital role in ensuring equitable transit services in the Seattle region. KCM reported that it provided over one million paratransit trips in 2019.

KCM’s Access Transportation Program is a useful case to study the impact of COVID-19 on paratransit users’ travel behavior and agencies’ policy responses. The program is similar to paratransit services in many other large metropolitan regions in the US, and insights from this study may be applicable to other cities. KCM made policy innovations to mitigate the negative impacts of COVID-19. For example, partnering with local food banks, King County used part of the fleet and drivers of Access Transportation to deliver

Fig. 1. Home locations of all Access Transportation riders in the Seattle metropolitan area, February 2020.
groceries to people with disabilities, thereby reducing their need to travel to grocery stores. Studying how these policy innovations helped meet the needs of paratransit users may provide useful information for guiding transit agencies’ policymaking in response to future pandemics and other major disruptions.

Because Access Transportation serves many users and maintains complete records of service trips and riders, a large dataset from before and during the COVID-19 pandemic is available for this study. The dataset has advantages as it consists of actual observations and for all trips made through the program, thus avoiding issues of small sample sizes and response biases.

1.4.2. Data
The data we obtained contained information on 14,534 riders and 1,328,287 trips taken from January 2019 to July 2020. For each trip, the data included origin, destination, scheduled time, and mobility aids needed. The trip data also included all the new service trips, where food or groceries instead of passengers were transported. These trips typically started from a food bank or a grocery store and ended at a rider’s front door. For individual riders, the dataset contained information about their age, gender, ADA eligibility, information, travel preference (e.g., prefer door-to-door or curb-to-curb), as well as location information (e.g., rider’s home location and frequent travel destinations). Fig. 1 visualizes the home locations of riders in the data. The trip data and rider data were linked through a unique ID for each rider. These data together allowed us to investigate how each rider changed paratransit usage during the early months of the pandemic, as well as the underlying contributing factors. The research team obtained IRB approval for using these data.

Like most of passively collected data, the Access Transportation Program data contained limited information about riders’ socioeconomic characteristics, which were not collected by KCM. We collected census block-group-level data from the American Community Survey (ACS) to fill this gap. Additionally, we obtained data from Environmental Planning Agency (EPA)’s Smart Location Database to derive relevant measures of the built environment (Ramsey and Bell 2014). These data helped test two key hypotheses regarding the second question: 1) ADA paratransit riders with low socioeconomic status were more likely to continue to use the service during the pandemic, while riders with higher income and greater access to private vehicles were more likely to use other options; 2) riders living in neighborhoods with adequate retail and services nearby might find it easier to secure daily needs without using the paratransit service. The model results of these block-group variables need to be interpreted with caution to prevent ecological fallacy.

1.5. Methods

We used descriptive statistics and statistical modeling to answer the research questions. The descriptive statistics summarized ridership trends and changes in trip purposes, and then compared the characteristics of riders who stopped using the service versus riders who continued to use it during the early months of the COVID-19 pandemic.

The regression analysis employed the Hurdle model at the level of individual riders. The Hurdle model is a modeling technique to deal with excessive zeros in count data, which in our case represents the many riders no longer making any paratransit trips during the pandemic. It is a two-part model as shown in equation (1). It has a component \( f_{\text{zero}}(0; z, \gamma) \) for zero counts and another component \( f_{\text{count}}(y; x, \beta) \) for positive counts. \( \gamma \) and \( \beta \) are parameters to be estimated. In our case, the \( f_{\text{zero}} \) is a logistic function and the \( f_{\text{count}} \) takes a negative binomial form. The logistic component examines factors affecting whether a pre-existing rider continued to use the service during the pandemic, and for those who did, the negative binomial component investigates factors affecting the number of trips they took. We define ‘pre-existing riders’ as someone who took at least one Access Transportation trip in February (pre-pandemic), and ‘riders who continued to use the service’ as someone who took at least one trip in April (one month after the pandemic became widespread).

\[
\Pr(y; x, z, \beta, \gamma) = \begin{cases} 
  f_{\text{zero}}(0; z, \gamma), & y = 0 \\
  \frac{f_{\text{count}}(y; x, \beta)}{1 - f_{\text{count}}(0; x, \beta)}, & y > 0 
\end{cases}
\]

Table 1 shows the variables included in the Hurdle model and their sources. Many of these variables were directly available from the Access Transportation Program data, while some required extra processing. For example, since the trip purposes were not explicitly recorded, the two related variables, i.e., whether the rider has commuting needs and medical needs, were based on trip purposes inferred by KCM. And we will discuss the inference process in more details in the next section. If the rider preferred door-to-door pick up (as opposed to curb-to-curb pick up), the rider was likely to be more mobility challenged. Hand-to-hand pick up indicated that the rider preferred to be picked up from and dropped off to a caregiver or household member, which implied severe disability. According to KCM’s staff, these two variables serve as good proxies for riders’ levels of disability. The average trip distance was measured by the Euclidean distance between the origin and the destination, as the network distance was not available. In addition, we included a dummy variable that took the value 1 when the riders were believed to have adopted new food and grocery delivery services during the pandemic. Because food and grocery delivery trips did not include user ID in the KCM data, such trips were assigned to an ADA rider by matching the endpoint of the trip to the nearest rider’s home location. We expect the coefficient for this variable to be negative, as riders who got some of their trip purposes fulfilled through delivery may need to take fewer rides.

For riders’ home location, census block-group-level median household income, percent of non-white population, and percent of housing units without vehicles were acquired from ACS 2014-2018 Five Year Estimates. The population density, obtained from EPA, is the gross population density on unprotected land at the census block-group level. Service accessibility and retail accessibility of riders’ home locations, also at the block-group level, were computed using gross employment density (jobs/acre) from EPA. However, to
account for the fact that people tend to access service and retail in nearby areas, for each block group, we calculated the averages of census block groups that intersected with a 1-km (0.6 miles) buffer from riders’ home locations. We log-transformed five variables with severe right-skewed distributions (average trip distance in February, median household income, population density, service accessibility, and retail accessibility). We performed a Variance Inflation Factor test and the results indicated the multicollinearity among variables was not a concern.

2. Results

2.1. Access transportation ridership trends and changes in trip purposes

Fig. 2 shows the ridership trends for Access Transportation from January 1, 2020 to July 15, 2020. The bars in the figure show the daily numbers of COVID-19 cases in King County. The first case of COVID-19 in King County was reported on March 1, 2020. The grey solid line indicates the daily trip counts. The trip counts fluctuate between weekdays and weekends, we therefore calculated the seven-day moving average shown by the dotted line. In comparison, the black longdashed line in Fig. 2 shows the seven-day moving average without including the new delivery service trips.

The figure shows that due to the outbreak of COVID-19, the ridership soon dropped to about one-fourth of the pre-pandemic level. The ridership slowly recovered after April, but by July it was still substantially below the pre-pandemic level. The first spike of COVID-19 cases in King County in March had a strong impact on the ridership, while the impact of the second spike in July was relatively modest. In addition, the new food and delivery service offered by the KCM was quickly adopted in late March, and by July it made up about 25% of the total trips.

ADA trip purposes changed after the outbreak of the pandemic, as shown in Table 2. Analyses were based on KCM data on inferred trip purposes because KCM did not systematically collect trip purpose data. Although inferring trip purpose may not be accurate on certain trips, we believe that collectively, it is adequate to show the overall trends in trip purposes. Paratransit rides in April consisted

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1 Service/retail density = \( \frac{\text{Total number of service (retail) jobs}}{\text{Total unprotected land area}} \) for census block groups that intersect with the 1-km buffer from the riders’ home location. Service (retail) jobs are originally from Census Longitudinal Employer-Household Dynamics data and are classified by EPA using a 5-tier employment classification. Here total unprotected land area refers to total land area in acres that is not protected from development (i.e., not a park or conservation area).

2 The inference for trip purpose was conducted by KCM staff using one of the three methods: 1) matching the trip origin/destination to a location book for common locations in the region (e.g., hospitals, malls); 2) looking up the labels (e.g., ‘work’, ‘my doctor’s’, ‘favorite restaurants’) created by the riders that annotate the origin/destination; 3) looking up the notes taken by KCM staff when booking the trip.
of fewer personal trips (from 24.6% to 15.1%), work trips (from 30% to 4.9%), and adult day care trips (from 17.1% to 0.1%). The shares of school trips and recreational trips also significantly decreased, from 0.9% and 3.8%, respectively, in February to 0% in April. These changes show the disruptive impacts of the pandemic on travel demand, as well as the statewide stay-at-home order that limited non-essential travel and the shutdown of places such as offices, restaurants, and malls. Medical trips, likely considered as essential travel, constituted a disproportionally high share of all trips in April. The purposes for over half of the total trips were unknown because KCM did not have adequate information to infer the purposes for those trips.

Fig. 2 and Table 2 show that some riders continued to rely on the paratransit service to fulfill their travel needs during the
pandemic, while many others stopped using it. We next examined what factors, in addition to the urgency of the trip, explain the changing levels of service usage in response to the pandemic.

2.2. Changes in access transportation rider profiles

Table 3 shows the descriptive statistics for 1439 riders who continued to use ADA paratransit ride service versus 4232 riders who stopped using the service (i.e., who made zero trips in April). Compared to those who remained as active users, riders who stopped using the service skewed towards young (<30 years old) and senior populations (>60 years old). This group included a lower percentage of individuals who indicated medical needs in February, the month before the pandemic, as well as a lower percentage who adopted KCM’s new food and grocery delivery services. Those who stopped riding paratransit on average made fewer but longer trips in February. The two groups were not significantly different in other individual-level variables.

In terms of census block-group-level statistics, riders who stopped using the services were more likely to live in neighborhoods with higher median household income ($82,587 versus $70,722), a smaller share of non-white population (40% versus 44%), and a lower percentage of households without vehicles (10% versus 14%). The median household income and percent of non-white population for King County, WA were $89,418 and 35%, respectively (US Census Bureau 2018). The lower income and higher racial diversity of the residential neighborhoods for Access Transportation users indicate that the service played a critical role in ensuring transportation equity. Riders who stopped using the service on average lived in neighborhoods with lower population density and poorer service and retail accessibility. These results are best interpreted using multi-variate analyses.

2.3. Explanatory factors for ADA ride service usage during the pandemic

We estimated a Hurdle model that takes the number of trips in April as the dependent variable and the variables in Table 3 as explanatory variables. Part I in Table 4 shows the results for the logistic component of the Hurdle model. The positive coefficients in the logistic component indicate a greater likelihood to make any trip using Access Transportation during the pandemic. The absolute values of the coefficients measure the magnitude of changes in the log-odds. Compared to the reference group (riders between 30 and 60 years old), riders who were less than 30 years old or more than 60 years old had lower odds to make any trip, i.e., continue riding paratransit. The odds for these two groups were, respectively, about 60% and 20% lower than those for the reference group. These results suggest that higher percentages of young and senior riders sought alternative means to fulfill their demand or chose not to make the trip, probably due to their concerns of virus exposure on paratransit rides. Other possible explanations may include closures in adult daycare centers in the region during the pandemic, and riders’ family members and/or caregivers no longer being constrained by in-person work schedules, both of which reduced the need to call an Access ride. Compared to male riders, female riders tended to continue to use the ride service. The two variables that served as proxies for different levels of disability, prefer door-to-door and prefer hand-to-hand, showed negative coefficients. The odds for riders who prefer door-to-door were 24% lower than the odds for those who do not, and the odds for the riders who prefer hand-to-hand were 80% lower. These results suggest that riders who faced greater challenges in mobility were more likely to stop using the program, presumably due to concerns of contracting the virus as a result of close contact with others.

Commuting needs were associated with reduced odds of 30%, which could be explained by most employers implementing work from home policy. In contrast, medical needs were associated with much increased odds at 17 times higher, confirming that most medical needs persisted during the pandemic, and riders with such needs continued to rely on Access Transportation to go to hospitals and clinics. Riders with higher numbers of trips in February, which reflected higher demand for ADA paratransit, tended to continue to use the service. In contrast with our hypothesis, adopting delivery services was positively associated with the odds of continuing using the traditional ride service. It may suggest that riders with higher dependency on ride services were more likely to find the new delivery services effective to fulfill certain needs. A 1% increase in housing units without vehicles was associated with a 0.5% decrease in the odds. Both estimates show that riders who lived in socioeconomically disadvantaged neighborhoods were more likely to rely on paratransit service during the pandemic. Finally, although there were noticeable differences in the average population density, retail accessibility, and service accessibility between riders who continued to use the service and riders who stopped using it, none of these variables was statistically significant in the logistic component of the Hurdle model.

Part II in Table 4 shows the negative binomial component of the Hurdle model, which investigates factors affecting the trip counts for riders with non-zero counts. The absolute value of a coefficient represents the difference in the log value of expected trip counts corresponding to one unit change in the independent variable. Compared to riders between 30 and 60 years old, on average riders who were younger than 30 years in age made 1.30 more trips, while riders who were older than 60 made 0.8 fewer trips. Therefore, the number of trips a rider made during the pandemic generally decreased as the rider’s age increased. Riders’ service usage during the pandemic was significantly associated with their characteristics and prior levels of travel demand. For example, riders with commuting needs and medical needs made 1.18 and 2.44 more trips than those without, respectively. Additionally, one more trip made in February was associated with 1.03 more trips in April. Lastly, riders who lived in denser neighborhoods tended to use ADA paratransit less, although this association was only weakly significant.

To test the robustness of the Hurdle model and address the potential issue of spatial autocorrelation, we examined the level of
spatial autocorrelation in the dependent variable. We first generated a binary distance matrix where any two riders whose home locations were within 1 km (0.6 miles) were considered neighbors. Using this spatial matrix, we performed Moran’s I test, which returned a p-value of 0.073, suggesting that we cannot reject null hypothesis (no spatial autocorrelation) at alpha < 0.05, but can reject null hypothesis at alpha = 0.1. In light of this marginally significant p-value, we estimated a spatial lag Hurdle model incorporating a spatially lagged dependent variable on the right-hand side of the model. Appendix 1 in the Supplemental Material shows the

**Table 3**
Characteristics of riders who continued to use the ADA ride service compared to riders who stopped using the service after the beginning of the COVID-19 pandemic.

| Dependent variable | Riders who continued to use ADA ride service | Riders who stopped using the ADA ride service |
|--------------------|---------------------------------------------|---------------------------------------------|
| n                  | mean | s.d. | min | max | n                  | mean | s.d. | min | max |
| Number of trips in April | 1439 | 12.28 | 11.78 | 1.00 | 86.00 | 4232 | 0.00 | 0.00 | 0.00 |
| Gender (Female = 1) | 1439 | 0.61 | 0.49 | 0.00 | 1.00 | 4232 | 0.61 | 0.49 | 0.00 | 1.00 |
| Age: (<30 years old = 1) | 1439 | 0.04 | 0.20 | 0.00 | 1.00 | 4232 | 0.11 | 0.32 | 0.00 | 1.00 |
| Age: (30 – 60 years old = 1) | 1439 | 0.51 | 0.50 | 0.00 | 1.00 | 4232 | 0.42 | 0.49 | 0.00 | 1.00 |
| Age: (>60 years old = 1) | 1439 | 0.45 | 0.50 | 0.00 | 1.00 | 4232 | 0.47 | 0.50 | 0.00 | 1.00 |
| Whether the rider prefers door-to-door pick up (1 = Yes) | 1439 | 0.68 | 0.47 | 0.00 | 1.00 | 4232 | 0.69 | 0.46 | 0.00 | 1.00 |
| Whether the rider prefers hand-to-hand pick up (1 = Yes) | 1439 | 0.07 | 0.25 | 0.00 | 1.00 | 4232 | 0.08 | 0.27 | 0.00 | 1.00 |
| Whether the rider has commuting needs in February (1 = Yes) | 1439 | 0.21 | 0.47 | 0.00 | 1.00 | 4232 | 0.26 | 0.48 | 0.00 | 1.00 |
| Whether the rider has medical needs in February (1 = Yes) | 1439 | 0.26 | 0.48 | 0.00 | 1.00 | 4232 | 0.27 | 0.49 | 0.00 | 1.00 |
| Number of trips in February | 1439 | 18.67 | 14.64 | 1.00 | 94.00 | 4232 | 12.13 | 12.32 | 1.00 | 93.00 |
| Average trip distance (Euclidean) in February (meters) | 1439 | 11,952 | 8373 | 481 | 59,267 | 4232 | 13,528 | 9176 | 11 | 66,661 |
| Whether the clients have adopted delivery service (1 = Yes) | 1439 | 0.21 | 0.41 | 0.00 | 1.00 | 4232 | 0.15 | 0.35 | 0.00 | 1.00 |

| Independent variable: block-group level |
|-----------------------------------------|
| Median household income |
| Percent of non-white population |
| Percent of housing units without vehicles |
| Population density (persons/acre) |
| Service accessibility |
| Retail accessibility |

**Table 4**
Results of Hurdle modeling of paratransit use in King County in 2020 after the outbreak of the pandemic.

| Hurdle Model | Dependent variable: number of Access Transportation trips in April |
|--------------|---------------------------------------------------------------|
| Part I: Logistic | Part II: Negative Binomial |
| **Dependent variable** | **Coef.** | **Std. error** | **Sig.** | **Coef.** | **Std. error** | **Sig.** |
| age < 30 (ref: 30–60 years old) | −0.914 | 0.153 | *** | 0.26 | 0.116 | ** |
| age > 60 (ref: 30–60 years old) | −0.224 | 0.074 | *** | −0.194 | 0.048 | *** |
| female | 0.127 | 0.072 | * | −0.018 | 0.047 | |
| prefer door-to-door | −0.27 | 0.073 | *** | −0.0001 | 0.05 | |
| prefer hand-to-hand | −1.563 | 0.387 | *** | 0.232 | 0.289 | |
| have commuting needs | −0.313 | 0.138 | ** | 0.169 | 0.093 | * |
| have medical needs | 2.926 | 0.164 | *** | 0.894 | 0.058 | *** |
| number of trips in February | 0.035 | 0.003 | *** | 0.032 | 0.002 | *** |
| log (average trip distance in February) | −0.04 | 0.046 | | −0.039 | 0.031 | |
| adopt delivery service | 0.318 | 0.089 | *** | 0.063 | 0.056 | |
| block group: % housing units without vehicles | 1.103 | 0.392 | *** | 0.152 | 0.25 | |
| block group: % non-white | 0.038 | 0.193 | | −0.038 | 0.122 | |
| block group: log (median income) | −0.463 | 0.098 | *** | −0.058 | 0.064 | |
| block group: log (population density) | 0.028 | 0.048 | | −0.057 | 0.031 | * |
| block group: log (retail accessibility) | 0.006 | 0.036 | | −0.033 | 0.024 | |
| block group: log (service accessibility) | 0.027 | 0.042 | | 0.012 | 0.027 | |
| Constant | 3.757 | 1.248 | *** | 2.618 | 0.802 | *** |
| Observations | 5671 | | | | | |
| Log Likelihood | −7,331.50 | | | | | |
| Theta | 2.224*** (0.101) | 14,733 | | | | |

*p < 0.1; **p < 0.05; ***p < 0.01.
comparison of the results between the Hurdle model (Table 4) and the spatial lag model. The coefficients and the significance levels of all variables are highly consistent across both models, which suggests that the effect of spatial autocorrelation is minimal.

3. Discussion and policy recommendations

3.1. Discussion of empirical results

The COVID-19 pandemic dramatically impacted the ADA paratransit service. Using observed data on service trips and riders, our results show how different paratransit riders responded to the pandemic through changing their service usage. Older riders and those with severe mobility challenges tended to stop using the service, which might be a reflection of their concerns over the health risk, their frequent travel destinations being shut down, or having their family members take care of their needs. However, this adjustment means they may need to seek alternatives with higher costs, ask family members or friends for help, or forgo trips and leave some essential needs unmet. It means that riders may not acquire certain employment, education, medical care, and other opportunities, which can profoundly impact their quality of life. On the other hand, a substantial percentage of riders, especially riders with medical needs and riders who lived in neighborhoods with lower car ownership and lower income, continued to use the service. This suggests that the paratransit service served as the ‘safety net’ for riders who must travel during the pandemic but lacked other options.

Adding food and grocery delivery service is an innovative strategy for ADA paratransit operators, which made effective use of available vehicles and drivers to meet the needs of disadvantaged persons while minimizing the risk of contracting COVID-19 through transportation. For riders who were most dependent on paratransit service, the new delivery option appeared to be especially helpful in meeting their daily needs. For transit agencies, this strategy could help reduce layoffs of drivers during major disruptions.

Our analysis does not find a strong significant relationship between built environment characteristics and paratransit usage. One possible explanation is that people with disabilities who lived in amenity-rich neighborhoods have yet to realize the existence of options that could be accessed without using vehicles. This would suggest that in the short run, the more effective effort to ensure equitable transportation for people with disabilities is through a safe, responsive, and adaptive paratransit service. However, in the longer run, if more devastating disruptions occur and severely impair the transportation system, we imagine that proximity to destinations may play a more important role for people facing mobility challenges to meet essential needs.

3.2. Policy implications

The findings discussed above have important policy implications for pandemic recovery and future disruptions. First, estimated model results suggest that safety concerns were prominent in affecting ADA paratransit riders’ response to the pandemic, especially in the early stage and for riders who were most vulnerable to a new virus. We believe that in future disruptions, transit agencies should learn from the experience, promptly develop and implement strict safety measures, and immediately inform riders about such efforts. Secondly, in light of the findings that paratransit served as a ‘safety-net’ for the most disadvantaged, we recommend that transit agencies identify neighborhoods where people with disabilities are most in need of public transportation services and prioritize paratransit services for those neighborhoods. This consideration is critical because often transit agencies’ resources are severely constrained during a major disruption such as the COVID-19 pandemic. Thirdly, as demonstrated by the food and grocery delivery service offered through the partnership between KCM and food banks in the region, new channels for meeting the essential needs can be effectively created through collaborations between transit agencies and other organizations. Transit agencies should consider proactively pursuing collaboration for the purpose of providing innovative services if similar pandemics or other major disruptions occur in the future. Finally, although our model did not indicate statistical significance in built environment variables, urban and transportation planners should consider the role of land use in mitigating the impacts of major disruptions through providing locally accessible services.

4. Limitations

Three limitations should be considered in interpreting the results of this study. First, our paper aims at obtaining timely insights for paratransit operators during the COVID-19 pandemic and relies on the passively collected trip and rider data from the KCM. Our data miss some key socioeconomic information on individual riders, and the consequent use of census block-group-level data as proxies is less than ideal. Second, although our model has made use of almost all the information available in the data, the model may fail to account for endogeneity when making inferences on existing variables in the Hurdle model. Both these gaps can potentially be filled if future research can supplement passive data with a carefully designed comprehensive rider survey. Third, this study is not able to investigate the mode choice between paratransit and alternatives due to data constraints. Future research should combine quantitative and qualitative approaches to gain a deeper understanding of how people with disabilities cope with pandemic-related mobility challenges. In addition, future research will need to explore the paths to the recovery of paratransit service and usage from the pandemic disruptions.

5. Conclusion

The adverse impacts of the COVID-19 pandemic weigh more heavily on people with mobility challenges, especially those with disabilities. This paper analyzed data on ADA paratransit service trips and riders collected by the primary transit agency in the Seattle
region. It generated important insights on ridership trends and changes in trip purposes after the outbreak of the COVID-19 pandemic, as well as factors influencing riders’ changing levels of service usage. We found that the ridership dramatically decreased, and that most of the remaining trips were for medical purposes, whereas the percentages of trips for working and non-essential purposes substantially decreased. We also found that riders’ service usage during a pandemic was associated with their sociodemographic characteristics, disability conditions, and pre-pandemic travel demand. Most importantly, when controlling for other factors, riders who lived in neighborhoods with lower income and lower access to vehicles were more dependent on the service. Public transit agencies and paratransit operators may find these results useful as they develop plans to prepare for future disruptive events.

CRediT authorship contribution statement

Yiyuan Wang: Conceptualization, Methodology, Data curation, Writing – original draft, Writing – review & editing. Qing Shen: Conceptualization, Methodology, Supervision, Writing – original draft, Writing – review & editing. Lamis Abu Ashour: Conceptualization, Data curation, Writing – original draft, Writing – review & editing. Andrew L. Dannenberg: Conceptualization, Supervision, Writing – original draft, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jtra.2022.03.013.

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