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Barriers and opportunities for paratransit users to adopt on-demand micro transit

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ABSTRACT

Paratransit services represent a primary reliable transportation service for older adults and/or persons with disabilities in the U.S., but transformative services like micro-transit, in the form of ride-hailing and other shared services, may offer new mobility options. However, scant research exists on paratransit system riders' barriers and opportunities to adopt on-demand micro-transit service as an alternative mobility option. This study focused on the identification of potential barriers and system benefits for switched users from paratransit to on-demand micro transit. Face to face and telephone interview surveys were conducted with 128 paratransit users in the city of Arlington, Texas to identify potential barriers towards accepting on-demand micro-transit. Secondary data analysis was performed on the city's real-time paratransit database. The survey results showed that 15% of the respondents reported lack of spatial coverage, 13% indicated lack of walking access, and 18% specified difficulty in use as potential barriers in the path of adopting on-demand micro-transit. Although the overall adoption of Via by current paratransit users remains low, the secondary data analysis indicated that riders who are not disabled, without an assistive device, and older (age>54) who have frequent healthcare and discretionary trips are willing to adopt on-demand micro-transit (Via) service. This paper will provide transit authorities a better understanding of the needs of on-demand micro-transit users and the potential benefits of providing micro-transit service.

1. Introduction

Paratransit services provide a mobility option for persons with disabilities and older adults who may not be able to access all of their activities using other transportation modes such as automobile, walking, and fixed-route transit. These services provide flexible scheduling and routing to accommodate the specific needs of transportation disadvantaged populations; however, most of these services require at least a day in advance scheduling.

Demand for paratransit continues to grow in the United States (U.S.). The population aged 65 and older increased 33% from 2006 (37.2 million) to 2016 (49.2 million), and is projected to double by 2060 (98 million) (U.S. Department of Health and Human Services, 2018, pp. 1–20). This growth represents a potential financial and quality of service burden to current and future operations. According to the 1990 Americans with Disabilities Act, paratransit systems represent a crucial strategy for providing mobility to these transportation disadvantaged populations. However, the increasing population leads to continuing annual growth in paratransit system expenses. Many paratransit systems require significant financial outlays to serve large numbers of the population. For example, the New York City paratransit system serves 144,000 customers at $456 million per year, while the Chicago system serves 50,000 subscribers at $137 million per year and the Boston system serves 80,000 subscribers at $75 million per year (Kaufman et al., 2016). San Mateo County, California, provides paratransit service to 8500 registered customers. This service costs more than $18 million a year that represents 12% of the agency's operating cost (Gee & Kersteen-tucker, 2017). These examples demonstrate a range of costs per subscriber for these services and indicate their large operating costs, which appear poised to increase with increasing demand/need.

Many U.S. cities have launched private or public-private partnership (PPP) pilot projects involving on-demand micro-transit service, including Chariot in San Francisco, Bridj in Boston and Washington, and Via in New York City and Arlington, Texas. Micro-transit is a form of

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Demand Responsive Transit (DRT) for shared-used transportation services using dynamically generated routes (KFH, 2018). DRT is a combination of affordable public transit services and personalized (single occupancy) taxi services with flexible routes and schedules (Franckx, 2017). DRT operates a minibus for shared ride transport and responds to passenger demand at flexible pick up and drop off points using optimized routes. It provides curb-to-curb or door-to-door mobility in major metropolitan areas and surrounding suburbs as well as small cities and rural communities to fill the gaps in the fixed route system. It may be viewed as an extension of regular transportation service as many public transportation departments collaborate with private agencies to provide this service as first- and last-mile options for fixed transit systems. Direct trip service of micro-transit could also significantly reduce travel time for transit users who need a transfer to complete a trip (Doug Kaufman, 2018).

On-demand micro-transit provides shared rides to all. Therefore, they can accommodate older adults and riders with a disability. The popularity of micro-transit hinges on its increased mobility over public transit for paratransit users. This is because micro-transit improves the flexibility of current paratransit operations by allowing users to request service in real-time through a smartphone application, which instructs a vehicle to deviate from its current route to pick up the customer. Micro-transit can also possibly reduce more expensive ADA paratransit trips to save agency resources because it is cheaper per trip than paratransit but more expensive per trip than fixed-route transit (Volinski, 2019). Moreover, micro-transit may perform better in lower-density environments and provide a viable alternative to expensive ADA paratransit, while increasing the mobility of the transportation disadvantaged populations currently served by the ADA paratransit.

Future transportation systems should be synchronized between Mobility-on-demand (MOD) such as car sharing, bike sharing, ride-hailing (e.g., Uber and Lyft), micro-transit (e.g., Bridj, Chariot, and Via) and public mass transit (train and bus). MOD will cover low-density areas and first/last mile service gaps while public mass transit will cover high demand corridors (Mahéo et al., 2017; Shen et al., 2018; Stiglic et al., 2018; Yan, Levine, & Zhao, 2019). A Michigan-based survey has shown that mobility-on-demand is strongly preferred by disadvantaged travelers over existing fixed routes due to enhanced transit accessibility to different destinations despite their concerns about the high fare and technological barriers to reserve a ride (Yan, Levine, & Zhao, 2019).

Many cities are using on-demand micro-transit as an alternative mode of transportation for fixed routes during a crisis such as a pandemic. For example, in May 2020, the City of Columbus, OH, launched on-demand micro-transit (Via) in Grove City, OH, to provide further access to jobs, healthcare, and a faster, convenient, and comfortable transit solution during the COVID-19 pandemic. A Los Angeles, CA, micro-transit firm provided point-to-point services as of April 2020 within a specific area to ensure transportation. In April 2020, the Denton County Transportation Authority of Texas expanded its micro-transit to replace fixed-route bus services. In March 2020, the St. Louis, MO, area started to integrate micro-transit with other micro-mobility options. Finally, the Capital District Transportation Authority (CDTA) of Albany, NY, launched FLEX in January 2020 as an on-demand micro-transit pilot to provide curb-to-curb service through flexible routing and scheduling. (*Microtransit - American Public* Transportation *Association*, 2019).

As with innovation for any new mobility service, users may switch from one mode to another and engage in additional previously unserved trips (latent demand). This paper is focused on identifying the barriers to paratransit users adopting micro-transit and quantifying the financial benefits to the system associated with adoption. This study answers the following research questions:

1) Are users of an ADA paratransit system willing to use on-demand micro-transit?
2) What barriers do older adults and persons who are disabled identify for using micro-transit?
3) What are system benefits for converting ADA paratransit trips to on-demand micro-transit trips?

The paper first presents a literature review on the usages of ADA paratransit and on-demand micro-transit. This is followed by a description of the research methodology and survey analysis conducted in Arlington, Texas, to demonstrate the barriers and opportunities that an ADA paratransit system provides. This study introduces two data analytics, a decile and simulation approach in order to identify potential users and system benefits by investigating the trip patterns and profiles of ADA paratransit users. The paper concludes with a summary of key findings and directions for future study.

2. Literature review

The current paratransit system faces three major challenges: rising demand for service, rising costs, and rising competition (National Express Transit, 2018). Paratransit demand continues to increase due to the growth in older adult population and persons who are disabled increasingly leading more active lifestyles. Although paratransit serves just 1–2% of the overall ridership of a city, it uses at least 9% of the total transit operating cost (Comfort, 2017). According to Comfort (2017), the total per passenger cost for ADA service is $45 per trip, which is over ten times more than fixed-route bus service. Volinski (2019) found that the average cost for ADA paratransit was $29.30 in 2010, compared to $8.15 for fixed-route where the micro-transit average cost per trip was $21.70 for a deviated route. These high paratransit costs make agencies eager to find less expensive alternatives such as micro-transit.

Researchers need to understand the potential barriers to micro-transit in order to develop a clear idea about its potential to replace paratransit. Hernandez (2018) notes that in general, the lack of access to a smartphone, the Internet, and credit cards represent potential barriers to micro-transit use for many low-income residents of Los Angeles County, because customers require credit accounts and smartphones to get on-demand micro-transit service. In addition to economic barriers, older adults and persons who are disabled face difficulties in accessing customer service. Several transit agencies launched a pilot project to introduce a micro-transit service to their transit operating area in recent years. However, many of the projects have failed due to their operational or marketing strategies. A pilot project, Bridj, in Kansas City was not successful due to poor marketing. A survey reported that 40% of the residents did not know about the service, and the registered users did not use it regularly because of its limited service area and operating hours (Marshall, 2017). In 2016, Santa Clara County's Valley Transportation Authority (VTA) launched an on-demand micro-transit service, FLEX, to increase first- and last-mile connectivity. It completed 2714 trips with an average of 16 boardings per day in the first three months. The ridership increased to 41 boardings per day when the service area expanded from 3.25 to 5.5 square miles. The customers reported the small service area, no access to nearby light rail, lack of advance scheduling, limited payment options (i.e., for unbanked customers), high operating cost, poor marketing strategies, and inexperienced staff as the main barriers to adopting the service (Westervelt et al., 2018). In addition, the Alameda-Contra Costa Transit (AC Transit) launched on-demand micro-transit in 2015 to improve connectivity, access, and equity between two areas with low population density and transit demand. A pilot implementation with an infrequent headway (45–60 min) did not attract much attention. However, another pilot area showed a significant increase in ridership when the headway was reduced to 30 min (Westervelt et al., 2018). The Sacramento Regional Transit (SacRT) operated on-demand micro-transit in the low-density suburb of Citrus Heights with a traditional dial-a-ride service. An early investigation suggests that the system would not accommodate more than three boardings per hour due to the service's limited real-time response. These previously

identified challenges require a further investigation with a diverse population to ascertain the importance of these barriers.

The performance and efficiency of integrating paratransit service with public transit, taxi, and ride-hailing (Uber, Lyft and Didi) represent important current research issues for Demand Response Transit (DRT). Turmo et al. (2018) developed a model that identified switched trips from paratransit to taxi and total operating cost savings. A model developed by Flora et al. (2008, pp. 1–16) estimates the operating cost for different geometric zoning structures, and Amirgholy and Gonzales (2016) reduced the total cost for a DRT system using schedule management and dynamic pricing strategies. Paratransit scheduling and routing require significant effort to handle the random fluctuation of travel demand, continuous interruption of traffic controls, and unpredictable traffic incidents (Aldaihani & Dessouky, 2003; Fu, 2007a; Shioda et al., 2008; Toth & Vigo, 2008; Xiang et al., 2008; Figliozzi, 2009a, 2009b, pp. 438–447; Karabuk, 2009; Häll & Peterson, 2013; Liu et al., 2014). Reliability, one of the most important paratransit service performance measures, can be enhanced by integrating advanced technology (Hardin et al., 1996; Fu, 2002, 2007b; Chira-Chavala & Venter, 2007) such as automatic vehicle location, telecommunication, and computer systems with the existing service or by improving paratransit operation strategies (e.g., zoning and (de)centralization) (Quadrifoglio et al., 2008; Shen and Quadrifoglio, 2010, 2012a, 2012b; Lu et al., 2014). Dikas and Minis (2018) developed a mathematical formula that shows cost minimization with ensured quality service for taxi and bus service integrated with paratransit. Mo et al. (2018), pp. 1–12 found that paratransit combined with ride-sharing will serve 15% more people if the ridesharing policy provides a 20% discount for 15-min earlier pick-up or later drop-off time. These studies identify many strategies for agencies to use to develop efficiencies in their current operations, but they focus primarily on service quality and efficiency rather than competing transportation alternatives.

No research, to date, investigates paratransit user adoption of on-demand micro-transit. Studies related to micro-transit generally support its success and popularity due to its comfort, creation of routes that match rider demands, and relative affordability. According to a 2018 Eno Foundation report, smartphone technology, cellular data connectivity, and mobile applications have enabled on-demand micro-transit to be more appealing and cheaper than traditional taxi service (Westervelt et al., 2018). Transportation Research Board (TRB) special report 319 suggested that policymakers and regulators integrate innovative shared mobility services into existing transportation systems (Kortum, 2015). In 2016, the Shared-Use Mobility Center (SUMC) reported that the collaboration between shared mobility and paratransit using emerging approaches and technologies will reduce cost, increase service availability, and improve the rider experience (Feigon, 2016). For example, the City of Centennial, Colorado, implemented a pilot collaboration project with a paratransit provider, Via, to provide service for wheelchair users. The study found that the partnership appeared more cost-effective than the previously available options such as ADA paratransit and fixed-route transit (Centennial Innovation Team and Fehr & Peers, 2017). These studies suggest that micro-transit may strengthen the future transportation system by providing mobility options not found in current ADA paratransit services. However, further research must illuminate any barriers that may hinder adoption by the paratransit users. Given that cities across the country are increasingly focused on transportation options that allow older adults and individuals with disabilities to remain independent, mobile, and engaged in the community, this study has important implications for livable communities (AARP, 2015).

3. Research methodology

The current study utilized a paper-based/telephone survey and trip analysis followed by a system benefits estimation (Fig. 1). This study conducted face-to-face and telephone interviews to identify user barriers

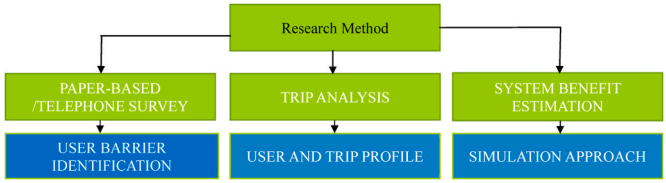


Fig. 1. Methodology overview.

to adopt micro-transit and willingness to switch from paratransit to micro-transit. This study further investigated paratransit user and trip profiles using the city data archive to characterize user sociodemographic profiles while comparing their trips by major trip purpose (i.e., healthcare, mandatory and discretionary trips). Lastly, this study investigated potential system benefits due to the adoption of micro-transit by paratransit users using random samples. This study uses Bootstrap simulation to select random samples. Bootstrap simulation is a computer-based statistical procedure that resamples a single data set to create many simulated samples without any assumptions. Independent resampling with replacement makes the bootstrap simulation a powerful and unbiased method to extract random samples and perform inference analysis (Kleijnen and Deflandre, 2006). The bootstrap simulation requires a few input parameters including sample size (N), iteration (B), and distribution statistics (Θ) to draw N random samples B times based on statistical inference of Θ. In this study, the random samples contain 10%, 20%, and 30% (N) of the total customers in the database for 1000 iterations (B) based on the assumption of normality of the samples (Θ). The statistical software R was used for data pre-processing and analysis.

3.1. Survey

A survey collected information from the paratransit riders to understand the potential barriers that they perceive in using Via. The research team collected 128 responses through face-to-face and telephone-administered surveys in May and June 2018. The team started with rider-intercept oriented face-to-face methods. However, to maximize the sample size, the team administered additional surveys by telephone. The latter proved particularly effective, because many paratransit riders are largely homebound and ride paratransit infrequently, in part due to the challenges that they identified in the survey. As recommended by Dillman et al. (2014), the research team followed a standard protocol for both in-person and telephone survey methods in terms of informing participants about the purpose of the study, asking for informed consent, reading the survey aloud, and recording responses. The participants responded to nine questions including socio-demographics, physical disability, perception about the on-demand micro-transit service, and willingness to use the service.

3.2. Trip analysis

This study analyzed the current paratransit user trip profiles using the City of Arlington database (https://arlington.ecolane.com/login.php) and explored user and trip patterns from ten years of paratransit operations (2009–2018) to understand the longitudinal trends in completed, same day canceled, and no-show trips. Since 2009, the City of Arlington has operated a door-to-door ADA paratransit service, called Handitran, for older adults and persons with disabilities residing within Arlington. The researchers categorized the trips into three categories, including healthcare, mandatory, and discretionary trips, based on the trip purpose (activity) that the users indicated when they requested a trip. Healthcare trips represent medical and special personal trips, and mandatory trips include work and school trips. Using Handitran trip data reported between January 01, 2018, and December 31, 2018, this study divides the Handitran users into deciles based on the total trips where each decile contains approximately a tenth of the total completed

trips. This approach identifies the most frequent service users. The customers represent discrete units, which must belong to a single decile; the total trips in each decile differ slightly, because the research team allocates each customer at a boundary value to the decile containing a greater proportion of their trips.

3.3. System benefit estimation

This study investigates the potential system savings when paratransit users adopt on-demand micro transit for two types of users – randomly chosen users (the random customer sample) and the most frequent users (the targeted customer sample). For the random customer sample, the researchers randomly selected users from the Handitran database (https://arlington.ecolane.com/login.php) based on three different levels of adoption rates, 10%, 20%, and 30%. Therefore, the random samples contain 10%, 20%, or 30% of the total customers in the database. The targeted samples use the most frequent users who can be directly incentivized or marketed to adopt Via. This study uses the same adoption rates to extract the top 10%, 20%, and 30% of frequent users, which correspond to the customers in Decile groups 1, 2, and 3, respectively. This study considers two fleet types for Handitran service, taxi and bus. The City of Arlington currently spends $14.75 for taxi trips and $27 for bus trips. The customers pay $2 for Handitran and $3 for Via, which gives the city/Via $1 profit from the switched customer's payment. Therefore, the study reduces the savings to $13.75 per trip for the taxi fleet and $26 per trip for the bus fleet, without considering any additional costs for incentives, advertising, or subsidies for Via.

4. Study area

This study used data collected in Arlington, Texas, as a case study. The study was approved by a university institutional review board.

Arlington has a unique position in Texas and in the U.S., because it is the largest (population of 398,112) city without public transportation service (Limón, 2019); Arlington currently is the 48th most populous city in the US (Arlington, 2019). Persons with a disability under age 65 and persons 65 years of age and older make up roughly 7.3% and 10% of the total population, respectively (Bureau, 2018).

Handitran allows a personal attendant to accompany a passenger at no additional charge when the passenger requires the attendant. If the passenger, due to a visual or mental impairment, is unable to properly orient and navigate to reach a particular destination, the personal attendant is available to help. If a passenger needs assistance in wheelchair boarding or securement, the driver helps the passenger to safely board and secure all wheelchairs and other assistance devices (Federal Transit Administration (FTA), 2000). Individuals eligible for Handitran must apply for the service with a $10 application fee and, once approved, receive a certificate to use the service. Customers can use the service for a $55 monthly pass or $2 per one-way trip. Handitran operates within the city boundaries Monday to Saturday, and trips can be scheduled up to 14 days in advance. At times, the service has to supplement its buses with taxicabs due to excess demand. This service produces substantial mobility for transportation-disadvantaged populations and helps them complete essential trips for medical and other activities.

On-demand micro-transit includes various services that provide high-occupancy rides using vehicles smaller than traditional buses. Via serves as the case study micro-transit service in the City of Arlington, TX. Other forms of private transit, such as Uber Pool or Lyft Line, also provide ride-splitting service but the private sector may provide these services without a public partner. These services, either micro-transit or private ride-splitting, mostly provide stop-to-stop mobility, which requires a short walk to board a vehicle or to reach the final destination. However, they provide door-to-door rides when requested by a customer. Arlington launched Via on-demand micro-transit in 2017 for all residents to connect community members to key destinations around the city center through a Public-Private Partnership (PPP). Via supplements the ADA paratransit system since ADA paratransit only serves older adults and people with disabilities.

Unlike Handitran, any individual can request the Via service in real-time using either the Via app or a phone for a flat fee per ride. Via does not require riders to meet an age threshold or have a disability. Via currently operates with 10 six-passenger vehicles within limited service areas in central Arlington (see Fig. 2) between 6 a.m. and 9 p.m. weekdays and 9 a.m. and 9 p.m. on Saturdays. Out of the 10 Via vehicles, a few vehicles are wheelchair accessible and provide door-to-door service for people with disabilities at their request. The customers who request a wheelchair accessible vehicle enter a specific code on the Via app when they book a ride. A driver will assist them (e.g. open the door and help riders) with a door-to-door trip (Via Rideshare - City of Arlington, 2018).

Handitran and Via represent the only public vehicle mobility options for Arlington residents. Since the City subsidizes Via through a PPP, adoption of Via by current Handitran users has the potential to reduce the operating costs associated with the Handitran service and provide enhanced flexibility and mobility to the users.

5. User barrier identification survey

5.1. Survey

A survey collected information from the paratransit riders to understand the potential barriers that they perceive in using Via. The survey was conducted with ADA paratransit users only since this study sought to understand paratransit system riders' barriers and opportunities to adopt on-demand micro-transit service as an alternative mobility option. Those who already switched to micro-transit were not our focus, since they are already using the service.

The age of the survey respondents ranged from 17 to 98 and the majority (19.5%) of the respondents were aged 56–65 years old. The majority of people self-identified as White (34.4%), followed by Black (33.6%), Hispanic (8.6%), and Asian (4.7%). The education level varied; the majority (28.9%) had a high school degree or equivalent, followed by less than high school education (23%), and closely followed by college degree (22.7%). Over 28% of respondents were retired at the time of the survey.Table 1 .

5.2. Identification of potential barriers

The research team classified the survey respondents into two groups: (1) 'Favorable or Positive' comprised those currently using Via or expressing interest in using the service; and (2) 'Unfavorable or Negative', which included those who previously had used Via but do not plan to use it again. The team then compared the two groups' perspectives on eight potential barriers to adopting the micro-transit service grouped into three categories: spatial and temporal coverage, financial barriers, and user's overall perception about Via services. The questions about spatial and temporal coverage include (i) whether or not Via operates to the respondent's desired destination (Via Destination), (ii) whether or not Via operates during desired time of travel (Via Schedule), and (iii) users' willingness to walk to or from Via pickup/drop-off locations (Walking Access). The financial barrier category includes (iv) credit card and (v) smartphone ownership, which may represent a barrier to adopt micro-transit service due to its payment and reservation method. A separate survey question response addresses the use of pre-paid credit cards bought with cash. The researchers discuss this topic separately because its role in adopting micro-transit appears less clear. The user perception category includes information about the respondent's opinion on Via's (vi) difficulty to use, (vii) affordability, and (viii) overall safety.

Fig. 3 compares the responses between those individuals currently using or having a favorable perception of Via to those with an

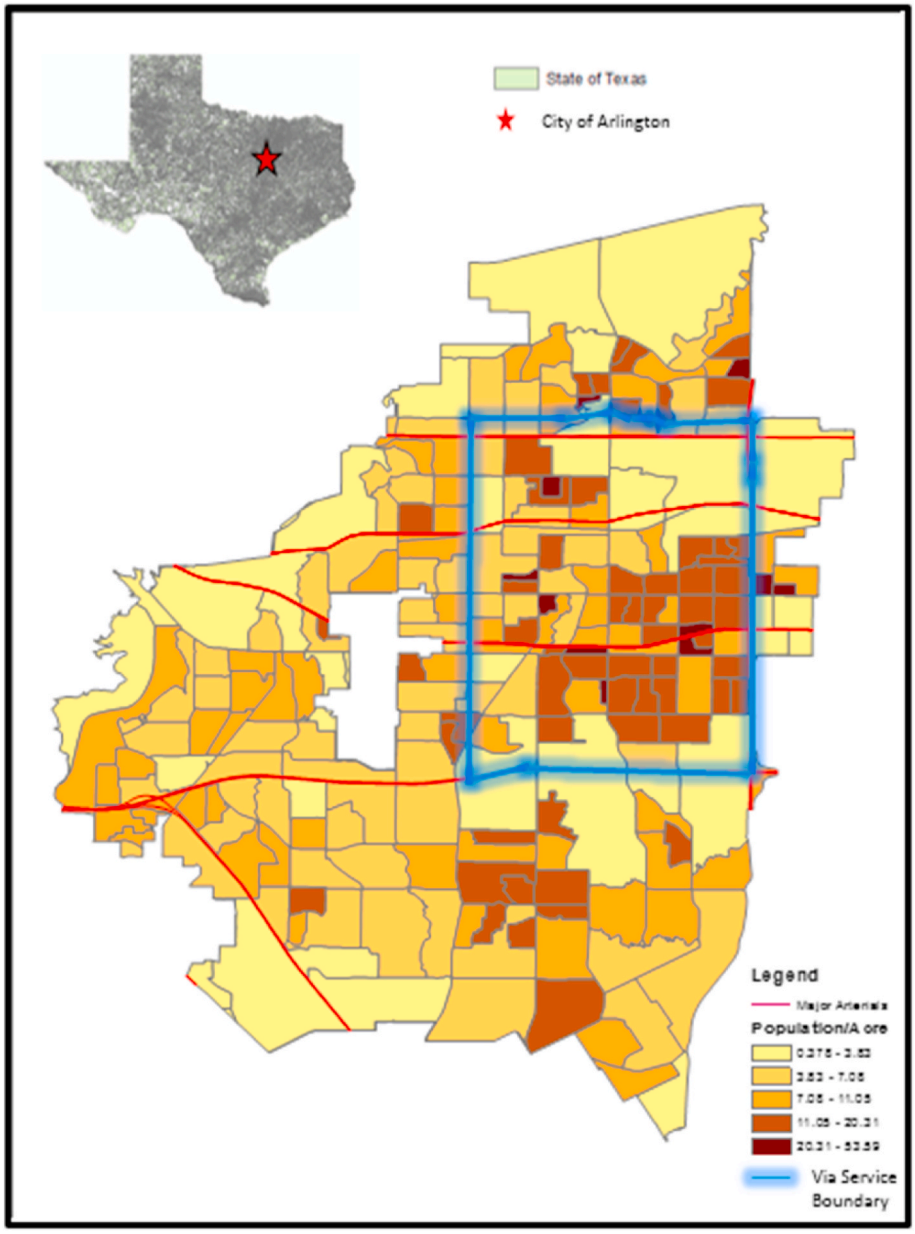


Fig. 2. Study area map.

unfavorable perception of Via. Across both groups, the highest percentage of selections reflected spatial-temporal barriers. Respondents in the 'Favorable or Positive' group reported more barriers to adopting Via, perhaps because they are using the service and are more familiar with it. The most frequently selected barrier was "Walking Distance", selected by 69% of those with a favorable perception of Via. This was followed by "Via Destinations", which 44% of the favorable Via respondents selected. Among those with an unfavorable perception of Via, the highest percentage selected "Difficulty to Use" (18%) followed by "Destinations" (15%). None of the respondents in the 'Unfavorable or Negative' group identified payment/pass barriers.

6. Observed trip patterns analysis and results

The archived data were used to estimate potential system benefits that may occur by switching paratransit users to on-demand micro transit.

6.1. Paratransit user and trip profiles

Paratransit users range in age from 16 to 98 with an average age of 60. As shown in Fig. 4, customers without a disability represent 79% of the users but only account for 70% of the trips. Persons with disabilities appear to use paratransit more than those without a disability, and the former represent 20% of the customers and account for 28% of the total trips. However, persons with visual disabilities appear to use the service less frequently than even the non-disabled population. Users with no assistive device complete a large portion of the trips (71%), while individuals using a wheelchair (14%) or walker (11%) account for most of the trips using assistive devices.

Overall, healthcare trips account for 63% of total trips, while mandatory and discretionary trips account for 15% and 21% of the total

Table 1
Socio-demographic information of the survey respondents.

Variables	Sub-Categories	% (n)
AGE	17–25 Years Old	11.7% (15)
	26–35 Years Old	13.3% (17)
	36–45 Years Old	10.2% (13)
	46–55 Years Old	13.3% (17)
	56–65 Years Old	19.5% (25)
	66–75 Years Old	14.8% (19)
	76 Years and Older	7% (9)
	Missing	10.2% (13)
ETHNICITY	Arab	0.8% (1)
	Asian/Pacific islander	4.7% (6)
	Black	33.6% (43)
	White	34.4% (44)
	Hispanic/Latino	8.6% (11)
	Multi-Racial	2.3% (3)
	Other	2.3% (3)
	Prefer not to answer	13.3% (17)
EDUCATION	Less than high school	18% (23)
	some high school	2.3% (3)
	High school degree or equivalent	28.9% (37)
	Some college	22.7% (29)
	Bachelor's degree	9.4% (12)
	Master's degree	3.9% (5)
	Other	1.6% (2)
	Prefer not to answer	13.3% (17)
EMPLOYMENT	Full time employed	7.8% (10)
	Part-time employed	9.4% (12)
	Out of Work and looking for work	5.5% (7)
	Out of work but not currently looking for work	17.2% (22)
	A homemaker	3.9% (5)
	A student	2.3% (3)
	Retired	28.9% (37)
	Prefer not to answer	25% (32)
PHYSICAL DISABILITY	Present	77.3% (99)
	Not Present	14.1% (18)
	Prefer not to answer	8.6% (11)

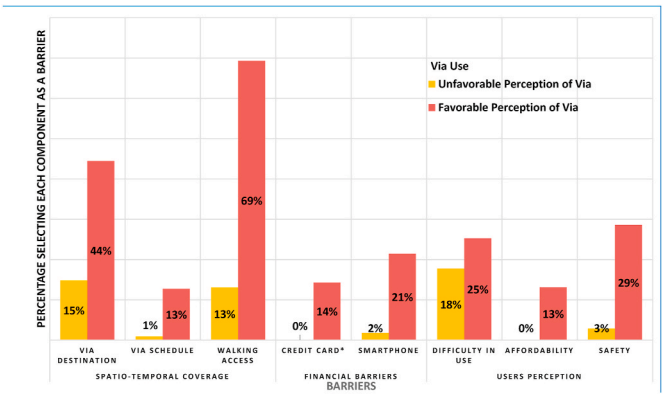


Fig. 3. Comparison of Barriers to Use Via, based on Favorable vs. Unfavorable Perceptions of Via.

* In addition to credit card usage, the prepaid credit card was also considered in the analysis and discussed separately

* Percentages reflect those who agreed with each barrier option on the survey. As such, percentages may not add up to 100%

trips, as shown in Fig. 5. Overall, older adults (age 65 or over) represent the primary customers of the service, followed by 55–64 and 45–54 age groups (Fig. 5(a)). Trip patterns by age group for each trip type (Fig. 5(b) to 5(d)) indicate that respondents with a disability account for a far greater share of mandatory trips compared to older adults, perhaps because they are more likely to have employment or education activities. Adults 65 and older, and adults, ages 55–64, heavily rely on paratransit for healthcare activities, which may explain the shift in health needs across the age profiles. The discretionary trip distribution by age group largely follows the overall distribution.

Since Handitran started its operation in 2009, the percentage of completed trips declined gradually while the percentage of same-day canceled trips increased (Fig. 6). The 10-year average same-day canceled trip rate may exceed the completed trip rate in the future. No-show trips represent only 2.92% of the total scheduled trips with an average of 1307 annually. On average, same day canceled trips occur almost 11 times more frequently than no-show trips.

6.2. Trip analysis

Table 2 shows the number of customers, median and total trips in each decile group. The research team compares the total number of trips by trip purposes and status to identify trip patterns or behaviors by user groups. Decile groups of D1 to D9 contain 90% of the total trips, but include only about 35% of the total 567 customers. The most frequent

Table 2
Equal trip decile approach.

Decile Group	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10
No. of Customers	5	8	9	11	14	19	27	41	68	365
Median trip per customer	455	322	284	226	190	135	99	62	37	4
Standard dev. of trips	59.2	43.5	17.6	13.2	13.4	13.7	10.1	9.6	6.8	6.8
Total Healthcare Trips	524	1497	1552	1366	1054	1637	1918	2117	1982	2092
Total Mandatory Trips	990	759	128	497	771	259	88	175	74	140
Total Discretionary Trips	916	468	810	675	784	680	608	350	525	358
Total Completed Trips	2430 (84.0%)	2724 (80.9%)	2490 (85.9%)	2538 (77.0%)	2609 (81.8%)	2576 (71.8%)	2614 (76.3%)	2642 (71.2%)	2581 (70.1%)	2590 (63.8%)
Same Day Cancelled Trips	403 (13.9%)	439 (13.0%)	178 (6.1%)	539 (16.4%)	439 (13.8%)	661 (18.4%)	469 (13.7%)	729 (19.6%)	778 (21.1%)	895 (22.0%)
Total No Show Trips	60 (2.1%)	206 (6.1%)	230 (7.9%)	219 (6.6%)	141 (4.4%)	353 (9.8%)	342 (10.0%)	340 (9.2%)	325 (8.8%)	574 (14.1%)
Same Day Canceled trips per customer	80.6	54.9	19.8	49.0	31.4	34.8	17.4	17.8	11.4	2.5
No show trips per customer	12.0	25.8	25.6	19.9	10.1	18.6	12.7	8.3	4.8	1.6

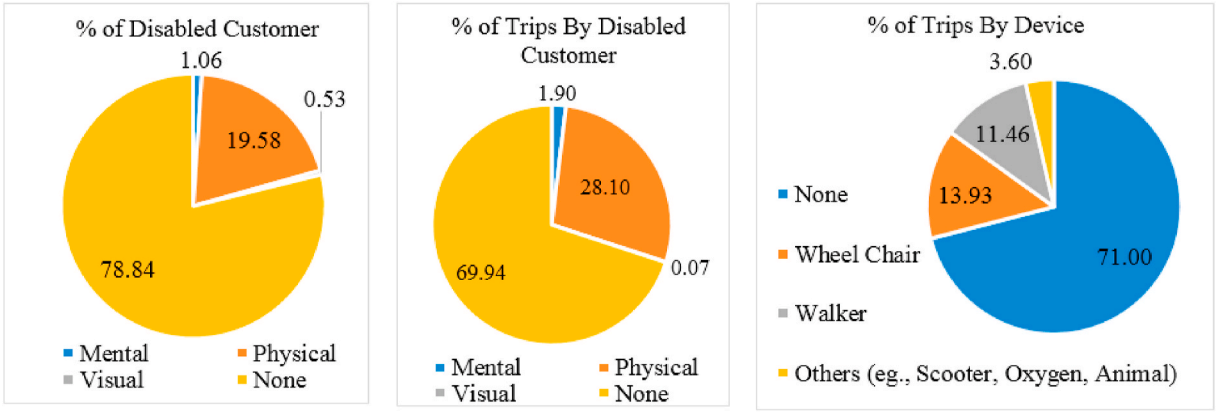


Fig. 4. User Profiles of Paratransit users.

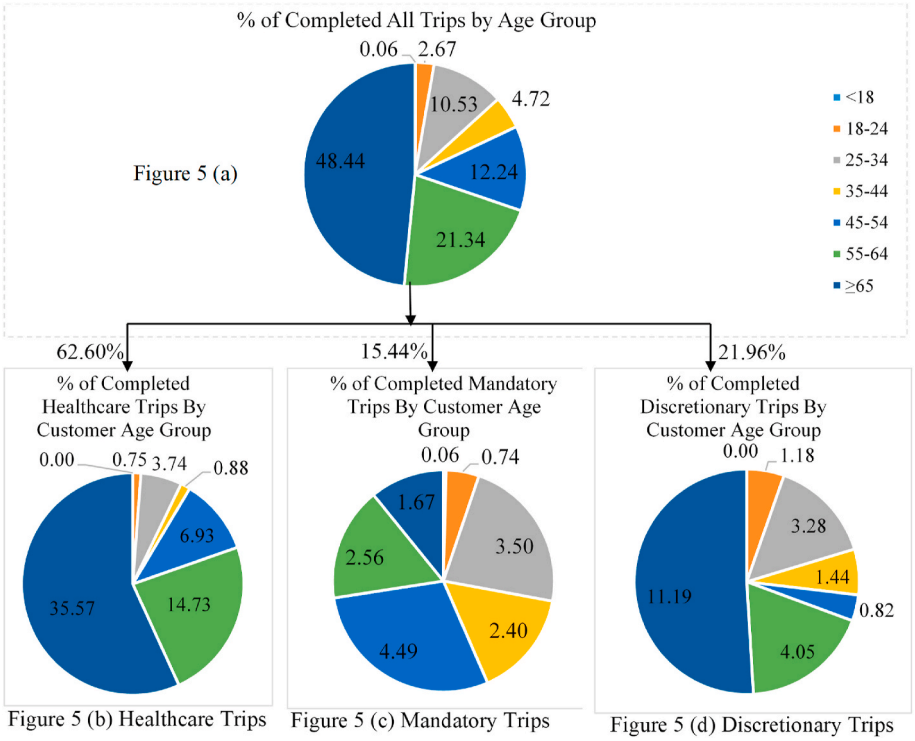


Fig. 5. Trip Profiles of Paratransit Users: Percentage of a) Completed Trips by Age Group, b) Healthcare Trips by Age Group, c) Mandatory Trips by Age Group, c) Discretionary Trips by Age Group.

users complete more mandatory and discretionary trips while less frequent users complete more healthcare trips. The first decile (D1) contains the largest number and highest frequency of mandatory trips, which indicates that these five customers likely have jobs. For the other deciles (D2-D10) healthcare trips account for at least 40% of the trips, which shows the important role this service plays in meeting most customers' basic needs. The users in decile groups 1 to 6, who complete over 100 trips per year, show high same-day cancellation rates, which, range from 31 to 81 trips per customer (except D3). The same-day cancellation rate likely relates to a local policy that allows customers to cancel trips on short notice during the day of commute even when their vehicle is en route. An examination of the user database confirms that many customers who use the service for regular trips such as work or volunteer trips tend to request multiple departures and return trips about every 15–30 min around their expected departure and return time and cancel the overbooked trips right before their actual ride. High-frequency users also produce a higher no-show rate. The third decile group (D3) shows noticeably higher completed and lower canceled trips (6.1%), which may correspond with their low number of mandatory trips, which makes overbooking service more challenging. Canceled and no-show trips place additional cost burdens on City operations and require more careful studies in the future to calculate the exact cost burden of different no-show and cancellation events and to identify the time before service that the cancellations occur.

6.3. *System savings for converting paratransit trips (Handitran) to on-demand micro-transit (via)*

Fig. 7 compares the annual cost savings from the targeted and random customer scenarios with all trips completely served by either

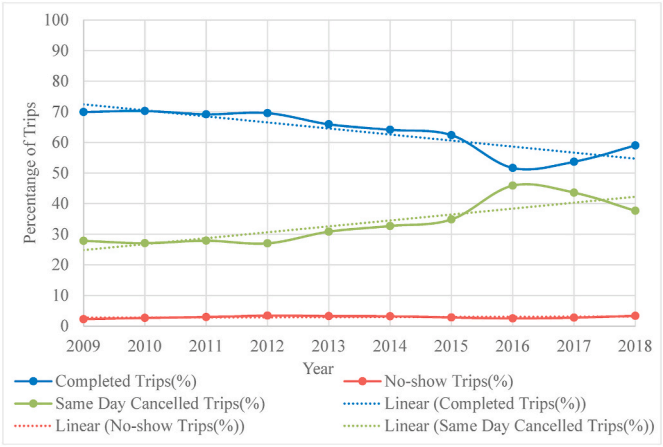


Fig. 6. Trip Status variation from 2009 to 2018.

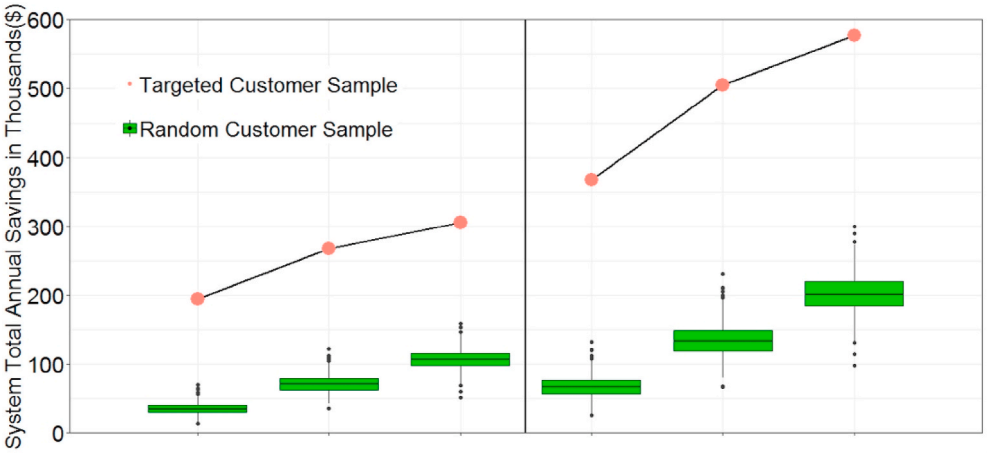
taxi or bus fleets. Targeted customers see much higher rates of paratransit trip reduction. The system can save annually $35,069 to $106,459 from random customers and $194,191 to $304,948 from targeted customers if the paratransit system previously used a taxi fleet. In the case of a bus fleet, the system may save $66,313 to $201,305, and $376,198 to $576,628 for random and targeted customers, respectively. The cost savings increases with higher proportions of adopters for both random and targeted samples; however, the targeted samples achieve much higher savings.

The results from these six scenarios indicate that the knowledge of users and their trip profiles benefit the decision-makers when they develop strategies for system adoption. Without any prior information about users and their trip patterns, a city can only rely on randomly attracting micro-transit adopters; however, targeting high-frequency users may allow the paratransit service to realize three to five times more savings.

7. Conclusion and discussion

This study identifies several barriers to adopting on-demand micro-transit. Difficulties accessing and using the system represent a significant barrier to on-demand micro-transit adoption. The user perceptions category (i.e. difficulty to use, affordability, and overall safety) suggests that the Via destinations may not be well-matched to the needs of older adults and persons with disabilities. Expanding the Via service area may encourage more riders to switch from paratransit to micro-transit. For example, Via service should expand to cover all major health care services, as well as grocery stores, as prior research indicates that these are important destinations to older adults (Fields et al., 2019). In addition, the Via operating schedule may be incongruent with the needs of older adults and persons who are disabled. Similarly, the restricted hours of paratransit services may diminish older adults' activities and linkages to the community (e.g. leisure, social, civic participation) (Parekh et al., 2016). Furthermore, walking to and/or from the Via pick up and drop off location may represent a significant challenge for older adults and persons with disabilities who experience difficulties with mobility (e.g. require a walker, wheelchair, or other assistive devices). Finally, previous research suggests that older adults with disabilities may be concerned about their safety, especially when traveling alone (Fields et al., 2019). Thus, walking to/and from the pick-up and drop off locations may pose safety concerns that hinder the use of Via for some ADA paratransit riders. While the on-demand micro-transit service may be more flexible and provide better travel times, ADA paratransit users still require the service to meet their aforementioned needs for them to switch travel modes.

Overall, though, this study's results indicate a need for greater research into potential financial barriers (i.e. credit card and smartphone ownership). The survey results show that 'Favorable or Positive' respondents cited financial components as barriers, but not those with an 'Unfavorable or Negative' view of Via. The result may be due to the latter respondents' lack of familiarity with Via because they have not used the service. Among those having used the system, it appears that



Fleet Types		Taxi			Bus		
Cost Savings per trips		$13.75			$26.00		
% of customer Sample		10%	20%	30%	10%	20%	30%
# of trips	T*	14,123	19,437	22,178	14,123	19,437	22,178
	R*	2,551	5,147	7,743	2,551	5,147	7,743
Total Savings	T*	$194,191	$267,259	$304,948	$367,198	$505,362	$576,628
	R*	$35,069	$70,764	$106,459	$66,313	$133,809	$201,305

Fig. 7. Minimum/maximum system annual savings due to switch trips from paratransit to on-demand micro transit (via). * T = Targeted Sample, R = Random Sample.

the payment systems may be a barrier for ADA paratransit users to adopt micro-transit service. Indeed, ADA paratransit riders tend to be lower-income, in addition to being older and/or with a disability, which suggests that they may face challenges with using the smartphone and credit card payment system that Via requires (Sion et al., 2016). Cities hoping to encourage paratransit riders to move to micro-transit services may realize greater success if they offer alternative payment options (e.g.cash or voucher). Additionally, some potential riders may have credit cards but require assistance linking their payment choice to the app. Travel navigators could be employed to assist first-time riders with setting up the payment process and explaining the safety of the online payment system.

An ADA paratransit service may realize substantial operating cost savings by encouraging its users to adopt alternative transportation modes that could provide more flexibility and mobility. This process of incentivizing Via may require special services to reduce financial barriers and to increase affordability. The on-demand micro-transit system's service area and operating policies should be developed through engagement with the ADA paratransit users to verify that their needs are sufficiently addressed. For this case study, the ADA paratransit system serves far fewer customers than the large paratransit services in New York City, Boston, and Chicago, but Arlington's Handitran service could still realize cost savings of $200,000 to $600,000 by targeting the most frequent users for conversion.

8. Limitations and future research

This study lacks access to the user profiles for the micro on-demand transit service to compare them with the ADA paratransit user profiles. This study also lacks a mode choice or adoption rate model to quantify the uptake of the new mode by current paratransit users, which represents an important topic for future study. The lack of these models requires the researchers to assume that all trips for a given user will switch to the new mode when many users may opt for a mix of both modes. Topics for future research may be, identification of potential customers for newly emerged on-demand micro-transit, how paratransit is different from micro-transit in addressing the technology knowledge gap/digital divide among customers, potential decision factors of micro-transit acceptance in urban areas with fixed-route transit, the influence of population density, employment and local route infrastructure on the performance of paratransit and micro-transit in different geographic areas, and the environmental impacts of micro-transit over public transit.

While the adoption of micro-transit by current ADA paratransit users shows the potential for significant cost savings, this study also identifies several new areas of investigation to provide stronger estimates of the cost savings. The barriers to micro-transit adoption should be specifically addressed using a mixed-methods (e.g., qualitative and quantitative data collection) strategy to capture the needs of the different types (e.g. older adults, visually impaired, physical disability, very low income) of ADA paratransit users, as well as how technology and financial barriers can be mitigated most effectively. Additionally, mixed methods could help to explain how some riders come to switch from paratransit to micro-transit, and why other riders, with similar demographics, are less willing to do so. As previously discussed, the different types of cancellations and no-shows, and their related costs to the agency and other users, require more investigation. Removing these costs from the system may improve customer service and efficiency, and produce additional cost savings not included in this study. A comprehensive study on costs should try to include any marketing and/or incentive costs and the cost per trip for the on-demand micro-transit (if it receives a subsidy). Finally, expanding this investigation to other paratransit systems may provide a more complete picture of the potential cost savings for different sizes of agencies.

CRediT author statement

Miah: Conceptualization, Methodology, data curation and analysis, writing - original draft, Naz: Survey data curation, writing- original draft. Hyun: Conceptualization, validation, resources, writing - review & editing, supervision, project administration, funding acquisition, investigation. Mattingly: Conceptualization, validation, resources, writing review & editing, supervision, project administration, funding acquisition, investigation. Cronley: Survey, writing - review & editing and funding acquisition, Fields: Survey, review & editing and funding acquisition.

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