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Mobility-on-demand versus fixed-route transit systems: An evaluation of traveler preferences in low-income communities

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A R T I C L E I N F O

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A B S T R A C T

Emerging transportation technologies such as ridesourcing services (i.e. Uber, Lyft, and Via) are disrupting the transportation sector and transforming public transit. Some transit observers envision future public transit to be integrated systems with fixed-route services running along major corridors and ridesourcing servicing lower-density areas. A switch from a conventional fixed-route service model to this kind of integrated Mobility-on-Demand (MOD) transit system, however, may elicit varied responses from residents. This paper evaluates traveler preferences for a proposed integrated MOD transit system versus the existing fixed-route system, with a particular focus on disadvantaged travelers. We conducted a survey in two low-income localities, namely, Detroit and Ypsilanti, Michigan. A majority of survey respondents preferred a MOD transit system over a fixed-route one. Results of ordered logit models revealed a stronger preference for MOD transit among males, college graduates, and individuals who currently receive inferior transit services and have used Uber/Lyft before. By contrast, preferences varied little by age, income, race, or disability status. Survey results further imply that low technology self-efficacy can be a more serious barrier for many people to adopt MOD transit than lacking access to bank accounts, smartphones, or the internet. The most important benefit of MOD transit perceived by respondents is enhanced accessibility to destinations, whereas their major concerns include the need to actively request rides, possible transit-fare increases, and potential technological failures. Addressing the concerns of female riders and accommodating the needs of less technology-proficient individuals should be priorities for transit agencies that are considering MOD initiatives.

1. Introduction

When designing their transit systems, transit agencies need to carefully balance two competing goals—ridership and coverage (Walker, 2012). To maximize ridership under a fixed budget, an agency would avoid providing transit services to places where the demand is low; however, to ensure equitable geographic coverage and especially to accommodate the travel needs of transit-dependent

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populations, almost every transit operator has to make such efficiency sacrifices to some degree. More generally, the trade-off between the two competing goals results in the first- and last-mile problem of public transit, which refers to transit's inability to deliver travelers all the way from their point of origin to their destination.

The emergence of ridesourcing services (e.g., Uber, Lyft, and Via) has inspired many transit operators to incorporate these alternatives into their service suite to address these challenges. Ridesourcing can enhance public transit in several ways, such as expanding services to low-density areas or providing convenient last-mile connections to transit stops. Recognizing this potential, many transit providers have forged partnerships with transportation network companies (e.g., Lyft and Uber) to develop Mobility-on-Demand (MOD) initiatives (Schwieterman et al., 2018; Feigon and Murphy, 2016). MOD refers to an integrated and connected multi-modal network with a variety of public and private travel options that serve travelers on an as-needed basis. Some pilot projects, such as those funded by the U.S. Department of Transportation's MOD Sandbox Program, have been deployed across the United States to examine if MOD initiatives can help enhance last-mile transit connections, reduce operating costs, improve service availability, and elevate rider experiences.

Success in these initiatives would encourage transit operators to scale up efforts to embrace MOD, opening up the possibility of designing future transit systems that fully integrate ridesourcing with conventional public transit.[1] In fact, many transit observers envision future transit systems to be integrated ridesourcing and conventional mass transit systems (to be termed as MOD transit systems or MOD transit for the rest of the paper). MOD transit features the synchronization of the two types of services, with large-volume mass transit (trains and buses) efficiently servicing high-demand corridors while on-demand ridesourcing services covering low-density areas and filling first- and last-mile service gaps (Mahéo et al., 2017; Stiglic et al., 2018; Yan et al., 2019; Shen et al., 2018).

While a MOD transit system is conceptually appealing and technologically feasible, the existing knowledge regarding the traveler preferences for it is limited. When considering a switch from a predominantly fixed-route system to a MOD transit system, transit operators need to assess community support beforehand. Since public transit is often charged with equity goals, it is especially important to pay special attention to the travel needs and preferences of transportation-disadvantaged populations. This paper aims to advance research in this area by investigating public preferences for a MOD transit system versus a fixed-route transit system, with a particular focus on transportation-disadvantaged populations. We follow the U.S. federal agencies to define transportation-disadvantaged populations as older adults, people from low-income households, and individuals with a disability (U.S. General Accounting Office, 2012; Zhao et al., 2013). Since a truly integrated MOD transit system does not exist yet, our research approach involves conducting a stated-preference survey among residents, in selected neighborhoods of two low-income localities in Michigan—the City of Detroit and the Ypsilanti area (Ypsilanti Township and the City of Ypsilanti).

We seek to answer three questions: Do residents of low-income communities prefer a MOD transit system over a fixed-route system? What factors (e.g., the socioeconomic and demographic characteristics of a respondent, the transit services they receive currently, and their use and perception of public transit and ridesourcing services) shape their preferences? What are the potential benefits associated with MOD transit services that individuals perceive, and what concerns do they have? Answering these questions can help transit agencies assess overall community support for MOD, identify the primary customer base for it and the benefits they receive, identify potential geographic areas for pilot deployment, and learn who might be left out by MOD transit services and the obstacles that these people face.

The remainder of this paper is organized as follows. The next section provides more background information on the concept of MOD transit systems and reviews relevant literature. Section 3 describes the data and methodology, and Section 4 presents and interprets the survey results and statistical model outputs. Section 5 applies findings to policy and discusses the limitations of this study. Section 6 concludes.

2. The rise of Mobility-on-Demand, public transit, and traveler preferences

2.1. Emerging transportation technologies and the transformation of public transit

The rapid rise of ridesourcing services in recent years is disrupting the transportation sector and changing how people travel. Powered by the advances in information and communication technology, ridesourcing serves travelers on demand and in real time, providing consumers with convenience, flexibility, and cost-savings. While some concern that these privately-operated ridesourcing services threaten public transit as they may siphon off transit users who have better ability to pay, others see a potential for ridesourcing to complement public transit (Shaheen and Chan, 2016; Clewlow and Mishra, 2017). Recently, many transit agencies in the U. S. have partnered with private ridesourcing providers (e.g., Uber, Lyft, and Via) to develop MOD initiatives (Schwieterman et al., 2018). These initiatives include providing subsidized Uber or Lyft rides to transit stops, replacing low-ridership fixed-route services with ridesourcing, experimenting ridesourcing as a new form of "paratransit" services for aged and disabled individuals, and expanding ridesourcing services (often called microtransit) to underserved areas.

[1] Since MOD initiatives are very recent, to our knowledge, there is not yet a comprehensive analysis of their performance. After reading some online newspaper articles and several published reports and interviewing eleven transit professionals, we found that the performance outcomes (in terms of usage and user experience) are somewhat mixed (Schwieterman et al., 2018). Some pilots are deemed to be successful, such as the Pinellas Suncoast Transit Authority's Direct Connect program and Innisfil, Ontario, Canada's Innisfil Transit project. One example of a "failed" experiment is the Bridj/Kansas City microtransit program, which ended after six months due to extremely low ridership. Since little research has been done to evaluate these projects, the main reasons behind the success or failure of MOD transit initiatives are still unclear.

Parallel to the growth of MOD pilots is the increasing popularity of the Mobility-as-a-Service (MaaS) concept, which visions a full integration of various mobility options into a single digital platform that enables users to make customized and multimodal travel decisions. MaaS would be made feasible by the use of information and communication technologies and the coordination of different travel modes provided by various mobility-service providers, both private and public. As the MaaS phenomenon gains momentum across the globe (primarily in Europe at present), it is likely to greatly transform the role of public transit, both in terms of its operating model and the type of services it provides to travelers (Hensher, 2017; Mulley and Kronsell, 2018). At one extreme, traditional fixed-route transit services may be replaced by privately-operated mobility services in all places except the highest-demand corridors; at the other, public transit agencies become the single MaaS provider that operates a variety of shared modes, which may include fixed-route mass transit (rail and bus services), microtransit, carsharing, bikesharing, and scooter-sharing.

The future of public transit is thus full of uncertainties. While market-driven technological changes such as the rise of new mobility, the MaaS movement, and the development of autonomous vehicles play a vital role, institutional decisions also matter. When adapting to emerging transportation technologies, transit operators need to find creative approaches to improve operational efficiency. Before a transit agency implements any significant service changes, however, it must carefully evaluate the preferences of residents to assess what types of changes would be better received (Sochor et al., 2015; Durand et al., 2018).

2.2. Envisioning the future Mobility-on-Demand transit systems

Conventional buses and trains are most efficient in moving large volumes of travelers along busy traffic corridors, and small-sized vehicles can better serve low-density areas due to their flexibility. Accordingly, some transit observers have envisioned an ideal transit system as integrating the two types of vehicles, with mass transit operating in high-demand corridors and on-demand shuttles providing ridesourcing services to other geographic areas (Mahéo et al., 2017). This type of integrated MOD transit systems is a natural extension of previous efforts to synchronize various transit components, such as the connection between rail and bus lines and between the line-based transit services and demand-response services (Errico et al., 2013; Wang et al., 2014). The development of fully connected and autonomous vehicles can further augment this vision, as automation technologies are predicted to significantly reduce the operation costs of transit (mostly driver cost) and to facilitate communication and coordination among the vehicles (Buehler, 2018).

Recent years have seen a growing research interest in MOD transit. For example, Atasoy et al. (2015) proposed a flexible MOD concept that integrates transit, shared taxi, and mini-bus. Their simulation results demonstrated increased consumer surplus and operator profits. Stiglic et al. (2018) applied a complex-system modeling approach to evaluate the benefits of integrating ride-sharing and public transit in a hypothetical metropolitan region and showed that this integration can potentially enhance personal mobility and increase transit use. Yan et al. (2019) conducted a stated-preference survey to evaluate the traveler responses to an integrated transit system with ridesourcing and public transit. They found that such a system can help transit agencies improve level-of-service and reduce operating cost. Shen et al. (2018) further explored the synergy between autonomous vehicles and the public transit in Singapore, and their agent-based simulation results suggested that integrating autonomous vehicles with mass transit has the potential of enhancing service quality, reducing road use, and improving operating efficiency. These studies have demonstrated the benefits of MOD transit systems from an operations perspective; that is, MOD transit can result in higher operational efficiency and better overall service quality. However, there is a dearth of studies that focus on the travelers, particularly regarding how they perceive and would use MOD transit services.

To anticipate possible traveler responses to MOD transit, it is useful to examine empirical evidence on existing on-demand transportation options. Several empirical studies have shown that early adopters of bikesharing, carsharing, and ridesourcing are similar, who are often the young to middle-aged, college-educated, and moderate- to middle-income individuals living in urban areas (Clewlow and Mishra, 2017; Dias et al., 2017; Alemi et al., 2018; Feigon and Murphy, 2016). It is thus natural for these individuals to become early adopters of and supporters for MOD transit services. Nonetheless, it is unclear why other population groups have not adopted ridesourcing or other shared modes. Possible explanations include affordability concerns, a lack of geographic availability, and technological barriers such as technology illiteracy and lacking access to a bank account, a smartphone, or a data plan (Dillahunt and Veinot, 2018).

From a user's perspective, switching from a conventional fixed-route system to MOD transit can bring both benefits and costs. The most tangible benefit is the enhanced "last-mile" access to transit services (less walking to transit stops), a major deterrent to transit use. In addition, by matching travel demand and service vehicles in real time, a MOD transit system may reduce the wait time (by assigning the closest vehicle to pick up a customer) and the travel time (by generating customized routes based on trip origin and destination) of a trip. On the other hand, in order to improve operating efficiency, a MOD transit system has to incorporate some features that may significantly deter transit use, such as requiring users to accept additional pickups and transfers (e.g., between on-demand vehicles and buses). Moreover, MOD's heavy reliance on technology is likely to elicit varied responses from transit riders. For tech-savvy individuals, the convenience created by technology may encourage them to use transit more. However, some low-income and less technology-savvy individuals may be excluded from the serve due to technological barriers (Dillahunt and Veinot, 2018; Kodransky and Lewenstein, 2014; Shaheen et al., 2017).

2.3. Mobility-on-Demand transit and the disadvantaged travelers

When considering the development of MOD transit, agencies should pay special attention to transportation-disadvantaged individuals, including the low-income people, senior individuals, and people with a disability. Since these individuals are also more likely to lack technological capacity and lack access to a bank account, a smartphone, or a data plan (Pew Research Center, 2018), switching from conventional public transit to MOD transit may leave these travelers further behind. Such equity concerns are commonly raised in discussions of MOD initiatives. In addition, some are concerned that the trip requests of some minority travelers, particularly Blacks, may be rejected by some drivers due to racial prejudice or unwillingness to go to certain neighborhoods (Ge et al., 2016).

Transit agencies have sought to find solutions to address these challenges. For example, when establishing partnerships with Uber and Lyft, transit operators often include a third-party mobility provider to separately serve wheelchair customers. When the City of Arlington, Texas contracted with Via to replace its fixed-route bus line, Via implemented a series of measures to accommodate disadvantaged travelers. These measures include adding prepaid debit cards as the payment option, allowing people to call into request a ride, and including wheelchair-accessible vehicles into its service fleet. Other solutions to access barriers for MOD services include building neighborhood access kiosks, providing data-plan subsidies for low-income travelers, and adding voice-activated mobility app features (Shaheen et al., 2017). Moreover, several MOD transit pilot projects have reported that these equity concerns may not be as acute as many perceive. For example, the Go Centennial pilot in Colorado found that no user was denied by the program because of barriers to access. A survey conducted in Arlington, Virginia found that seniors are readily willing to learn to use app-based MOD services. These findings should nonetheless be interpreted with caution, as they reflect the behavior and preferences of the MOD transit service users instead of nonusers who were excluded from these services in the first place.

On the other hand, switching from a conventional fixed-route system to a MOD transit system can bring many benefits to transit-dependent individuals. Since MOD transit has the potential to extend transit coverage areas, expand service hours, and enhance last-mile transit connectivity, it may provide an affordable option for disadvantaged travelers to get to key destinations of interest that were not adequately served by the existing transit network (Dillahunt et al., 2017). For older and disabled travelers, the on-demand, real-time feature of MOD transit may reduce the wait time of a trip and also give them more flexibility in scheduling their daily activities (the existing demand-responsive paratransit services usually require advanced booking). Since MOD transit has both pros and cons compared to a fixed-route system, it is unclear whether disadvantaged travelers prefer a MOD transit system or a fixed-route one. This paper fills this research gap by evaluating preferences for MOD transit versus fixed-route transit systems among residents of low-income communities.

3. Data and methodology

We conducted a web-based survey in the City of Detroit and the Ypsilanti area, Michigan (i.e., the City of Ypsilanti and Ypsilanti Township). The City of Detroit had an estimated population of 672,662 in 2018 and the City of Ypsilanti and Ypsilanti Township combined had an estimated population of 76,630 in 2018. Both places had a significant proportion of the population living under poverty.[2] According to the American Community Survey 2014–2018 5-year estimates, the median household income in the city of Detroit and the city of Ypsilanti was $29,481 and $36,982, respectively. Their poverty rate was 36% in Detroit and 32% in Ypsilanti. However, it should be noted that some Ypsilanti residents counted as "poor population" were college students who were attending the University of Michigan, Ann Arbor or the Eastern Michigan University. The proportion of people aged 25 years and above and received a bachelor's degree or higher was 42% in Ypsilanti, and it was only 15% in Detroit. About 24% of Detroit households and 16% of Ypsilanti households, respectively, did not have access to a car. The commuting mode share in Detroit was about 83% by driving, 7% by public transit, and 4% by walking or biking. In Ypsilanti, the corresponding percentages were 73% by driving, 9% by public transit, and 13% by walking or biking.

The Detroit Department of Transportation (DDOT) is main transit service provider in Detroit. In 2018, DDOT operated ten 24–7 Core Routes and about 30 other routes. The headway for these routes ranged from 15 to 60 min during daytime on weekdays. The Suburban Mobility Authority for Regional Transportation (SMART) operates several routes that connect suburban Metro Detroit to downtown Detroit. The Ann Arbor Area Transportation Authority (AAATA) serves the Ypsilanti area. In 2018, it operated nine routes between the city of Ypsilanti and Ann Arbor and one express bus line in Ypsilanti Township. These routes had a headway of 15 or 30 min during daytime on weekdays. In addition to fixed-route services, transit agencies in both localities provided paratransit services to seniors and disabled individuals as required by the Americans with Disabilities Act (ADA). The quality of the paratransit services provided by AAATA was higher, as AAATA offered same-day service whereas DDOT required customers to book trips at least a day in advance.

Participants were recruited from July to November 2018. Ideally, we hoped to obtain a representative sample from each locality and to ensure that transportation-disadvantaged populations are well represented. We advertised the survey through a variety of means, including postal mails, flyers, posting on Nextdoor (a social network platform for neighborhoods) and neighborhood association's email newsletters. In Detroit, we also complemented these distribution methods with in-person on-site recruitment at several public libraries and non-profit organization buildings to account for individuals who were potentially uncomfortable with digital devices or who did not have access to such devices. These efforts, which led to 170 valid survey responses, allowed us to recruit some individuals who are in the lowest-income bracket and who are completely technology illiterate. Thus, we consider the quality of the Detroit sample data to be superior to that of the Ypsilanti sample data. A $10 cash incentive was offered for participants recruited in person and a $5 electronic gift card incentive was offered for other participants. We obtained a total of 497 and 534 completed

[2] The survey was distributed to the northern part of the Ypsilanti Township, which is an area with population and housing characteristics more similar to the City of Ypsilanti than the southern part of the township. Therefore, we only discuss the statistics on the City of Ypsilanti when referring to poverty status and educational attainment associated with the Ypsilanti sample.

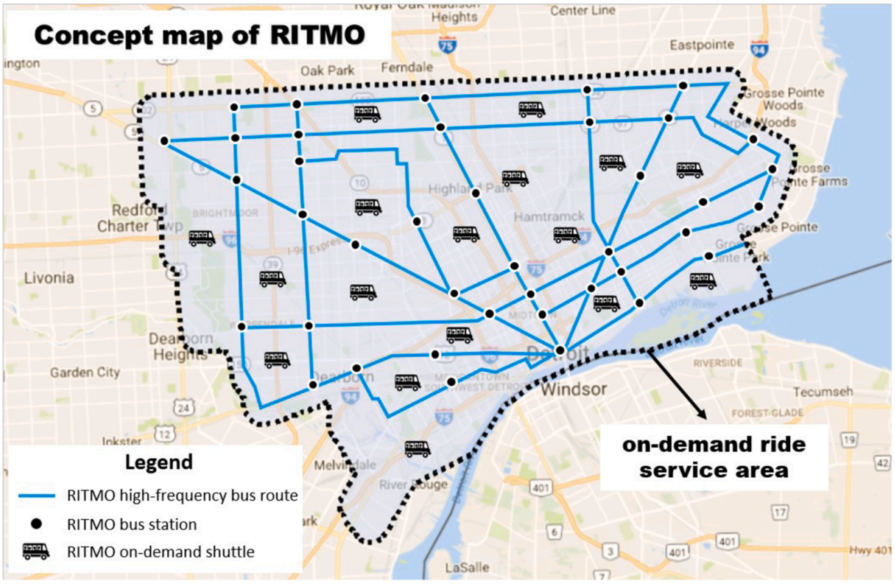


Fig. 1. A concept map of the RITMO system (for Detroit respondents).

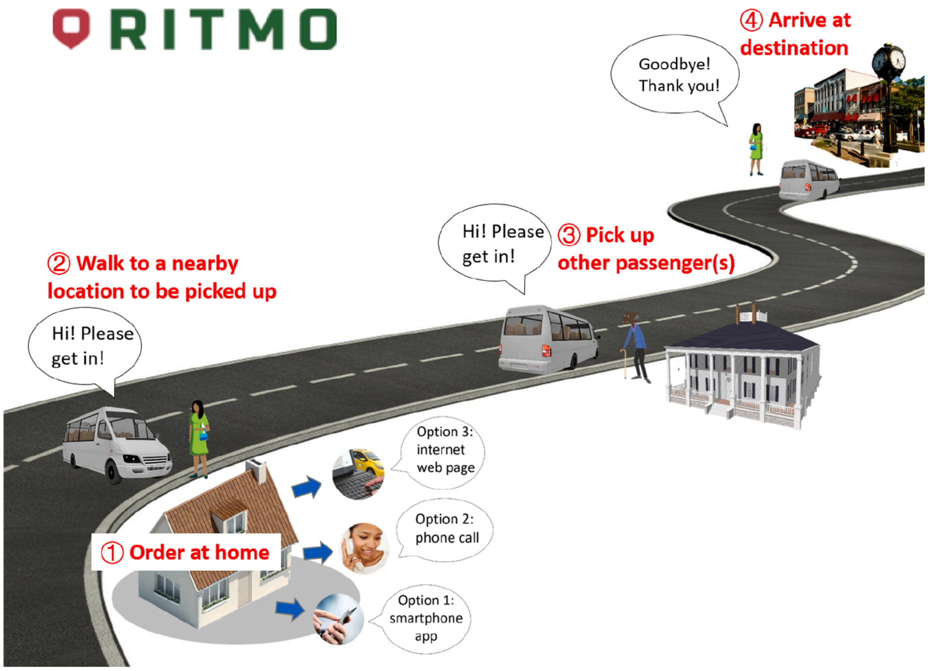
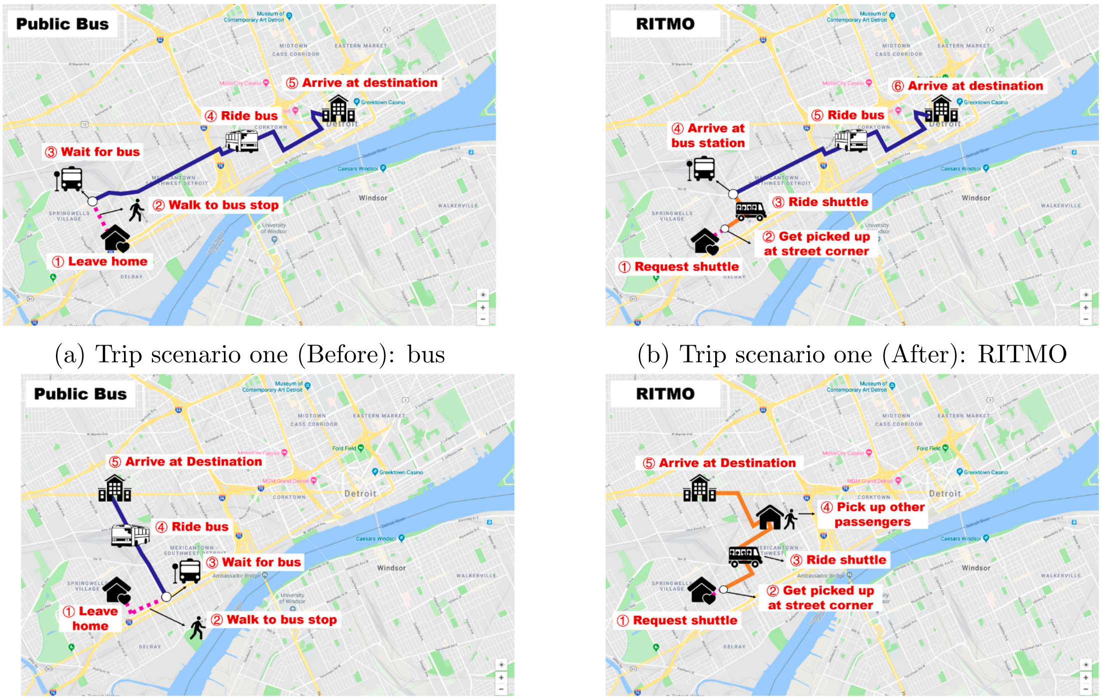


Fig. 2. An illustration of riding with RITMO shuttles.

responses from Ypsilanti and Detroit, respectively. After removing invalid responses, we retained 457 and 443 responses for further analysis.

The survey solicited the following information from the respondents: their use and perception of public transit and ridesourcing (Uber/Lyft), their demographic and socioeconomic characteristics and home locations, and their preference for a proposed MOD transit system (which was named RITMO) versus the current fixed-route system. Also, respondents were asked if any of the following potential constraints to adopting MOD services applies to them: do not own a cellphone, own a cellphone but not a smartphone, do not have a mobile data plan, do not have a bank account, have no internet access at home, and have a disability that requires the accommodation of specialized vehicles. We asked about cellphone ownership because we mentioned to respondents that calling in would be one of the options to request for on-demand rides (two other options are through a smartphone app and an internet web page).



(a) Trip scenario one (Before): bus

(b) Trip scenario one (After): RITMO

(c) Trip scenario two (Before): bus

(d) Trip scenario two (After): RITMO

Fig. 3. Before-after image illustrations of trip scenarios in Southwest Detroit.

Finally, the survey asked individuals to select from a list of potential benefits and drawbacks associated with the RITMO system the ones that matter to them.

The MOD transit system was introduced as follows: “The research team is testing the idea of offering a new type of transit service, called RITMO, in Detroit. This service combines rapid and high-frequency RITMO buses running in major corridors and on-demand RITMO shuttles serving the outer area. Below is a concept map of RITMO (see Fig. 1).” The survey then further described RITMO with both text and image illustrations, highlighting that the RITMO on-demand shuttles can be requested by using a smartphone app, or the internet, or with a phone call. Also, respondents were told that the RITMO shuttle services will not be door-to-door, and instead they would be picked up or dropped off at a street corner close to their points of origin and destination; RITMO shuttles would also pick up passengers who shared similar origins and destinations along the way (see Fig. 2). To illustrate the travel-experience changes under RITMO versus the current fixed-route system, we presented respondents with two sets of before-after image comparisons between a bus trip and a hypothetical RITMO trip (see Fig. 3). One set describes a short trip that would involve an on-demand shuttle only and the other describes a longer trip with a transfer between an on-demand shuttle and a bus.[3] The survey followed with the main question examined in this study: “Compared to a fixed-route bus system, do you prefer the RITMO system?”[4]

We constructed a five-level Likert-scale response variable based on answers to this question (“1” is “I strongly prefer a fixed-route system over RITMO”, “2” is “I sort of prefer a fixed-route system over RITMO”, “3” is “I am not so sure”, “4” is “I sort of prefer RITMO over a fixed-route system”, and “5” is “I strongly prefer RITMO over a fixed-route system”). Therefore, larger values represent a stronger preference for MOD over fixed-route. Since the response variable was measured with an ordinal scale, we applied the ordered logit model to analyze it. We hypothesized respondents’ preference toward RITMO versus fixed-route to be shaped by a host of variables such as their demographic and socioeconomic characteristics, the current bus services available at their residence, and their current use and perception of public transit and ridesourcing. In particular, we were interested in examining if the transportation-

[3] In some cases, users of the RITMO system may need to take two or more transfers to complete a trip. For instance, a three-leg journey may involve taking a on-demand shuttle to a bus station, taking the bus, and finally taking another on-demand shuttle to get to the destination. Due to their complexity, we did not illustrate such trips to the survey respondents. Had we done so, users may have a less favorable view toward MOD transit. In other words, the surveyed traveler responses to MOD transit may have a positive bias. Moreover, since we illustrated the trip scenarios with home-based trips, survey participants may perceive less access barriers to MOD transit than they would if the trips are not home-based.

[4] The survey also contains a section where each participant was asked to respond to seven stated-choice experiments. These stated-choice experiments were designed in such a way that the service attributes of MOD transit (including price, travel time, number of transfers, and number of additional pickups) traded off with each other. For example, a higher price of a MOD transit trip was associated with a shorter travel time whereas a lower price was accompanied by longer travel time. These stated choice experiments aimed to gauge how respondents make trade-offs between these service attributes. We will examine the results of these state-choice experiments in a separate study.

Table 1
Preference for MOD versus fixed-route transit.

	Detroit sample					Ypsilanti sample				
	All		Disadv.			All		Disadv.		
	Freq.	%	Freq.	%	Diff. in %	Freq.	%	Freq.	%	Diff. in %
Strongly prefer RITMO over fixed-route	137	30.90%	65	29.82%	−1.10%	171	37.42%	17	25.0%	−12.4%*
Sort of prefer RITMO over fixed-route	128	28.90%	57	26.15%	−2.70%	161	35.23%	19	27.9%	−7.3%
Not so sure	114	25.70%	61	27.98%	2.20%	74	16.19%	17	25.0%	8.8%
Sort of prefer fixed-route over RITMO	47	10.60%	24	11.01%	0.40%	40	8.75%	11	16.2%	7.4%
Strongly prefer fixed-route over RITMO	17	3.80%	11	5.05%	1.20%	11	2.41%	4	5.9%	3.5%

Note: Disadvantaged travelers are defined as those who are low-income (household income below $25,000), aged over 60, or with a disability.

Table 2
Socioeconomic and demographic profile of the sample.

Variable	Categories	Detroit sample (N = 443)		Ypsilanti sample (N = 457)	
		Freq.	%	Freq.	%
Gender	Male	249	56.21%	240	52.63%
	Female	194	43.79%	216	47.37%
Age	Under 25	32	7.22%	53	11.62%
	25–29	100	22.57%	82	17.98%
	30–39	138	31.15%	153	33.55%
	40–49	75	15.93%	72	15.79%
	50–59	47	10.61%	73	16.01%
	60–69	44	9.93%	18	3.95%
	70 or over	7	1.58%	5	1.10%
Black	Yes	236	53.27%	38	8.33%
	No	207	46.73%	419	91.89%
Household income	Less than $25,000	184	41.53%	49	10.75%
	$25,000-49,999$	104	23.48%	126	27.63%
	$50,000-74,999$	64	14.45%	80	17.54%
	$75,000-99,999$	37	8.35%	90	19.74%
	$100,000-124,999$	21	4.74%	70	15.35%
	$125,000-149,999$	18	4.06%	30	6.58%
	$150,000 or more	15	3.39%	11	2.41%
Education attainment	Less than high school	31	7.31%	2	0.45%
	High school graduate	201	47.41%	40	8.91%
	Professional degree	63	14.86%	124	27.62%
	Bachelor degree	85	20.05%	249	55.46%
	Master's/Doctorate	44	10.38%	34	7.57%
Car ownership	Yes	301	67.95%	401	87.75%
	No	142	32.05%	56	12.25%
Primary travel mode	Public bus	117	26.41%	156	34.14%
	Other	326	73.59%	301	65.86%
Ridesourcing knowledge and use	Never heard of or used Uber/Lyft	223	50.34%	130	28.45%
	Used Uber/Lyft at least once	220	49.66%	327	71.55%
Have a cellphone	Yes	408	92.10%	446	97.59%
	No	35	7.90%	11	2.41%
Have a smartphone	Yes	394	86.91%	410	89.72%
	No	49	13.09%	47	10.28%
Have a mobile data plan	Yes	385	88.94%	393	86.00%
	No	58	11.06%	64	14.00%
Have internet access at home	Yes	368	83.07%	438	95.84%
	No	75	16.93%	19	4.16%
Have a bank account	Yes	371	83.75%	451	98.69%
	No	72	16.25%	6	1.31%
Have a disability	Yes	40	9.03%	4	0.88%
	No	403	90.97%	453	99.12%

disadvantaged individuals, and those who may face access barriers to adopting MOD (e.g., do not have a smartphone and/or a mobile data plan) would have a stronger preference for fixed-route transit compared to other travelers.

Most variables of interest, except the bus services available to each respondent, were directly obtained from the survey data. We computed three spatial indicators to measure the fixed-route transit services that respondents were receiving from their home location, including a dummy variable that indicates if the closest bus stop to a respondent's home is within a quarter mile (about 400 meters), the number of buses passing by within a quarter-mile buffer of a respondent's home during the morning peak hours, and the transit accessibility to jobs. To compute the first two measures, we geocoded the home address of respondents using the Google Maps Geocoding API, obtained bus scheduling information from Google Transit Feeding Services (GTFS), and performed simple geo-processing functions such as Near, Buffer, and Dissolve in ESRI's ArcMap. For the last measure, transit accessibility to jobs, we calculated the number of jobs reachable within 45 min of transit travel time based on the 2015 Longitudinal Employer-Household Dynamics Origin–Destination Employment Statistics data and the GTFS file (during the morning peak hours).

4. Data analysis and results

4.1. Descriptive statistics

Table 1 shows the results for the outcome variable, i.e., traveler preferences for MOD transit versus fixed-route transit. As shown in the "all travelers" columns, survey respondents from both localities were strongly in favor of the RITMO transit system (i.e., an integrated system of fixed-route bus and on-demand ridesourcing services). A majority of respondents (nearly 60 percent in Detroit and over 70 percent in Ypsilanti) strongly or sort of preferred the RITMO system over the existing fixed-route transit system, and the opposite only applied to a small fraction of them (about 15 percent in Detroit and a little over 10 percent in Ypsilanti). The most recent on-board survey conducted by the Ann Arbor Area Transit Authority (the transit agency serving Ypsilanti) found that about 90% of the riders were satisfied with the existing fixed-route services, which means individual preferences for MOD transit over fixed-route were not likely to be primarily driven by a dislike for the current system.[5] Moreover, compared to Ypsilanti respondents (16%), a higher proportion of the Detroit respondents (26%) suggested that they were "not so sure" between the two systems, which may result from a higher level of uncertainty toward modern technology and distrust of public entities (Kodransky and Lewenstein, 2014).

The following conclusions can be drawn regarding disadvantaged travelers. First, compared to the whole sample, the support for MOD transit was slightly weaker among the disadvantaged travelers. But these differences were mostly statistically insignificant at the 0.05 level except for the "strongly prefer RITMO over fixed-route" response category in Ypsilanti. The proportion of disadvantaged travelers who prefer MOD over fixed-route is still the majority in both localities. In addition, a higher proportion of disadvantaged travelers selected "not so sure" than the rest of the respondents, which may be because they hope for improvements to existing transit system but in the meantime feel uncertain about the MOD option. Again, the difference between disadvantaged travelers and all travelers was not statistically significant at the 0.05 level.

Table 2 presents the descriptive profile of the survey samples. Our survey samples were not representative of the populations from which they were drawn. By examining the census data (i.e., American Community Survey 2013–2017 5-year estimates), we found that males, non-Black population, young adults (age between 25 to 40), college graduates, and transit riders were overly represented in both samples.[6] In addition, the Ypsilanti sample included fewer low-income individuals (household income below $25,000), Blacks, older adults (over 60 years old), and people with a disability compared to their population shares. Over 50 percent of the Detroit respondents reported that they either have not heard of Uber/Lyft or never used them, whereas less than 30 percent of the Ypsilanti respondents stated the same. By contrast, several recent national-scale surveys on ridesourcing (e.g., found that about 75% of the U.S. population had not used Uber/Lyft before in 2015 (Clewlow and Mishra, 2017; Smith, 2016). Possible sources of discrepancy here include sample bias and the rapid market penetration of ridesourcing services in recent years (our survey was conducted two to three years latter). Finally, it appeared that we undersampled individuals who face potential access barriers (people without a smartphone, a data plan, or internet access at home) to adopting MOD. For example, about 13 percent of the Detroit respondents and 10 percent of the Ypsilanti respondents, respectively, reported that they did not have a smartphone. However, surveys conducted by the Pew Research Center from 2008 to 2018 suggested that about 33% of U.S. adults do not own a smartphone as of November 2016 (Pew Research Center, 2018). These results suggest that the overall support for MOD transit can have a positive bias due to sampling bias; that is to say, we expect that the proportion of individuals who prefer MOD transit over fixed-route to be somewhat lower than the results presented in Table 1.

Furthermore, results of some cross-tabulation analysis (not shown here) suggested that individuals facing with potential MOD access barriers are more likely to be older, are from low-income households, and are without a college degree. A chi-square test of independence further showed that these relationships were statistically significant at the 0.05 level. These findings are consistent with those from the Pew Research Center surveys (Pew Research Center, 2018). Together with the fact that these individuals tend to use transit more frequently than other population groups (e.g., more than 50 percent of the Detroit respondents with a household income of less than $25,000 used bus five times or more in the past week, whereas only about 15 percent of respondents with higher income levels did the same), these findings suggest that addressing the access barriers to MOD for disadvantaged travelers should be a priority for the development of MOD transit systems.

Table 3 presents the descriptive statistics for the three spatial indicators that measure the level of fixed-route transit service received by each respondent. These results showed that large variations exist across individuals in terms of the transit services they

[5] We reached out but did not get on-board survey results from the transit agency serving Detroit.

[6] Census Data Statistics for Detroit: 46.3% adults are males, 79.1% of the population is Black, 34.5% adults are between the age of 25 to 44, 14.3% of the population 25 years and older have a bachelor degree or above, 8.2% of workers use public transit for commuting. Census Data Statistics for Ypsilanti (the City of Ypsilanti and Ypsilanti Township combined): 48.8% adults are males, 30.6% of the population is Black, 26.1% adults are between the age of 25 to 44, 33.9% of the population 25 years and older have a bachelor degree or above, 4.6% of workers use public transit to commute.

Table 3
Descriptive statistics for the transit-service-related indicators.

	Variable type	Detroit sample	Ypsilanti sample
Live within a quarter-mile to a bus stop	Dummy	Yes = 181 (43.6%) No = 234 (56.4%)	Yes = 157 (38.2%) No = 254 (61.8%)
No. of buses passing by within a quarter-mile of a respondent's home	Continuous	12.2 ± 24.0	2.3 ± 3.4
No. of jobs reachable within 45 min of transit travel time	Continuous	17685 ± 25719	2744 ± 1470

Note: For the dummy variable, we present the frequency and proportion (e.g., 181 (43.6%). For the continuous variables, we present the mean and the standard deviations (e.g., 12.2 ± 24.0)).

Table 4
Description of independent variables.

Variable code	Type	Value and description
Male	Dummy	1 = Male; 0 = Female
AgeBelow40	Dummy	1 = Age is below 40; 0 = Age is 40 or above
AgeAbove60	Dummy	1 = Age is 60 or above; 0 = Age is below 60
LowIncome	Dummy	1 = Household income is below $25,000; 0 = Household income is $25,000 or above
Black	Dummy	1 = Race is Black; 0 = Race is not Black
CollegeDegree	Dummy	1 = Have a bachelor degree or above; 0 = Do not have a bachelor degree
CarOwnership	Dummy	1 = Have a car; 0 = Do not have a car
BusTravel	Dummy	1 = Primary travel mode is bus; 0 = Primary travel mode is not bus
NoRidesourcingExperience	Dummy	1 = Never heard or used Uber/Lyft before; 0 = Used Uber/Lyft at least once
NoBankAccount	Dummy	1 = Do not have a bank account; 0 = Have a bank account
NoSmartPhone	Dummy	1 = Do not have a smartphone; 0 = Have a smartphone
NoDataPlan	Dummy	1 = Do not have a mobile data plan; 0 = Have a mobile data plan
NoInternetAccess	Dummy	1 = Do not have Internet access at home; 0 = Have internet access at home
HaveDisability	Dummy	1 = Have a disability that require wheelchair accessibility; 0 = Have no disability
LiveCloseToTransit	Dummy	1 = Live within a quarter-mile to a bus stop; 0 = Do not live within a quarter-mile to a bus stop
JobAccessibilityByBus	Continuous	No. of jobs (divided by 10,000) reachable within 45 min of transit travel time
BusFrequency	Continuous	No. of buses passing by in the morning peak hour within a quarter-mile of a respondent's home

received. Also, the overall transit service received by Detroit respondents appeared to be higher than that by Ypsilanti respondents.

4.2. Ordered logit model specification

We further applied ordered logit models to examine the determinants of individuals' preference for MOD transit versus fixed-route. The independent variables examined in this study were described in Table 4. We fit three models: one using the Detroit data only, one using the Ypsilanti data only, and one using the pooled data. We estimated sample-specific models because we found that the estimated parameters of the pooled-data model were not transferable spatially. Specially, following a procedure described in Washington et al. (2020), we conducted extensive likelihood ratio testing of different model specifications; in all cases, we found that the model parameters were not transferable across localities. We further exclude variables *NoBankAccount*, *NoInternetAccess*, and *HaveDisability* from the Ypsilanti model due to sample size concerns (see Table 2). Finally, we excluded the variabe *BusFrequency* from the Ypsilanti model because it is highly correlated with *JobAccessibilityByBus* (the correlation index is 0.85).

Two additional technical details regarding the ordered logit model warrant further discussion. First, we checked the proportional odds assumption. The proportional odds assumption constraints the coefficients that describe the relationship between each pair of response categories to be the same, e.g., coefficients that describe the relationship between the lowest versus all higher categories of the response variable is the same as those that describe the relationship between the highest versus all lower categories of the response variable. The violation of this assumption often leads modelers to use a generalized ordered logit model instead. We tested the proportional odds assumption for all three models and found that only the pooled data model violated this assumption at the 0.05 level of significance. After examining the results of the generalized ordered logit model for the pooled data, we decided to stick with the ordered logit model due to two reasons: First, the generalized ordered logit model did not generate additional substantive insights; second, it resulted in some case outcomes with a predicted probability that is less than zero (Williams, 2016).[7]

Second, we considered whether to collapse categories of outcome with small sample sizes or not. As shown in Table 1, the sample size for the "strongly prefer fixed-route over RITMO" response category is very small for both the Detroit sample ($N = 17$) and the Ypsilanti sample ($N = 11$), which motivated us to consider the option of combining these responses with the closest response category (i.e., "sort of prefer fixed-route over RITMO"). We thus refitted the three ordered logit models with four categories of outcome, but the

[7] The problem of negative probabilities have been tackled by recent extensions of the generalized ordered response model, such as the mixed generalized ordered model (Eluru et al., 2008) and the random thresholds random parameters ordered model (Fountas and Anastasopoulos, 2017). However, we did not further examine these models due to the first reason.

Table 5
Ordered logit model outputs.

Variable	Detroit data		Ypsilanti data		Pooled data	
	Coeff.	S.E.	Coeff.	S.E.	Coeff.	S.E.
Male	0.387*	0.192	0.536**	0.196	0.350**	0.132
AgeBelow40	0.354	0.220	−0.051	0.21	0.166	0.148
AgeAbove60	0.455	0.346	−1.273*	0.523	−0.203	0.276
LowIncome	−0.148	0.229	0.068	0.351	−0.090	0.187
Black	0.262	0.201	0.210	0.344	0.258	0.159
CollegeDegree	0.588**	0.224	1.180**	0.225	0.818**	0.153
CarOwnership	−0.415	0.256	−1.233**	0.356	−0.741**	0.201
BusTravel	−0.085	0.245	−0.051	0.213	−0.102	0.151
NoRidesourcingExperience	−0.685**	0.199	−0.794**	0.232	−0.778**	0.148
NoSmartPhone	−0.462	0.289	0.170	0.354	−0.146	0.218
NoDataPlan	−0.893**	0.316	−0.387	0.288	−0.556**	0.202
NoBankAccount	0.170	0.293			−0.077	0.274
NoInternetAccess	−0.208	0.284			−0.326	0.232
HaveDisability	−0.149	0.339			−0.361	0.313
LiveCloseToTransit	−0.563*	0.234	−0.395*	0.196	−0.529**	0.151
JobAccessibilityByBus	−0.184**	0.059	−3.980**	0.682	−0.168**	0.056
BusFrequency	−0.001	0.006			−0.003	0.006
Cutpoint 1	−4.424**	0.477	−6.043**	0.601	−4.693**	0.357
Cutpoint 2	−2.763**	0.403	−4.213**	0.516	−2.985**	0.298
Cutpoint 3	−1.076**	0.377	−2.889**	0.492	−1.510**	0.280
Cutpoint 4	0.324	0.375	−0.966*	0.471	0.062	0.275
Observations	415		411		826	
Log likelihood (Null model)	-592.67		-546.43		-1148.12	
Log likelihood	-546.71		-482.81		-1059.33	
Likelihood ratio chi-square statistic	91.92		127.24		177.58	
p-value	0.00		0.00		0.00	
Pseudo R-squared	0.08		0.12		0.08	

** $p < 0.01$, * $p < 0.05$

model outputs were very similar to those of the original models with five categories of outcome. Since some statisticians have raised concerns of obtaining biased effect estimates when response categories were collapsed (Strömberg, 1996), we decided to keep the original five response categories.

4.3. Ordered logit model results

Table 5 presents the model outputs for the three ordered logit models. Although some of the independent variables were statistically insignificant, we kept them in the final models because of their practical significance. We have estimated additional models that only contain statistically significant variables (the model outputs are presented in the Appendix). Since the coefficient estimates of the statistically significant variables barely changed, we only discuss the model outputs presented in Table 5. As shown at the bottom of the table, the likelihood ratio chi-square test showed that all three models are significant improvements compared to the intercept-only null model. The McFadden pseudo R-squared values were relatively low (between 0.08 and 0.12), which is common for this type of model.

The subsequent analysis examines the two sample-specific models only. We interpreted the statistical significance of the coefficient estimates and their signs. It should be noted that a positive coefficient indicates a higher probability of *choosing a response category coded with a larger value*, which means *a stronger preference for MOD transit or a weaker preference for fixed-route rather than a higher probability of choosing MOD transit over fixed-route*. Independent variables that were significant at the 0.05 level in both the Detroit model and the Ypsilanti model include *Male*, *CollegeDegree*, *NoRidesourcingExperience*, *LiveCloseToTransit*, and *JobAccessibilityByBus*. We found that males and college graduates have a stronger preference for MOD transit than females and individuals without a bachelor degree. For example, the Detroit model showed that males were 1.47 ($\exp(0.387)$) times more likely than females to express a stronger preference for MOD transit. Based on the comments we received from the survey respondents, we speculated that the preference differences between males and females may result from the fact that females were more concerned about potential safety or privacy issues associated with ridesourcing such as feeling uncomfortable sharing rides with strangers in small-size on-demand vehicles. This is consistent with other studies showing that distrust of strangers and a concern for safety are major barriers to the sharing economy (Tussyadiah and Pesonen, 2018). College graduates may have a stronger preference for MOD transit because they were more tech-savvy and were more adaptable to new and innovative concepts.

Individuals who had never heard of or used ridesourcing services before and who were better served by the existing fixed-route system (i.e., living within walking distance to a transit stop and being able to reach more opportunities) had weaker preferences for MOD transit. For example, compared to those living more than a quarter-mile to the nearest bus stop, Ypsilanti respondents who lived within a quarter-mile were only 0.67 ($\exp(-0.395)$) times as likely to choose a response category that indicates a stronger preference for MOD transit. These findings were not surprising. Individuals who had no experience with ridesourcing tend to be people who are not tech-savvy or who hold a negative perception of ridesourcing. Therefore, it is natural for them to be less supportive of MOD transit than other individuals. Previous studies have found that technology proficiency and perceived ease of use are major factors that impact individuals' willingness to participate in the sharing economy (Hsiao et al., 2018). It is also not surprising that individuals who received better transit services from the existing fixed-route transit system expressed less support for MOD transit.

Some variables were significant in one of the two sample-specific models but not the other. For instance, in the Detroit model, coefficients on *NoDataPlan* suggested that individuals without a data plan were less likely to favor MOD transit over fixed-route. While *NoDataPlan* shared a negative sign in the Ypsilanti model, it was not statistically significant at the 0.05 level. Moreover, the Ypsilanti model showed that older respondents and car-owning individuals had a weaker preference for MOD transit. By contrast, neither variables were statistically significant at the 0.05 level in the Detroit model. Finally, *AgeAbove60* had a negative sign in the Ypsilanti model but a positive sign in the Detroit model. A possible explanation is that seniors living in Ypsilanti were less supportive of reducing the coverage of fixed-route services. As mentioned above, the paratransit services provided by AAATA to seniors and disabled individuals in Ypsilanti were quite good. Since paratransit services are tied to fixed-route services in the U.S. (the ADA requires agencies to provide paratransit services within 3/4 of a mile of a fixed-route bus service), the senior respondents in Ypsilanti can be concerned that a switch from fixed-route to MOD transit may reduce paratransit services.

The variable *AgeBelow40* was statistically insignificant in both models, which means that the preferences of young adults (age between 18 and 40) were not significantly different from middle-aged individuals. Moreover, *AgeBelow40* had a positive sign in the Detroit model but a negative sign in the Ypsilanti model. This finding implies the reported higher use of ridesourcing among young adults may not be due to individual preferences but result from the geographic availability of these services at the places where they live. In addition, individual preferences appeared not to vary significantly by income or race, as *LowIncome* and *Black* were both statistically insignificant. We also found that the preferences of people whose primary travel mode is bus did not differ from people who traveled with other modes.

The preferences of individuals without a bank account (*NoBankAccount*), with a disability (*HaveDisability*), without a smartphone (*NoSmartPhone*), or without internet access at home (*NoInternetAccess*) were not significantly different from other individuals. These findings are somewhat unexpected, as one would expect individuals facing these potential access barriers to adopting MOD to have a less preferable view of MOD transit than the rest of the population. These results may be an artifact of how we described the proposed RITMO system in the survey. The survey did not mention possible payment options and if the on-demand shuttles would be wheelchair accessible; therefore, individuals without a bank account and or a disability may simply assumed that, like the existing transit system, cash payments would be allowed and wheelchair accessibility would be provided under the RITMO system. Also, as mentioned above, we told the respondents that there would be three options to request for an on-demand ride—through a smartphone app, an internet page, or a phone call. We provided no further information on the convenience of use regarding the three options. Since very few of our respondents (13 individuals in the Detroit sample and zero in the Ypsilanti sample) had access to none of the three options, i.e., they have at least one of the following—a cellphone, a smartphone with mobile data, or internet access, they may not perceive accessing MOD services as a problem. This points to a major limitation of our study, that is, there is not enough representation of the least technology-savvy individuals in our survey sample. On the positive side, however, these results also suggest that allowing passengers to request rides with phone calls may effectively mitigate the technology-access problems for adopting MOD transit.

To conclude, our statistical analysis generates insights regarding the preference differences for MOD transit across population segments. First, results from both localities showed that people who are more likely to resist a switch from fixed-route to MOD transit include the following: females, individuals without a college degree, individuals who have never heard of or used ridesourcing, and individuals who are well served by the existing fixed-route services. We also found that individuals without a car and those without a data plan tend to hold a less favorable view on MOD transit, although the evidence is less conclusive (i.e., results are only statistically significant in one study area but not the other). Moreover, preferences seem to vary little by age, income, race, and primary mode of travel, as these variables had statistically insignificant coefficients or even contradictory signs. Finally, somewhat surprisingly, we found that individuals without a bank account, without a smartphone, without internet access at home, or with a disability are not less likely to favor a switch from fixed-route to MOD transit.

4.4. The pros and cons of MOD transit systems

To further shed light on what shapes respondents' preference for MOD versus fixed-route transit, in this section we discuss the pros and cons of MOD transit systems by examining survey responses to two relevant questions. The survey questions were stated as follows: "Below are some of the benefits/drawbacks associated with the proposed RITMO system, which of them matter to you (please select up to three items)?" Besides a predetermined list of benefits and drawbacks, an "other, please specify" option was also included to allow open-ended answers. Table 6 presents the responses from all respondents and also responses from the disadvantaged travelers only. Since the two questions were added to the survey after we launched it in Ypsilanti, only a small proportion of the Ypsilanti respondents answered them. Overall, the responses of the transportation-disadvantaged individuals are not very different from those of the full sample excepted that a smaller proportion of them.

The results show that the most important benefit of MOD transit perceived by respondents from both localities is the enhanced accessibility it provides, that is, improving access to the number of destinations that individuals can get to using transit. Potential benefits of secondary importance include reductions in walking time, higher flexibility, more comfort (due to being able to wait at home), and service-hour extensions. Notably, a higher proportion of the Ypsilanti respondents valued walking-time reductions and service-hour extensions compared to the Detroit respondents, which is likely because respondents from the Township of Ypsilanti often live far away from bus stops and receive inadequate transit serviced during the early morning, the late evening, and the weekends.

Table 6
Important benefits and drawbacks of the proposed RITMO system perceived by respondents.

	Detroit data					Ypsilanti data[a]			
	All (N = 441)		Disadv. (N = 233)			All (N = 251)		Disadv. (N = 48)	
Potential benefits of RITMO matter to respondents	Freq.	%	Freq.	%	Diff. in %	Freq.	%	Freq.	%
It increases the number of places that passengers can get to using transit	267	60.54%	138	63.01%	2.5%	161	62.89%	16	52.08%
It reduces the amount of walking (e.g. walking to bus stop) of a transit trip	210	47.62%	106	48.40%	0.8%	147	57.42%	16	45.83%
It allows passengers to request a ride whenever they want and wherever they are at	220	49.89%	83	37.90%	−12.0%**	129	50.39%	7	43.75%
It allows passengers to wait home instead of at a bus stop	214	48.53%	87	39.73%	−8.8%*	128	50.00%	7	35.42%
It can extend transit service hours for early morning/late evening/weekends	163	36.96%	64	29.22%	−7.7%	137	53.52%	13	18.75%
It can be more economically efficient than a fixed-route bus system	153	34.69%	60	27.40%	−7.3%	100	39.06%	12	22.92%
Potential drawbacks of RITMO matter to respondents	Freq.	%	Freq.	%		Freq.	%	Freq.	%
The cost for a RITMO trip is not likely to be lower than a bus trip	156	35.37%	82	37.44%	2.1%	89	35.46%	3	6.25%
The need to request for a ride instead of just simply waiting for a bus to come	200	45.35%	104	47.49%	2.1%	119	47.41%	7	14.58%
Passengers are unable to use it when phone battery runs out or have no internet access	170	38.55%	84	38.36%	−0.2%	78	31.08%	6	12.50%
Potential malfunction of the internet and the RITMO app	146	33.11%	64	29.22%	−3.9%	51	20.32%	7	14.58%
Difficulty in finding the “street corner” to be picked up	87	19.73%	41	18.72%	−1.0%	61	24.30%	4	8.33%

a: Note that since these questions were added to the Ypsilanti survey later on, the number of responses, especially those from the disadvantaged travelers, were quite small. Accordingly, we did not compare if the responses from the disadvantaged travelers differ from those from all travelers for the Ypsilanti data.

Finally, a small percentage of respondents indicated that they value the economic efficiency of the RITMO system. Some respondents selected the “other, please specify” option and suggested some additional benefits of the RITMO system. Such benefits include the “cool factor” associated with it and the potential to save parking and car ownership and operating costs when drivers decided to switch to transit.

Regarding the potential drawbacks of the RITMO system, respondents’ primary concern seemed to be the process required to use MOD (i.e., actively requesting for a ride). This is likely due to two reasons. First is the travel-behavior inertia effect. A stream of studies has shown that travelers tend to repeat their behavior and are not willing to accept changes unless the new alternative significantly improves their travel experiences (Gärling and Axhausen, 2003; Chorus and Dellaert, 2012). The need to actively request for a ride, wait for, and search for the assigned vehicle would be particularly undesirable for many transit riders who are satisfied with the existing fixed-route system and are accustomed to using it. Second is the need to be familiar with modern technology, which is more of a concern for less tech-savvy respondents. Our interviews with some transit professionals working on pilot MOD transit projects in the U.S. revealed that these projects often failed to attract senior users because of the difficulty that they encountered in using ridesourcing apps. Although some pilot projects provided the option of requesting for a ride by phone calls, such as the Via/Arlington partnership, the process may be perceived by users as somewhat burdensome.

Respondents’ secondary concerns were potential cost increases and logistic issues such as phone battery running out or lacking internet access or the malfunction of the technology that RITMO depends on. Finally, other issues raised from open-ended responses include uncertainty about service reliability (e.g., unknown wait time, particularly during peak hours), safety concerns (e.g., sitting with strangers in a small vehicle and vehicles going into unsafe neighborhoods), and environmental concerns (e.g., more congestion and green-gas emissions since more small-sized vehicles are required to replace large-volume buses).

5. Discussion

The findings of this paper generate insights that can inform transportation policymaking and guide the design of future MOD transit systems to ensure their successful implementation. First, we find that incorporating ridesourcing into the service suite of public transit is likely to gain widespread support among local residents. A majority of our survey respondents favor a proposed integrated MOD transit system over the existing fixed-route system. If the access barriers to MOD services can be eliminated (e.g., through accepting cash fare payment and allowing riders to book trips with a phone call or a text message), MOD transit systems can be especially beneficial for the low-income, aged, carless, and disabled travelers. The integration of MOD with conventional public transit brings the promise of offering affordable and convenient public transit services to areas that were unreachable to disadvantaged travelers.

Moreover, we find a weaker preference for MOD transit among individuals who had no mobile data plan and among individuals who never heard of or used ridesourcing. If a lack of affordability prevents people from purchasing mobile data, possible solutions to this issue would be installing Wi-Fi access hot spots at key locations or providing subsidies to certain populations for mobile data plan purchases. However, it is quite likely that a lack of technology proficiency is the main issue here; that is, less tech-savvy individuals who do not have a data plan or use ridesourcing express less support for MOD transit because of their perceived difficulty in using on-demand ride services. Consequently, addressing this digital divide and the unwillingness of some transit riders to adopt new technologies should be a priority for transit operators. Possible measures include targeting marketing and outreach programs to less technology-proficient individuals, making easy-to-understand materials to guide the use of MOD transit services, and incorporating more user-friendly features (e.g., voice activation) into the MOD smartphone app, etc.

Also, females have more reservations for MOD transit than males. We obtained scant evidence from the survey that suggests that such preference difference arose from women's safety concerns, e.g., being uncomfortable with sitting with strangers in a small-size vehicle and fearing that on-demand shuttles traveling to unsafe places. Transit agencies should address these concerns with appropriate measures, such as putting larger space gaps between seats, installing security cameras, and ensuring adequate driver training. In addition, the MOD transit concept appears to draw a similar level of support across different age, income level, and racial groups, assuming their level of technology proficiency and the current transit services they receive are similar. This findings suggest that while young to middle-aged and college-educated individuals are more likely to the first adopters of MOD transit services, other population groups would follow suit if the digital-divide gap is narrowed and if MOD significantly improves transit experiences.

Finally, pilot MOD initiatives should first target areas that are not receiving adequate transit services from the existing fixed-route system. As expected, we find that respondents living at places well-served by the fixed-route services are less supportive of the MOD transit concept than those who are not receiving adequate services. This further confirms that the biggest potential of MOD transit is providing services to previously under-served areas (i.e., low-density areas or places lacking convenient last-mile transit access), which was also the most important benefit of MOD transit perceived by our survey respondents. To identify transit-deficit areas to test MOD pilots, a transit operator may apply several criteria such as being distant from transit stops and having low job accessibility by transit (number of jobs reachable within a certain amount of transit travel time).

6. Conclusion

The rapid rise of ridesourcing (e.g., Uber, Lyft, and Via) services and the development of autonomous vehicles lead many to speculate their implications on the future of public transit. The speculated possible future scenarios range from the complete demise of public transit as cheap and convenient autonomous-vehicle trips make transit obsolete, to a segmented market where fixed-route transit serves the highest-demand corridors while autonomous vehicles occupy other markets, to a resurgence of public transit as new technology renders private auto ownership unnecessary (Polzin, 2016). Faced with many uncertainties, public transit needs to develop a vision for its future and look for creative ways to improve the service quality and operational efficiency in order to stay competitive. Many transit observers have suggested that an ideal future transit system should integrate conventional fixed-route transit with ridesourcing, with the former serving busy corridors and the latter serving lower-density areas and providing last-mile feeder service to transit stops.

Realizing such an integrated Mobility-on-Demand (MOD) transit system requires forward thinking and active planning from transit operators, and they should carefully consider a range of issues such as network design, organizational integration, operating model, and user buy-in, etc. To complement previous work that has primarily focused on the operation and system design aspects of MOD transit, this paper generates insights on user perceptions and preferences. We surveyed two low-income communities, namely Detroit and Ypsilanti, Michigan, to investigate how residents, particularly the disadvantaged travelers and the less technology-savvy ones, would react to the concept of an integrated MOD transit system. A majority of the survey respondents indicated that they strongly or sort of prefer the proposed MOD system over the existing fixed-route system, whereas a small minority would rather stick with the conventional fixed-route transit system. Note that these survey results may have a positive bias, however, as we undersampled individuals with potential access barriers to MOD. Moreover, the on-the-ground implementation of the proposed MOD transit system can be worse than how respondents had perceived it to be based on our descriptions.

Moreover, we found that males, college graduates, individuals who have used ridesourcing before, and individuals who currently receive inferior transit service from the fixed-route system are more likely to hold a more favorable perception of the MOD system. However, preferences appeared to vary little by age, income, race, or disability status. In addition, our study confirms the findings of some existing studies which show fear of crime deters transit use among females (Kim et al., 2007; Loukaitou-Sideris and Fink, 2009). Somewhat surprisingly, lacking access to a bank account, a smartphone, or internet at home or having a disability were not associated with individual preference for MOD transit versus fixed-route. As we have discussed in detail in the results section, these results may be an artifact of how described the proposed MOD system in the survey. Nevertheless, people who lack access to a mobile data plan had significantly weaker preference for MOD transit, which is likely due to a lack of technological self-efficacy.

This study is one of the first studies that examine how disadvantaged travelers react to MOD concepts and how their preferences differ from other population groups. A major limitation of the analysis present here is the lack of consideration for unobserved heterogeneity, to address which researchers have made many methodological improvements to the ordered logit model applied in this study (Anowar et al., 2014; Fountas et al., 2018; Fountas et al., 2018). Also, future research that examines the existing MOD transit initiatives would be helpful to verify the results of this study and to generate further insights on the pros and cons of MOD transit. Another direction of future research is to evaluate and quantify the potential of MOD transit systems to enhance transit accessibility to essential destinations, to lower car use, and to reduce parking demand. Finally, there is a practical need to identify effective solutions to overcome the barriers to adopt MOD transit and to explore user-friendly design features that can lower the level of technology proficiency required to it.

Table 7
Outputs of ordered logit model with significant independent variables only.

Variable	Detroit data		Ypsilanti data		Pooled data	
	Coeff.	S.E.	Coeff.	S.E.	Coeff.	S.E.
Male	0.375*	0.186	0.577**	0.189	0.358**	0.130
CollegeDegree	0.542**	0.205	0.912**	0.200	0.837**	0.145
CarOwnership					−0.595**	0.175
NoRidesourcingExperience	−0.667**	0.190	−0.776**	0.209	−0.803**	0.140
NoDataPlan	−1.002**	0.302			−0.679**	0.194
LiveCloseToTransit	−0.536*	0.213	−0.394*	0.193	−0.501**	0.141
JobAccessibilityByBus	−0.194**	0.043	−4.04**	0.666	−0.185**	0.037
Cutpoint 1	−4.324**	0.348	−4.885**	0.448	−4.577**	0.291
Cutpoint 2	−2.687**	0.244	−3.072**	0.326	−2.883**	0.219
Cutpoint 3	−1.027**	0.202	−1.792**	0.296	−1.423**	0.196
Cutpoint 4	0.328	0.195	−0.046	0.281	0.137	0.190
Observations	415		411		826	
Log likelihood (Null model)	-592.67		-546.43		-1148.12	
Log likelihood	-552.16		-494.70		-1064.43	
Likelihood ratio chi-square statistic	81.02		103.46		167.38	
p-value	0.00		0.00		0.00	
Pseudo R-squared	0.08		0.12		0.08	

** $p < 0.01$, * $p < 0.05$

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

Table 7.

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