Eliminating barriers to nighttime activity participation: the case of on-demand transit in Belleville, Canada

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Abstract

Demand-responsive technologies are rapidly changing the transportation landscape. The City of Belleville, Ontario has recently replaced its evening and nighttime fixed route bus service with an on-demand transit (ODT) service. Preliminary reports have found a 300% increase in nighttime bus ridership since the implementation of this service, yet to fully understand the social return on the investment in on-demand services, we must also quantify whether and for whom these new services have enabled time savings and increased levels of activity participation. Furthermore, it remains unclear whether riders are satisfied with the service, and whether satisfaction levels have an impact on activity participation. As such, this study explores the determinants of activity participation of ODT users using a custom ridership survey instrument. We collect information on travel experience, satisfaction, and perceived changes in activity participation due to ODT. We then performed a factor analysis and estimated structural equation models to identify the relationships between aspects of the ODT service and activity participation. Our results show that reliability and service quality are the most important aspects of the ODT services in terms of positively influencing activity participation, and that shorter wait times, are most likely to lead to an increase in activity participation. Our findings further suggest that Belleville can eliminate barriers to nighttime activity participation by providing reliable and affordable ODT service, and that ODT can be an effective solution to provide transit services for transport-poor in low demand areas or during low demand periods of the day.

Keywords On-demand transit · Transit satisfaction · Activity participation · Demand-responsive technologies · Structural equation model

Introduction

Many jurisdictions struggle to provide transit services in low demand areas or during low demand periods of the day, due to the high costs of operation in relation to low revenues from fares. As a result, recent evidence suggests that poor transportation provision may cause barriers to travel and limit participation in essential daily activities such

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as employment, medical appointments, and leisure (Farber et al. 2018). This is especially likely among those disadvantaged groups who suffer from socioeconomic and transportation deprivation conditions. Such individuals are understood to be suffering from transport poverty, and are at risk of being excluded from participating in the normal activities of everyday life (Lucas 2012; Martens 2016). Research contends that improvements in transit accessibility can encourage trip generation and activity participation in these groups and therefore alleviate social exclusion (Allen and Farber 2020; Roorda et al. 2010). Demand-responsive technologies, such as on-demand transit (ODT), offer public transit agencies new opportunities to deliver mobility services at reduced cost and improved customer experience. Despite this great potential, these services have seldom been investigated from the perspective of disadvantaged communities, nor have past studies looked at their ability to alleviate transport-related social exclusion.

Several studies have shown that ODT can significantly stimulate ridership (Chebbi and Chaouachi 2015; Zhao et al. 2018). For instance, an initial analysis of the Belleville ODT pilot project, which we will be examining in more detail in this paper, claimed that nighttime bus ridership had increased 300%, albeit starting with a small base ridership (Mellor 2019). However, a recent study by Coutinho et al. (2020) found significant ridership drop after launching a 12-month demand-responsive transportation pilot in low-density areas of Amsterdam, Netherland. Since most existing studies of the ODT services have focussed on the operational and service-level characteristics of these systems, we know very little about the factors that may influence ridership, such as user experience and satisfaction, and whether or not ODT services are successful in eliminating mobility barriers to improve activity participation.

This study intends to bridge this gap in research by investigating whether and how the launch of on-demand transit services has changed the nighttime activity participation patterns in Belleville, Ontario. In September 2018, the transit agency of Belleville started offering an ODT service for its residents. The underlying technology for this service is developed by Pantonium Inc., a Toronto-based mobility technology company. It enables passengers to hail and schedule transit trips on the city's nighttime bus using a mobile application. Passengers lacking access to a smartphone can also book the service by phone, email, or directly through the website. Busses would also pick up any passengers they saw waiting at bus stops as they drove by, but this behaviour was discouraged since passengers were subjected to very unpredictable wait-times unless others had specifically booked trips from the same stop at the same time. According to the transit agency, the number of registered users and ridership of this service have grown significantly since the launch of the ODT (City of Belleville 2019). Ridership increases are one indicator of success, but to understand what this represents in terms of societal benefit, it is imperative to understand where this ridership increase comes from. Is it due to mode-shifting, time-of-day shifting, or increases in overall activity participation? Of the three potential sources, we posit that increased overall activity participation rates are the most relevant and meaningful indicator of social benefit, as they most likely represent the elimination of transport barriers, according to the transport related social exclusion theoretical framework (Currie et al. 2010; Kenyon et al. 2002; Lucas 2012). To further understand the potential of ODT in providing sustainable service in low density areas or periods of the day, it is important to know the satisfaction of users and the factors that are most related to the changes in activity participation.

This study examines how the satisfaction of ODT users relates to changes in their activity participation. The data comes from a survey of ODT users that includes basic

socio-economic status, user experience, perceived changes in activity participation, and a detailed assessment of satisfaction. From the survey, we found that most of the respondents reported an increase in activity participation after the launch of ODT. To understand what specific factors influence activity participation, we used factor analysis and structural equation models to explore the relationship between satisfaction and activity participation. The results show that feeling satisfied with the reliability and service equality is associated with increased rates of activity participation. So, not only do governments need to offer new services, but the social outcomes they hope to achieve are clearly linked to the quality of the services they provide. Our findings reveal how ODT influences activity participation, and in so doing, provide a better understanding of the impacts of demand-responsive technologies on residents' daily life.

The rest of the paper is organized as follows. The next section contains a review of the literature on the transportation and social exclusion framework, and the contribution of on-demand mobility to the framework. The third section introduces the study context of this paper, providing details of the development of on-demand transit in Belleville. The fourth section covers research design and data collection, and the fifth section provides the model analysis and results. We provide a discussion with the implications of subsequent policies in the sixth section, and present conclusions in the seventh section.

Literature review

This article rests on the confluence of three streams of existing transportation literature. First, it draws on the transportation and social exclusion theoretical framework. This motivates the need to explore whether transport interventions can reduce the barriers to activity participation and derive social benefits for the community. Second, the work picks up on a growing body of literature focussing on operational considerations in the analysis of transportation equity. In particular, this paper focusses on the operational improvement targets of on-demand transportation, as well as the timing considerations of offering transit services during the low-demand nighttime period. Finally, this study draws on the transit satisfaction literature that provides scientific methodologies for measuring and assessing the user perceptions of transit service provision. We link these three strands by considering operational characteristics of ODT as an intervention on transport disadvantage, and by evaluating the success/failure of this intervention along the pathway to enabling increased activity participation among the transport-poor. Furthermore, we insert user satisfaction along the pathway, something that, to our knowledge, has not been done explicitly within an empirical investigation of transport and social exclusion. This literature review is structured around providing the reader with background in these three bodies of work, culminating in a conceptual diagram that lays the foundation for the theoretical and empirical contributions of this paper (Fig. 1).

Transport and social exclusion

There is a broad literature on the ways to eliminate transportation barriers and provide more opportunities for people to travel to their desired activity destinations. Prior research shows that the ability to engage in activities enhances well-being and, consequently, increases life satisfaction (De Vos et al. 2013; Ettema et al. 2011). In addition, activity participation has

Fig. 1 Adaptation of the transport and social exclusion theoretical framework. (Color figure online)

emotional benefits (Morris 2015), thus more trips can be associated with greater well-being and life satisfaction. For some disadvantaged groups who suffer from socio-economic and transportation deprivation conditions, barriers to travel can cause transport-related social exclusion. Such individuals are understood to be suffering from transport poverty, and are at risk of being excluded from participating in essential daily activities (Lucas 2012; Martens 2016). Therefore, eliminating transportation barriers for those suffering from transport poverty may generate social benefits by alleviating social exclusion (Currie et al. 2010).

Research has highlighted the role of car access because it can easily provide members in society with the freedom of travel (Blumenberg and Pierce 2014). These authors found that having access to a car is positively related to the likelihood of employment. Studies have also shown that not having a car may impair one's quality of life in automobile-oriented environments, since this can be a barrier to participating in meaningful activities, such as recreational activities, physical exercise, and social networking activities (Farber and Pérez 2009; Marottoli et al. 2000; Morris et al. 2020).

However, car ownership is not a panacea for eliminating transportation barriers, as it is difficult—and certainly undesirable—to give everyone access to a car. For socioeconomically disadvantaged groups, automobiles are expensive to own and operate, and may burden low income households and limit their spending potential on other essential goods and services (Kenyon et al. 2002; Mattioli et al. 2016). Many studies have demonstrated that people who don't have access to a car are often the poorest and most vulnerable members in society (Giuliano 2005; Lucas 2012), and those people must rely on active modes (walking, cycling), or public transit to get to their desired destinations.

Public transit agencies are facing challenges in eliminating transportation barriers for disadvantaged groups. In many North American cities, it is difficult to provide sufficient transit services in low demand areas or during low demand periods of the day, due to the high operational costs in relation to low revenues from fares (Bento et al. 2005; Giuliano 2005; Nourbakhsh and Ouyang 2012). Previous research has identified a range of groups in society that may be adversely affected by the unequal distribution of transit services, such as the elderly, young people, women, single parents, visible minorities, and people with disabilities (Foth et al. 2013; Lucas 2012; Pereira et al. 2017). These groups are also more likely to be excluded from mobility services due to their prohibitive prices (Mattioli et al. 2017). This is especially concerning given that income distributions are increasingly polarized, and that many socioeconomically deprived neighbourhoods in Canada are now

located in suburbs lacking frequent transit service (Hulchanski 2007; Walks and Twigge-Molecey 2014).

On-demand mobility technologies, such as online request systems and ride-hailing services, provide public transit agencies with novel opportunities to eliminate transportation barriers and alleviate transport-related social exclusion (Feigon and Murphy 2016; Wong et al. 2018). Public transit agencies can now provide more flexible services better adapted to passengers' demand, especially in areas or at times when transit demand is sparse. Many public transit agencies in North America have launched Mobility on Demand projects and partnered with transportation network companies (TNCs) to provide flexible and responsive transport service (DeVore et al. 2021; Parks et al. 2020). These projects aimed to provide services for people with difficulties to travel (disabilities), people who are outside the service areas of fixed route transit, and people who have difficulty completing the first mile and last mile of their commutes. New York City, Sacramento, and San Francisco have launched ODT services that allow riders to book transit trips by calling or using mobile on-demand apps (Zenasni 2019). Building upon these developments, our study documents how ODT influences activity participation, and we use this information to determine the nature of social benefits gained through ODT delivery of the Belleville night bus.

Operational considerations in transit equity

Transit level of service and accessibility have long been used to assess the equity in the distribution of transit benefits over space and between population groups (Currie 2010; Garrett and Taylor 1999). Shaheen et al. (2020) identified 5 dimensions of barriers to demand-responsive transport services (spatial, temporal, economic, physiological, and social), and advocated that policy makers and public transit operators should consider the potential equity impacts when assessing project performance.

More recently, in an attempt to better measure the user experience when assessing equity, researchers have begun to consider real-time measures of transit operational performance. For example, Palm et al. (2020) examined bus on-time performance in Toronto, and found that night bus routes that mainly serve marginalized groups underperform in comparison to daytime routes. Recent immigrants and carless households were further shown to experience lower on-time bus performance in comparison to other groups. In another study of bus bridging Liu et al. (2020) found that subway disruptions in Toronto were more likely to negatively influence the performance of bus routes serving disadvantaged neighbourhoods, as the transit agency tended to pull buses from its 10 min network, which predominantly serves suburban racialized communities.

To better understand transit performance and enhance accessibility for disadvantaged groups, researchers have generated new methods to analyze real-time datasets. Wessel and Farber (2019) questioned the validity of using General Transit Feed Specification (GTFS) data to measure accessibility and found that using GTFS data may overestimate net accessibility by 5–15 percent on average. They further showed how this estimation may vary by location, pointing to spatial inequalities and their potential impacts on equity assessments. Transit agencies are now increasingly using real time data to identify areas for service improvements (Mandelzys and Hellinga 2010).

As for methods, researchers are incorporating comprehensive data mining tools to measure accessibility scores and impacts of its unequal distribution. For instance, Wei et al. (2017) explored the ways of achieving optimal operational efficiency and equity in public transit service provision. They proposed a new method combining data envelopment

analysis and multi-objective spatial optimization to evaluate the overall performance of fixed route bus services operated by the Utah Transit Authority. By applying these new methods, researchers and policy makers are now able to better understand transit performance and enhance transit equity, both spatially and socially.

Despite these advancements in using operational performance in equity analyses, few studies have investigated whether improving the quality of transit service actually leads to increased activity participation (Farber et al. 2011; Roorda et al. 2010). This omission is especially true of service improvements involving the implementation of demand-responsive mobility services. Consequently, it remains unclear whether increasing service levels by applying an ODT solution will increase individuals' participation in social and economic activities, as claimed by the proponents of technology-driven solutions to public transit delivery. Furthermore, analyses on operational equity are often lacking or non-existent in less-populated regions of North America (Karner 2016). Although the US Department of Transportation has adopted guidelines to achieve environmental justice and transportation equity for Metropolitan Planning Organizations, most case studies remain focused on large regions. In Canada, since there is no strong legislative mandate to ensure service equity, its assessment on that front remains relatively scarce (Palm et al. 2020).

Transit satisfaction

It is important to link transit satisfaction to transit performance and activity participation, as satisfaction reveals the perceived transit service performance, and can ultimately influence whether changes in service provision will influence activity participation. Mamun and Lownes (2011) show that the integration of transit needs into transit accessibility indexing is important for evaluating existing transportation systems. They further find that transport disadvantaged groups are more sensitive to the performance of transit services, and that satisfaction levels may thus significantly influence their travel behaviors. It is less well understood whether the same is true for demand-responsive transit such as ODT. Cordahi et al. (2018) proposed an evaluation plan for Pinellas Suncoast Transit Authority (PSTA) in the US, who was partnering with transportation network companies (TNCs) to provide on-demand service. They pointed out that improving satisfaction of paratransit users with the transit system is one of the primary goals of the project. They emphasized comparing the satisfaction level before and after the launch of the service, but did not link satisfaction to increase of ridership or activity participation.

To assess the quality of transit services, previous studies have explored passengers' perceptions of transit performance through established indices (Eboli and Mazzulla 2007; Grisé and El-Geneidy 2018). The factors incorporated within these indices often include bus stop accessibility, route characteristics, frequency, reliability, cost, safety, information, etc. (Eboli and Mazzulla 2009). While these factors can help us understand how to improve the performance of public transit systems, rarely have they been used to test whether transit satisfaction is associated with activity participation. In this study, we intend to test if satisfaction with ODT service impacts activity participation rates.

Figure 1 illustrates how this paper fits within, and adapts, the transport and social exclusion theoretical framework of Lucas (2012). Previous studies have demonstrated that transport and socially disadvantaged groups face higher risks of social exclusion due to travel barriers and low accessibility (Martens 2015; Roberts and Babinard 2004; van der Kloof et al. 2014). This study intends to show that on-demand transit can combat transport related social exclusion by eliminating transport barriers and increasing accessibility for transport

Fig. 2 Map of the fixed route night bus alongside major transit demand sites of Belleville

disadvantaged groups. However, this effect is mediated by whether or not riders are satisfied with the new service. Since we don't have a valid measure of accessibility change due to ODT, a topic of important future research, we cannot directly measure the pathway from ODT through accessibility onto activity participation (the orange lines in Fig. 1). Instead, we test whether people who were satisfied with the new service report increased rates of activity participation (the dashed line in Fig. 1). While the role of user satisfaction in activity participation is our main concern in this paper, a secondary contribution is the investigation of operational characteristics of service delivery in alleviating transport poverty.

Study context

The City of Belleville (Fig. 2) is located along the Quebec City-Windsor Corridor and has a population of 50,000 people (Statistics Canada 2016a). Today, the manufacturing, packaging, food processing, distribution, and logistic sectors are the primary employment generators in Belleville, and the Canadian Forces Base located in the town of Trenton just west of Belleville is also a major contributor to the region's economy. Belleville is also home to Loyalist College, which is increasingly becoming a destination for international students who now account for 38% of yearly enrolments (Loyalist College 2020).¹ Spread over an area of 247 km², the majority of Belleville's municipal land remains rural, especially in the

¹ These figures pre-date the COVID-19 pandemic which has disrupted the flow of international students to Canadian institutions of higher learning.

northern and eastern parts of the city. Belleville's densest urban area is located along the Bay of Quinte and extends northward to just beyond Highway 401. In 2016, the majority of residents in Belleville commuted to work by car (78%), while active modes and public transit accounted for 6% and 2% of work trips, respectively (Statistics Canada 2020). Non-automobile modes receive a higher mode-share within particular population segments. For example, part-time workers or shift workers who leave for work between 12 p.m. and 4:59 a.m. had active mode and public transit shares of 13% and 7% of work trips, respectively, while 14% and 10% of commuting trips of workers aged 15 to 24 were made by active modes and public transit, respectively (Statistics Canada 2016b).

Prior to 2018, transit services in Belleville ended at 9 p.m. on Weekdays, 7 p.m. on Saturdays, and 6:30 p.m. on Sundays. Between January 2 and September 2018, the city offered a nighttime fixed route service. This original service was an hour-long, circumferential, fixed route service, operated by a single bus in each direction from 9:30 p.m. until midnight. The two buses used for the fixed route network were re-dedicated to an ODT service in September 2018, using the existing route number and drivers. The on-demand service runs from 9 p.m. to 12:30 a.m. on weekdays and 7:30 p.m. to 12:30 a.m. on weekends. To accommodate the growing demand, the City of Belleville added three more buses to the ODT system onwards from October, 2018.

During the pilot period, a smartphone app enabled users to book trips on the ODT bus route. Riders can specify desired pick-up or arrival times, pick-up and drop-off points, and the number of riders to be picked up. A call-in service is also available as an option, but only during regular business hours (e.g. 9–5 pm M-F). Users can book trips between any pair of bus stops in the city. The bus route is optimized in real-time according to the pick-up and drop-off demand points. In essence, the pilot brought the conventional bus service closer to a pooled ride-hailing experience. At the end of the year-long pilot, the service had approximately 3000 registered accounts, with rider numbers steadily increasing, especially as more busses were brought on to cope with the increase in demand. The City of Belleville contracted technology services from Pantonium Inc., a Canadian transportation technology company. Their delivery consists of the user-app, the back-end scheduling and routing system, and a dashboard tablet for each bus operator. At the time of the study, fares were paid by cash, ticket or pass cards, and were not integrated into the ODT application.

Research design and data

We designed and collected survey data from a sample of existing users of the ODT system. Partnering with Pantonium and the City of Belleville, as well as in accord with the University of Toronto Research Ethics Board, online questionnaires were sent to ODT users via email. The survey instrument consisted of five parts: (1) riders' recent travel behaviours, including trip purpose, frequency, and mode; (2) riders' reasons for using ODT services and their user experience; (3) riders' satisfaction with ODT services; (4) self-reported effects of ODT on activity participation and wellbeing; (5) each user's sociodemographic profile and their possession of mobility tools. The design of the survey was informed by focus groups and interviews conducted earlier in Belleville by the research team, as well as on past instruments used to assess transport and activity participation in Canada (Farber et al. 2018). The survey instrument (see Appendix B) includes a combination of multiple choice, Likert scale questions, and matrices allowing participants to provide information relevant to their travel behaviour and experience. It took about 15 min for a respondent

to complete the survey. After the responses were verified, we sent each respondent a \$10 electronic gift card via email. Recruitment information was disseminated via social media channels and paper fliers on the ODT night buses.

At the time of data collection, 2744 potential ODT users had created an account used to book trips, and 1342 of them had used the service at least once. This discrepancy is likely due to many people downloading the app or exploring the booking website out of curiosity upon hearing about the services on Canadian national news outlets. We only sent survey links to users who had completed one or more trips using the ODT service. The survey was collected from November 12 to December 21, 2019, somewhat later than the targeted September/October ideal collection period for most travel surveys. With a response rate of 19.60%, 263 responses were recorded. A similar survey from West Sacramento received a 14% respondent rate (City of West Sacramento 2019). Accordingly, we believe our sample to be an adequate representation of the ODT users in Belleville.

Analysis

Table 1 describes the socioeconomic status and mode availability of respondents. It also depicts the user experiences and changes in activity participation after the launch of the ODT service.

Socioeconomic attributes of respondents

From Table 1 we can see that many respondents in our sample may experience socioeconomic and transport disadvantages. The respondents in our survey are much younger than the City's overall population. The mean age of our sample is 29, whereas the mean age in Belleville is 43 (Statistics Canada 2016a). The data show that ODT users skew towards much lower incomes than Belleville, on average. According to Statistics Canada (2016a), in 2015, the median total income of individuals in the City of Belleville was \$30,661. 32% of the residents in Belleville earned less than \$20,000 in 2015, whereas 62% of the respondents in our survey reported earning less than \$20,000 per year. Roughly 30% of the respondents earn \$20,000 to \$40,000 per year, and only < 10% of the respondents earn over \$40,000 per year. The city-level percentages of middle- and high-income groups are 30% and 38%, respectively. Similarly, a mere 34% of the respondents in our sample have full-time jobs (the percentage of Belleville's full-time workers was 32% in 2016), whereas nearly half of the respondents have part-time jobs (the percentage of the City's part-time workers was 29% in 2016). In addition, 24% (64) of our respondents were students, among them, about 75% (48) were international students. The Census Profile (Statistics Canada 2016a) shows that only 17.62% of the population in Belleville were between 15 and 29 years. The high proportion of part-time employees and students in our survey may partially explain why our data skews towards younger and lower income brackets.

Transport disadvantages

The results from Table 1 also show evidence of transport disadvantages. In a region where nearly 80% of all work trips are done by car, only 6% of the respondents own a private

Table 1 Descriptive statistics of ODT users' profiles and their self-stated levels of satisfaction and activity participation

Socioeconomic variables	Measurement and unit	Cases/Mean	Percentages/S.E	Belleville city (Census subdivi- sion)
Age	Age of respondent	29	0.62	43
Male	= 1 if gender is male	127	48.7%	47.8%
Low income	= 1 if personal annual income is < \$20,000	109	61.9%	32.0%
Middle income	= 1 if personal annual income is \$20,000—\$39,999	51	29.0%	29.8%
High income	= 1 if personal annual income is > \$40,000	16	9.1%	38.1%
Full-time worker	= 1 if employment status is full time	89	33.8%	31.7%
Part-time worker	= 1 if employment status is part-time	121	46.0%	28.8%
Student	= 1 if the respondent is a student	64	24.3%	
<i>Mode availability</i>				
Car ownership	= 1 if respondent owns a car	15	5.7%	
Car access	= 1 if respondent has car access (or can borrow a car from friends or family members)	134	51.0%	
Changes in Activities	Significant decrease = 1; small decrease = 2; no change = 3; small increase = 4; significant increase = 5			
A1	Work	3.6	0.07	
A2	Groceries	36	0.06	
A3	Shop	3.6	0.07	
A4	Attend health care/personal care/other appointments	3.5	0.06	
A5	Participate in recreational or social activities (movies, entertainment, restaurant)	3.6	0.06	
A6	Visit friends or family	3.6	0.06	
Wait time	Less than 10 min	43	16.3%	
	11 to 20 min	67	25.5%	
	21 to 25 min	31	11.8%	
	26 to 30 min	42	16.0%	
	More than 30 min	80	30.4%	

Table 1 (continued)

Socioeconomic variables	Measurement and unit	Cases/Mean	Percentages/S.E	Belleville city (Census subdivi- sion)
In-vehicle time	It never took less time than a fixed-route bus trip	66	25.1%	
	It seldom took less time than a fixed-route bus trip	46	17.5%	
	It sometimes took less time than a fixed-route bus trip	85	32.3%	
	It often took less time than a fixed-route bus trip	45	17.1%	
	It always took less time than a fixed-route bus trip	21	8.0%

Fig. 3 Changes in activity participation. (Color figure online)

vehicle. In addition to low levels of car ownership, only half of the respondents in our sample can count on their friends or family for a ride. Coupled together, the socioeconomic disadvantage and transport disadvantage imply that respondents in our sample are more likely to become transport poor. Previous studies found that transport poor, such as low-income earners, zero-car families, and immigrants have a significantly higher transit mode share (Blumenberg and Evans 2010; Polzin and Chu 2005). The launch of the ODT service may offer them better transit services, and a solution to reduce the risk of social exclusion.

ODT satisfaction and participation impacts

Figure 3 demonstrates that many respondents report increase in activity participation since adopting ODT (blue bars in Fig. 3). The most significant increases in trip purpose are for: work, recreational or social activities, visiting friends and family, groceries, and other shopping. There were also a small number of users who reduced activity participation after the launch of ODT. In our model, we removed school and go to gym/physical activities because only a small portion of respondents reported an increase/decrease in these activities as the services were offered at night.

In addition to increased activity participation, it is important to see if respondents have positive user experience and are satisfied with the ODT service. In our survey, nearly 30% of the respondents have to wait for longer than 30 min to get on the bus. Similarly, the actual average wait times retrieved from the interface (Sanaullah et al. 2019) found 33% trips with the riders waited for over 30 min, whereas about half of the users gave the waiting tolerance time of 15 min when booking their trip. Longer wait time may affect users' level of satisfaction towards the ODT system and alter their travel behaviours. That said, about 60% of respondents reported that the average in-vehicle time of the ODT services is

Table 2 Satisfaction levels with different aspects of the ODT service

	Measurement and unit	Mean	S.E
Satisfaction with ODT	Very unsatisfied = 1; a little bit unsatisfied = 2; neutral = 3; satisfied = 4; very satisfied = 5		
Q1	The user interface of the app	3.35	0.08
Q2	The user interface of the website	3.38	0.08
Q3	Availability of schedule/maps/fares	3.40	0.08
Q4	Operating hours of transit service	3.13	0.08
Q5	Accessibility to nearest/most convenient transit stop	3.75	0.08
Q6	Availability of bus when requesting	3.20	0.08
Q7	Speed of the system handling an on-demand request	3.25	0.08
Q8	Average wait time of the bus	2.71	0.09
Q9	Reliability: detour or delay	2.95	0.09
Q10	Directness/number of transfers	3.38	0.09
Q11	Competence and manner of drivers	4.01	0.07
Q12	Personal security	3.95	0.07
Q13	Bus stop maintenance	3.62	0.08
Q14	Service quality of customer center	3.55	0.08
Q15	Cost affordability	3.42	0.09

less than the previous fixed bus route system, which in turn may also increase the satisfaction of users towards the service.

Exploratory factor analysis of user satisfaction

To fully understand the satisfaction of riders and prepare for the path analysis, we conducted an Exploratory Factor Analysis (EFA) to divide the factors into subgroups. EFA is a frequently used analytical tool in social science. The method can be used with novel or exploratory research scenarios as a precursor to latent variable modeling or confirmatory factor analyses (CFA) (Schumacker and Lomax 2004). In our study, we intend to use EFA to reduce 15 measurements of user satisfaction from the survey instrument to a smaller number of components, uncovering latent dimensions underlying the data set. Table 2 shows the scores of 15 satisfaction indicators measured on 5-point Likert scales. The table indicates that the respondents feel overall satisfied with the ODT service. The aspect of the ODT service that respondents report being most satisfied with is Q11, the competence and manner of drivers, whereas the aspect they report being least satisfied with are Q8 and Q9, wait time and reliability, respectively.

As seen in Table 3, the EFA depicts four latent aspects of ODT satisfaction: user interface, accessibility, reliability, and service quality. To evaluate the effectiveness of our factor analysis, we use the regression factor scores and Cronbach's alpha. Larger regression scores indicate better prediction. The Cronbach's alpha coefficients for the four items are larger than 0.8, which suggests that the items have relatively high internal consistency.

Table 3 Results of Exploratory Factor Analysis of Satisfaction with ODT Service

Variable number	Factor name	Factor loading	Correlation of (regression) scores with factors	Cronbach's alpha value
<i>Factor1: User Interface</i>				
Q1	The user interface of the app	0.794	0.90	0.83
Q2	The user interface of the website	0.665		
<i>Factor2: Accessibility</i>				
Q3	Availability of schedule/maps/fares	0.642	0.89	0.80
Q4	Operating hours of transit service	0.578		
Q5	Accessibility to nearest/most convenient transit stop	0.589		
<i>Factor3: Reliability</i>				
Q6	Availability of bus when requesting	0.749	0.95	0.89
Q7	Speed of the system handling an on-demand request	0.795		
Q8	Average wait time of the bus	0.837		
Q9	Reliability: detour or delay	0.753		
Q10	Directness/number of transfers	0.501		
<i>Factor4: Service Quality</i>				
Q11	Competence and manner of drivers	0.848	0.94	0.84
Q12	Personal security	0.864		
Q13	Bus stop maintenance	0.554		
Q14	Service quality of customer center	0.591		
Q15	Cost affordability	0.435		

Structural equation models

Next, we employ structural equation models (SEM) to investigate how the above latent factors combine with the delivery of the ODT services to affect changes in activity participation. SEM is a powerful tool increasingly used in travel behaviour research to incorporate endogenous and exogenous variables, as well as latent (unobserved) variables such as attitudes and preferences. Several past studies have used SEM to show that attitude towards travel modes can play an important role in mode choice (Zhao and Zhang 2018), and travel frequency (van den Berg et al. 2013). Some studies used SEM to deal with mediating effects on travel behavior, such as attitudes or perceptions that can mediate the effects of the built environment (Lin et al. 2017; Ma and Cao 2019). SEM can also depict complicated relationships between exogenous variables such as socioeconomic status, built environment, and travel behavior (Ding et al. 2017). In our model, the four satisfaction factors obtained from our factor analysis are taken as exogenous latent variables, and we hypothesize that they positively influence changes in activity participation.

The estimation of SEM follows the two-step approach by Anderson and Gerbing (1988). We first performed CFA to provide latent constructs that enter the second step of the SEM. In the factor analysis, we used the satisfaction matrix to measure users' assessment of ODT. Accordingly, these four factors (latent constructs) form the measurement model. The measurement model enables us to use multiple indicators of each latent variable and to isolate measurement errors. In step two, we combine the measurement model, derived in the first step, with a linear path model to construct the SEM. The path analysis portion of the model shows the theoretical causal linkage between the latent variables.

When estimating the model, R removes any observations that contain missing values for any input variable. Given our small sample size, we employed multiple imputation to fill the missing values in our dataset which has been shown to be effective in the literature (Carpenter and Kenward 2012). Instead of replacing the missing value with the mean or median, multiple imputation uses the distribution of the observed variables to estimate multiple possible values for the data points. This allows us to account for the uncertainty around the true value, and obtain approximate unbiased estimates. We apply the *MICE* package in R to conduct multiple imputation. It creates multiple copies of the dataset, using imputed values to replace missing values. The imputed values are sample from their predictive distribution based on the observed data. For our analysis, we created 100 datasets, and used them to estimate 100 SEM models, similar to bootstrapping methods that readers may be more familiar with.

In each iteration, we estimated the SEM using the *lavaan* package in R, with covariance matrices as data inputs and maximum likelihood estimation. We assume that satisfaction with ODT service, user experience, and socioeconomic status will influence activity participation. We use latent variables to present satisfaction and activity participation and use several exogenous variables to describe user experience and socioeconomic status. The change in activity participation is our dependent variable. We intend to explore if satisfaction with ODT associates with decrease, increase or no change in activity participation. In the SEM, we use a measurement model to generate one latent variable using 6 variables (changes in work trips, changes in grocery trip, etc.). The standardized loadings show the relationship between the latent variable and the inputs (factors). The loadings can be interpreted as normalized regression coefficients. We fix

Note: Exogenous variables are in the square boxes; latent exogenous variables are in the oval boxes.
The diagram presents the SEM parameter means

Fig. 4 Path diagram of the effects of ODT and user satisfaction on activity participation

the first factor loading to 1, to determine the variance of the latent variable, and increase the number of free parameters. Each standard deviation increase in the latent *Activity Participation*, corresponds to a 1.4 standard deviation increase in *Grocery*, etc.

We look at the distribution of p-values of the tested variables, and conclude that 5 variables are significant: satisfaction with reliability, satisfaction with service quality, wait time, in-vehicle time, and gender. A detailed description of our selection criteria appears in Appendix A and a path diagram summary of our final SEM model is presented in Fig. 4.

The total effects of exogenous variables are presented in Table 4. The table also presents the 3rd and the 97th estimation, which depicts the 94% empirical confidence interval based on 100 imputation iterations. It is worth noting that there are no endogenous variables in our model, which means that all of the effects we observe are direct. The interpretation of the effects is similar to standardized regression coefficients. A one standard deviation change in a independent variable is associated with a B-standard deviation change in the latent *Activity Participation* factor. SEM tests the relations among variables, and cannot be used to infer causality between the variables.

The results indicate that satisfaction with ODT positively influences activity participation. Although satisfaction with user interface and accessibility are insignificant in our model, the satisfaction with reliability and service quality are positively associated with activity participation. User experience can also influence activity participation. Respondents who reported longer wait times have a less pronounced increase in activity participation. Longer wait times are also found to decrease the satisfaction with ODT, and prevent users from participating in activities at night. Interestingly, respondents who have longer in-vehicle times are more likely to display higher activity participation. We believe this may be due to in-vehicle times associates with travel distance; at night travelling by ODT is often safer and more comfortable than walk or cycling, especially for long-distance trips.

As for the socioeconomic and mode availability variables, our results show that women display a higher increase in activity participation than men. Once again, this may be the added safety that ODT provides women at night. Other variables such as

Table 4 Standardized direct effects for the SEM (N=263, 100 models)

	Changes in activity participation		
	Mean	3rd Percentile	97th Percentile
<i>Latent exogenous variables</i>			
Satisfaction with user interface	–	–	–
Satisfaction with accessibility	–	–	–
Satisfaction with reliability	+0.200	+0.268	+0.128
Satisfaction with service quality	+0.143	+0.182	+0.100
<i>Exogenous variables</i>			
Male	–0.129	–0.078	–0.176
High income (> \$40 k)	–	–	–
Part-time worker	–	–	–
Car access	–	–	–
Wait time	–0.034	–0.013	–0.056
In-vehicle time	+0.060	+0.087	+0.029
<i>Model fit statistics</i>			
Chi square	643.10	694.19	604.93
Number of free parameters	58	58	58
Degrees of freedom	299	299	299
Root mean square error of approximation (RMSEA)	0.066	0.071	0.062
Comparative fit index (CFI)	0.916	0.912	0.888

A “–” sign indicates that the effect was tested but found insignificant

Fig. 5 Distribution of goodness-of-fit for the 100 SEM models

income, employment, and car access are found to be insignificant in our model. A reason for this may be the high occurrence of transport poverty in our sample (i.e. respondents with below average incomes and limited access to private vehicles). Demand-responsive transit services may significantly improve the activity participation of those in transport poverty, but our data does not allow us to differentiate between subsets of transport poor.

Figure 5 shows the goodness-of-fit of the 100 models. The mean of Comparative Fit Index (CFI) is 0.90, and the mean root mean squared error of approximation (RMSEA) is 0.07. The recommended values of CFI should be larger than 0.90. And the cut-off values of RMSEA should be 0.05 for a good fit and less than 0.08 for a reasonably close fit (Acock 2013). According to these criteria, our SEM model is acceptable, especially given the small sample size.

Discussion

This paper examines whether demand-responsive technologies, such as ODT, provide social benefits for disadvantaged residents in low demand areas or during low demand periods of the day. Our case study suggests that ODT in Belleville is doing more than just replacing fixed-route buses. It has significant social benefits by increasing ridership at night, and providing flexible and affordable transit options to disadvantaged segments of the population. In addition to alleviating the risks of social exclusion by improving accessibility, our study shows that improving the quality and performance of the ODT services can increase ridership and users' activity participation.

The results indicate that that ODT services present a new solution to combat social exclusion. The majority of ODT users in our study belong to low income categories, and only 5.7% of them own a private automobile. The ODT service enables these individuals to participate in various activities at night, including employment, groceries, entertainment, and social activities. It also provides a safe and comfortable transit option for women shift workers, which in turn may improve their mobility and well-being.

The changes in social trends and travel patterns also confirm the potential benefits of the ODT services. Many studies found that today's teenagers and younger adults are making fewer car trips than previous generations (Blumenberg et al. 2012; McDonald 2015). They are also shifting to alternative travel modes. A recent study in Germany found that public transit use and active modes (cycling) have been more popular amongst young generations (Krueger et al. 2019). Similarly, researchers found that the emergence of shared mobility, and increased dependence on information communicate technology (ICT) are creating more travel opportunities for young adults (Klein and Smart 2017; Thigpen and Handy 2018). Given the widespread availability of cell phones and web access, providing ODT services could yield substantial impacts on travel patterns and lifestyles.

This study shows that transit performance improvements need to be incorporated within equity considerations. In addition to improving transit accessibility, improving transit performance would also encourage transit ridership and activity participation. Previous studies have found short wait times to be critical for public transit (Rayle et al. 2016; Yoh et al. 2011), and these factors are likely as important for ODT users. During interviews and observations of the ODT riders, operators, and managers in Belleville, the issue of customer tracking came up repeatedly. In particular, for privacy concerns, the transit agency made the decision to not use the mobile app to track users with GPS, and users and drivers are not penalized for non-adherence to service assignment. This has led to longer wait times and lower reliability by causing "ghost" pick-ups and drop-offs, when busses are routed to stops but there are no riders to pick up or drop-off. Solving these issues will likely lead to higher levels of satisfaction, use, and most importantly, increased levels of activity participation among the transport poor.

This study further shows satisfaction with reliability and service quality are significantly associated with activity participation. These in turn, help us understand the determinants of activity participation, and provide an opportunity for transit planners and operators to take the needs of residents into account when designing transit services. Early, continuous, iterative community engagement is essential to ensure user satisfaction and equitable outcomes. Community members can provide comments on project design and resource distribution. When the project is launched, they can also help transit agencies assess if the services are truly serving their needs and provide feedback to adjust services accordingly (Shaheen et al. 2017). Specifically, when designing interventions for the transport poor, transport planners must consult with marginalized populations to ensure they are given better access, but also that they are satisfied and willing to use the new services. For example, it may be useful to design a multiple-language user interface to help immigrants and international students use on-demand transit services. For mobile-based transit services, having in-app mechanisms for feedback will allow users to directly express their comments and suggestions. Shaheen et al. (2017) also mentioned that successful marketing and advertising will re-brand transit service into something riders feel proud to use and will attract ridership from deprived neighbourhoods. Planners and transit agencies can cooperate with research teams and community groups to assess resident needs and community feedback of mobility pilots. Before and after surveys, on-board transit rider surveys, community meetings, and public hearings across the region are useful methods to evaluate the transit projects.

Finally, it is worth noting that this paper has several limitations. First and foremost, our data comes from a retrospective survey in which changes in activity participation were all self-reported. Despite this limitation, our survey provides the best available data in our study area on this ODT service. If access to industry and membership data becomes available, future studies should consider using actual changes, rather than reported changes, in order to reduce the possibility of memory-related biases. This also serves as a reminder to researchers that forming evaluation partnerships well in advance of pilot implementation is more desirable than coming to the table later in the process. Second, the sample size of the survey is not very large. We acknowledge this limitation and use multiple imputation to fill missing values and alleviate potential bias of the small sample size. Using 100 SEMs with imputed datasets, we obtain robust parameters and test the hypothesis that satisfaction with ODT can influence activity participation. Given the small sample size, the model results could be viewed as conservative, and we would likely find higher levels of significance, or more significant factors, if we had more data. Third, this study does not analyze the specific travel routes of respondents. Residential location, origin and destination likely also influence activity participation, but we are unable to capture these factors. Moreover, we only collected information on ODT users, and do not know the barriers that may face non-ODT users, or would-be ODT users were it not for these barriers. For instance, the majority of our sample are young people, and we don't know why there are so few older people in our sample. This may be because older people are less likely to travel at night, but it may also be due to the lower rate of smartphone usage in older adults, and their potential unfamiliarity with the technologies required to request on-demand mobility (Young and Farber 2020). According to the Belleville Transportation Master Plan (City of Belleville 2014), by 2036, the 55+ age group will represent 47% of Belleville's population and international evidence suggests that trip rates by public transit for tomorrow's seniors are expected to increase (Currie and Delbosc 2010). Future studies should explore whether ODT service can encourage the activity participation and fulfill the travel demands of older people. Although exploratory, the findings in this study suggest that ODT services expand

residents' mobility options, especially in small towns like Belleville where the those without a private car have very few options.

Conclusions

This study investigates how demand-responsive transit, such as ODT services, may encourage activity participation rates by reducing transportation barriers. It examines the determinants of activity participation of ODT users in Belleville, Ontario using a custom ridership survey instrument. The results suggest important positive social outcomes: ODT services can eliminate transport barriers for disadvantaged groups, and may reduce the likelihood of social exclusion. The evaluation of user satisfaction with regards to the ODT service demonstrates the importance of incorporating such measures within evaluations of transport and social exclusions. In this case, positive perceptions of reliability and service quality was significantly associated with increased activity participation. Actual service performance is further shown to positively contribute to activity participation. Finally, the results make a strong case for other transit agencies to adopt similar services. In terms of policy implications, this study suggests that when designing a transportation system or transit project, it is crucial to take residents' needs and preferences into account, and to incorporate community inputs along the way. Doing so will ensure user satisfaction, as well as their willingness to use the new transport services, and ultimately, the likelihood of unlocking suppressed demand for activity participation amongst the transport poor.

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Declarations

Conflict of interest On behalf of all authors, the corresponding author states that there is no conflict of interest.

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