Why Not Hail a Bus-ride? Evaluation of an On-Demand Transit (ODT) Service in Belleville, Canada

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ABSTRACT

The rapid increase in technology-based transportation, availability of GPS data, mobile applications and effective communication have led to the emergence of On Demand Transit (ODT) systems. In September 2018, the City of Belleville in Canada started an on-demand public transit pilot project, where the late-night fixed Route (RT 11) was substituted with the ODT providing a real time ride-hailing service. This study provides an in-depth and unique analysis of the spatio-temporal demand, supply, level of service, and origin and destination patterns of ODT users based on the data collected from September 2018 till May 2019. The results indicate that ODT trips demand is highest for 11:00pm-11:45pm and 8:00pm-8:30pm for weekdays and weekends, respectively, as most of the individuals are using ODT for commuting back to home from their work. In terms of waiting time for the bus, 39% of trips were found having the waiting time of less than 15 minutes while 28% trips with 15-30 minutes of waiting time. The higher number of ODT trips were created from the zones with higher population density; higher percentage of people belonging to working age group (15-65) and fall into the category of middle-income class.

Keywords: On-Demand Transit, Ride-hailing, Supply Optimization, Demand Patterns

INTRODUCTION

The main challenge with the conventional public transportation system in low population density areas is to maintain a reasonably high frequency and the operating cost per trip. During peak hours, the use of buses may be high, but for a big portion of the day they may run vacant. This affects the efficiency, sustainability and operating cost of the system. Therefore, it is necessary to incorporate advanced design and operations techniques within the traditional fixed route bus service to make it more efficient and suitable for the dynamic demand of users. The rapid increase in technology-based transportation, availability of GPS data, mobile applications and effective communication have led to the emergence of On Demand Transit (ODT) system (Alemi et al., 2019; Archetti et al., 2018; Djavadian and Chow, 2017). An attractive option is to merge the best of both services to fulfill the total demand i.e. running a fixed service during high demand and ODT in low demand periods. Such solution has recently been employed by the City of Belleville as the *"Pantonium-Belleville On-Demand Transit pilot project"* that started in September 2018. To the best of our knowledge, it is the first-of-its-kind case study where Pantonium in collaboration with Belleville, Ontario Public Transit, replaced the late-night fixed Route (RT 11) with the ODT service. The service is provided for the timings of 9:00pm-12:00am during the week and 7:30pm-12:00am on the weekends. Users can book a trip request through mobile app named as *"on demand transit"*, via online portal, and through the call centre. For booking a trip, rider provides the information regarding pickup and drop off locations, the time for pickup, the tolerance time and the number of riders to be picked. After requesting a trip, user can track the bus location, change the pickup time, rider count or cancel the trip. Through driver's application, the bus drivers get direction to navigate through different stops to serve riders and can have ad-hoc stops where needed.

Previous studies related to ODT have either focused on the specific group of users (elderly, disabled and deprived) or investigated very limited factors of supply and/or demand at individual or zonal levels. Recent related research on ride-hailing (Uber and lyft) services (Alemi et al., 2019; Young and Farber, 2019) are based solely on the user's survey data and therefore couldn't provide insight into trips analysis for spatio-temporal demand, supply and level of service and origin and destination patterns.

Having access to the unique dataset on the operations of Belleville ODT from Sep 2018 till May 2019, we investigated the performance of the service in terms of responsiveness, frequency of usage, waiting time (difference between time requested by rider and actual bus arrival time), most frequently used stops and trips demand pattern. Moreover, the DA level zones with higher ODT demand, trip origins and destinations were identified and the impact of sociodemographic characteristics of these zones were explored. This leads to a more robust and complete spatio-temporal demand, supply and level of service analysis that is based on the trips, trip-users, GPS and stops location data.

The remainder of the paper is organized as follows: Section 2 presents a background on the studies related to ODT system followed by the Section 3 on data description and methodology. Then Section 4 presents the results and discussion on spatio-temporal demand, supply and level of service and origin and destination analysis. Finally, the paper ends with conclusion and future research.

BACKGROUND

On Demand Transit (ODT) service is defined as a public transport with flexible and updated routing system based on the real-time demand information and auxiliary data (Häme, 2013; Wang et al., 2014). It is considered transitional mode of public transport mostly provided in low density and less demand areas where traditional bus service is not cost effective and efficient (Papanikolaou et al., 2017; Davison et al., 2014; Koffman, 2004). As traditional fixed route transport services are not economical and efficient particularly in low density areas, ODT is one of the most suitable solution to meet the required transport demand by using the real time vehicle location and information (Papanikolaou et al., 2017).

The potential benefits of ODT includes higher efficiency, increased coverage and convenience with flexible pick up and drop off locations, flexible scheduling of timings, increased ridership, better facility for low demand and low-density areas and enhanced and cost-effective mobility for all users (Khattak and Yim, 2004; Papanikolaou et al., 2017). It can also be used as a solution to "first/last mile" transit problem and as a feeder to the fixed route transit (Djavadian and Chow, 2017).

Khattak and Yim (2004) investigated the user's behaviour and perspective for Demand-Responsive Transit (DRT) service in San Francisco Bay Area to evaluate the user's tendency for DRT system. Respondents were strongly willing to use and even pay more for DRT system as compared to the traditional bus routes. They gave priority to the factors of reliability, flexible setting for pick up times and comfort of picking up and drop off stops.

Li and Quadrifoglio (2010) proposed a methodology to assist the policy makers to better decide the application of DRT system for feeder transit as compared to conventional fixed route bus services. The simulation models were developed to calculate the performance of DRT and fixed route bus services for different user's demands and the size of service areas. It resulted into finding the critical converting points (based on user's demand densities) between DRT and fixed route services. For the purpose of performance evaluation, the factors of user's walking time, waiting time and riding time were considered. The performance of DRT system was found better for less demand rates, when higher values were used for the weight of walking time and when the percentage of drop off users found higher. Wang et al. (2014) explored the socio-economic factors affecting the demand of ODT for the metropolitan region of Greater Manchester. Demand for ODT was found higher in the areas with low population density, less private vehicle ownership, higher percentage of white people and higher level of social scarcity. Wang et al., (2014) stated that very few studies have been conducted to evaluate ODT demand based on area wide data which would result in overlooking the factors which might have a significant impact on DRT system.

Papanikolaou et al. (2017) conducted a research to explore the critical parameters required for the successful operation of DRT system and to find out the deficiencies in procedural elements. This study presents a general theoretical assessment framework to evaluate different DRT cases in comparison to traditional public transport based on network and demand characteristics. Recently, Archettti (2018) performed a simulation study to evaluate the ODT system for its potential benefits. The results suggested that ODT system might be able to fulfill the higher percentage of users' dynamic nature of transportation demand and its efficiency increased with greater number of users' requests.

Alemi et al. (2019) investigated the factors affecting the frequency of use of ride-hailing services (Uber and Lyft) in California using data from September till December 2015. The results

indicated that frequency of using ride-hailing increases with the higher activity density and decrease with the increase in mixed land use. In addition, sociodemographic factors found to have significant influence on the adoption of the service, however, they didn't show any impact on usage frequency. Another ride-hailing study was conducted by Young and Farber (2019) for Uber in the city of Toronto. They used Transportation Tomorrow Survey (TTS) (household travel survey data, 2016) to compare the ride-hailing user's trips and socioeconomic characteristics to that of the users of other modes of travel. They explored the impact ride-hailing can have on the level of ridership of other modes of travel in the city. Most of the users of ride-hailing were found to belong to the younger and Millennials generation (20 to 39 years old) and with the annual household income of $100,000 or more. They concluded that ride-hailing has caused the substantial reduction in the ridership of taxi and as people will get more familiar with ride-hailing in future, it might affect the ridership of other modes of travel. As this study only used a 5 % of the population, it is limited in terms of a more complete understanding of ride-hailing trip characteristics. Moreover, as TTS represents only one typical day, the temporal analysis was not carried out. One of the small North American town Innisfil (40,000 residents) has also tried to use Uber (subsidized rides) instead of providing people with public transit which would have cost almost $1m in 2017. Initially the plan seemed successful, however, after two years it is costing more ($ 1.2m in 2019) than running a bus service. In addition, it didn't prove to be a sustainable solution as it resulted in to a greater number of cars on the road, which raised the concerns about greenhouse gas emissions and air quality (Cecco, 2019).

Previous studies established that the fixed route bus services are not suitable for low density and less demand areas and therefore ODT is not only the appropriate option to meet the dynamic demand of the users but also to provide a higher level of service (Archetti et al., 2018; Papanikolaou et al., 2017; Wang et al., 2014, Edwards and Watkins, 2013; Khattak and Yim, 2004).

Based on previous studies it can be concluded that there are supply and demand (area wide as well as individual level) factors, which can affect the operations of ODT (Wang et al., 2014; Brake et al., 2004). The supply side factors include routing, scheduling, booking of trips, types of vehicles, location tracking, communication, the fleet size (FS) and level of service (i.e. responsiveness, waiting time). While demand side factors include the frequency of users of ODT, the distribution of trips over time and space and origin and destination pattern. In most of the supply related studies only limited characteristics of the ODT system have been studied and demand related studies found to be only focused on the specific group of users for instance old, disabled and deprived people. In addition, there is a lack of research in spatial demand analysis for ODT (Wang et al., 2014). In this study detailed supply and demand side factors and their interactions have been investigated. More specifically, an extensive analysis related to spatio-temporal demand, supply and level of service, and origin-destination pattern is carried out.

DATA DESCRITPION and METHODOLOGY

This study is based on the unique data collected from *Pantonium-Belleville On-Demand Transit pilot project* from September 18, 2018 till May 29, 2019. Belleville is a city located on the Bay of Quinte in Central Ontario and is considered as the centre of the Bay of Quinte region with the population density of 205 per square kilometer. The population of the city has grown to 50,716 (2.6% increase from 2011) residents according to the Census of year 2016, with 48% males and 52% females. There are 22,744 private dwellings with an average household size of 2.3 individuals. Almost 63% of the population belongs to the age group between 15 and 65 years old

which is considered as the middle group of age and shows the population of working age. About 21% of the population is older than 65 years and almost 16% of individuals are younger than 15 years. The median age of population is 44 years old, which is higher than the national median age of 41 years old. According to the Census of 2016, median household income (after-taxes) in Belleville is $53,367, as compared to the national average at $61,348. Most of the residents of Belleville are Caucasian (90%) followed by Aboriginal (4%) and South Asian (1.3%). Due to a strong industrial background, the main jobs created in Belleville are related to production, packaging, food processing, supply and transport. According to the city transportation plan (2014), Belleville Transit service covers 9 routes throughout the city with 15 buses running 7 days a week.

According to National Household Survey conducted by Statistics Canada in 2011, 78% of the individuals use their own vehicle, while only 4% of the trips are made by transit to go to work. Regarding the distribution of trips, about 54% of the jobs in Belleville are held by the people living in Belleville and the rest of workers commute every day residing in Quinte West or Prince Edward. (Statistics Canada, 2011).

The shift workers in Bellville did not have good public transit options to travel at night in the industrial park located at the north end of the urban area. To deal with this issue, the night bus service was introduced to connect the industrial park with the city. Due to low demand, the service was operationally expensive and could not maintain a high frequency. With the help of Pantonium in September 2018, it was converted to ODT to increase the efficiency, ridership and providing service to all the users particularly shift workers and students to make their mobility easier at night time.

The data used in this research include trips data, trips users' data, stops data and the GPS data for completed journeys as shown in the Figure 1. There were 14,132 trips and 310,520 GPS points in total to be used for the analysis. Trips data have the information about trip planned date, origin and destination IDs and their location (longitude and latitude). Trips origin and destination locations were matched to the stops locations to extract the pick-up and drop off locations for OD analysis. Most frequently used stops were further analysed for the origin destination pattern for their respective trips. Trips user's data contain the information about trip creation and requested time, actual bus arrival time and the number of riders per request. Information on requested trips was combined with the data of bus's actual arrival time to sort out the information on completed and cancelled trips. Further the UTC timings were converted into local time and average waiting time was calculated for the level of service analysis. While stops data include the information about users ID, pickup and drop off stops, timings and the status of trip (assigned, not assigned, cancelled). This data was used for trip assignment analysis based on trips booking method and the individual demand analysis. Furthermore, the data provide insights into user's trip purpose and movement pattern. The GPS data of journeys were projected on DA level zones of Belleville using GIS package (QGIS). In addition, DA level zones and their demographic data for the city of Belleville was used to explore the demand level analysis. The GPS points of stops were also projected to see the ODT stops locations on map.

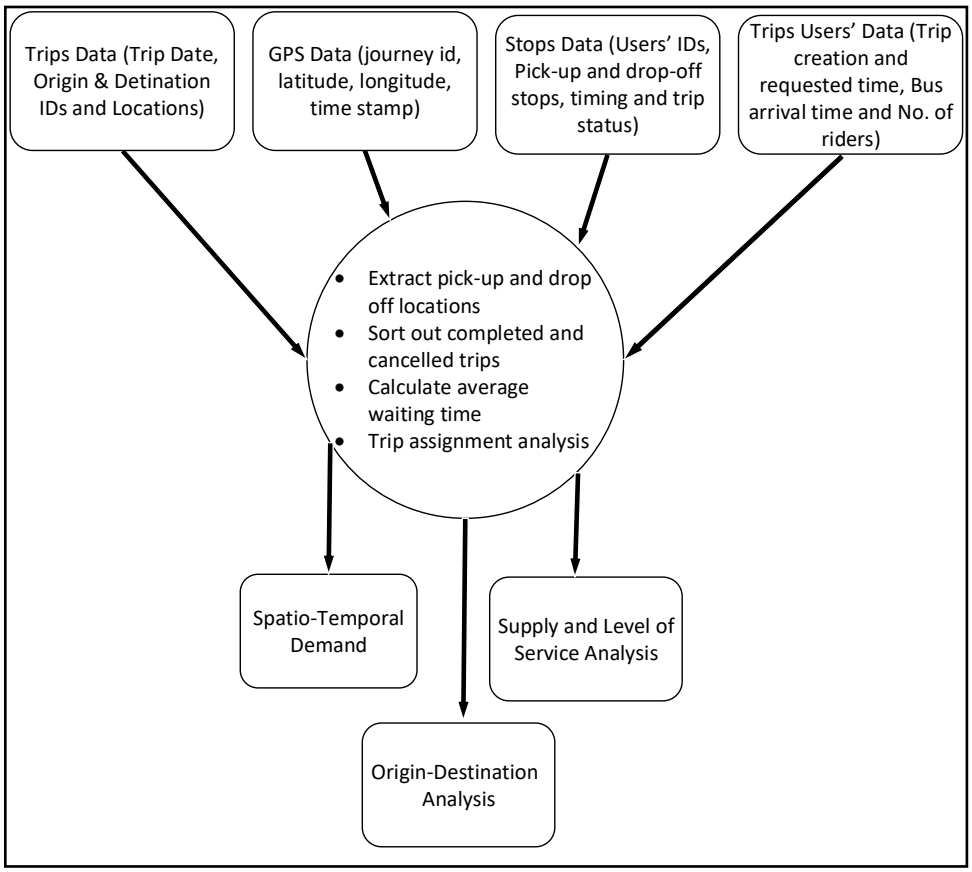


Figure 1 Steps of analysis

RESULTS AND DISCUSSION

This section first analyses the spatio-temporal travel patterns of ODT usage in Belleville at zonal and individual levels. Supply characteristics are then analyzed in detail. In the end the origin-destination demand patterns are analyzed.

Spatio-Temporal Demand Analysis

Table 1 presents the usage frequency of the On-Demand Transit service for 3 months (October to December 2018), as the individual level data was only available for these three months. The total users of ODT app are 2,074, out of which 1,420 are active and 654 non active users. The active users are further classified into frequent and infrequent users, based on the classification suggested by Alemi et al. (2019), where the users who used ride-hailing "at least once a month" were considered as frequent users and those who used ride-hailing "less than once a month" were taken as "infrequent users". In this study, the users who used ODT "3 times or more in a month" are considered "frequent users" and who used "less than 3 times in a month" are classified as "infrequent users". As shown in the Table 1, the percentage of infrequent users of ODT (62%) is more than the percentage of frequent users (6%), however, the trips made by frequent users are greater (54%) than the trips completed by infrequent users (46%). To some extent, this is consistent with the results of other recent study (Alemi et al., 2019), conducted to find the factors impacting the frequency of use of ride-hailing in California (Uber and Lyft).

TABLE 1 Frequency of use of ODT

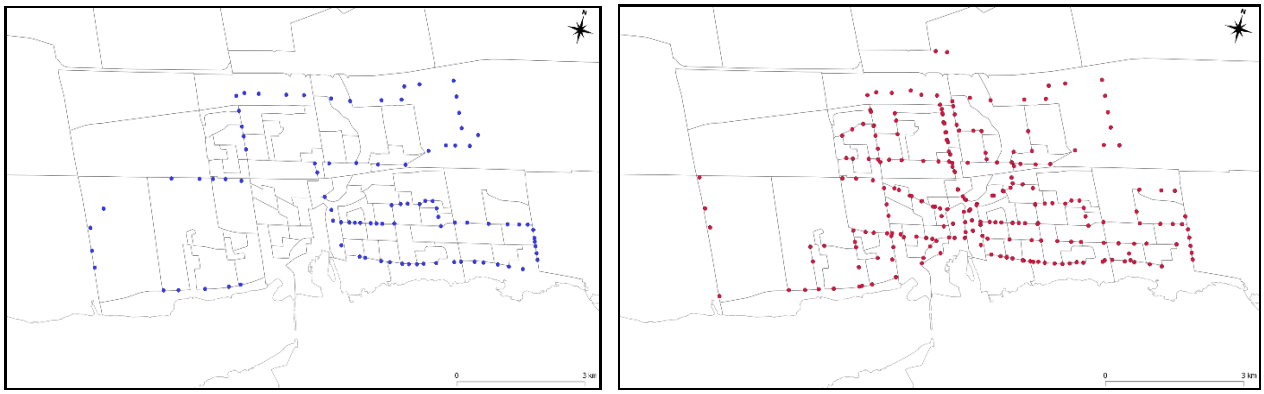
Users/Trips	Frequent Users	Infrequent Users	Non-Active Users	Total
Users	134	1286	654	2074
Users %	6%	62%	32%	100%
Trips	2584	2204	0	4788
Trips %	54%	46%	0%	100%

Table 2 shows the ten most frequently used pick up and drop off bus stop locations for ODT service in the Belleville area for the duration of 9 months (September 2018-May 2019). From pickup point of view Walmart has the highest usage frequency (21.92%) followed by Terminal (10.50%) and Jamieson Bone and University Avenue (7.84%). While for the drop off purpose, Terminal (6.50%) is the most popular stop followed by Walmart (5.07%) and College Street West (4.73%). Walmart Belleville Supercentre is situated on 274 Millennium Pkwy and it is large commercial area with 24 stores and warehouses in surroundings with the opening hours from 7am to 11pm. Which suggests that people working in these stores might be using ODT service regularly at night time for travelling to home. Belleville bus terminal is on 165 Pinnacle Street where the main intercity bus terminal is located and therefore commuters could be the frequent users of ODT service . While most of the neighborhood of Jamieson Bone and University Avenue is industrial area. This suggests that people working in this area are more likely to use ODT at night. There is residential area near College Street West and Yeomans Street North which is one of most frequently used stops for drop-off. The rest of the top pickup and drop off stops surroundings include industrial, commercial, residential, educational health and recreation facilities.

TABLE 2 Top 10 Pickup and Drop off ODT stops based on usage frequency

Pickup stop	Frequency	Drop off stops	Frequency
Walmart	3097 (21.92%)	Terminal	919 (6.50%
Terminal	1484(10.50%)	Walmart	717 (5.07%)
Jamieson Bone and University Avenue	1108(7.84%)	College Street West and Yeomans Street North	668 (4.73%)
Lions Community Centre	1080(7.64%)	179 Palmer Road	420 (2.97%)
Quinte Mall Main Bus Loop	617(4.37%)	Sidney Street and Moira Street West	353 (2.50%)
219 Jamieson Bone Road	485(3.43%)	Jamieson Bone and University Avenue	329 (2.33%)
Stream	480(3.40%)	Bell Boulevard at North Front Street	327 (2.31%)
315 University Avenue	334(2.36%)	179 College Street East	276 (1.95%)
University Avenue and Adam Street	267(1.89%)	Victoria Avenue and Foster Avenue	262 (1.85%)
Bell Boulevard at North Front Street	246(1.74%)	Dundas Street West at Applewood Drive	261 (1.85%)

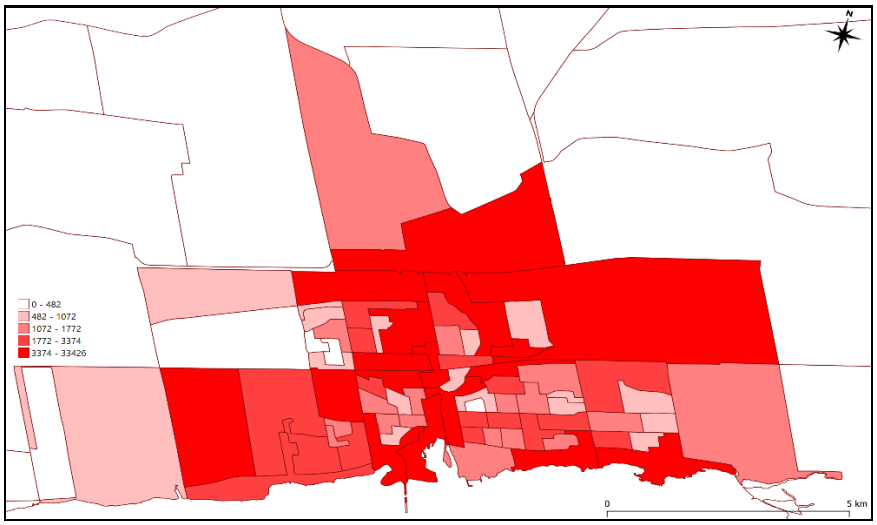
Figure 2 represents the projection of bus stop locations for fixed route RT 11 and drop-off locations for ODT bus service on Belleville map. The stops locations for fixed route (RT 11) are outside periphery of the central area as shown in the Figure 2 (a). While the demand for the trips is more concentrated in the middle zones of area which is clearly indicated from the ODT pick up and drop-off locations requested by users in those areas and shown in the Figure 2(b). The ODT bus service is covering more pick up and drop-off locations (311) as compared to the conventional fixed route RT 11 stops (93) which ensures the users' convenience in terms of lesser access and egress distances.



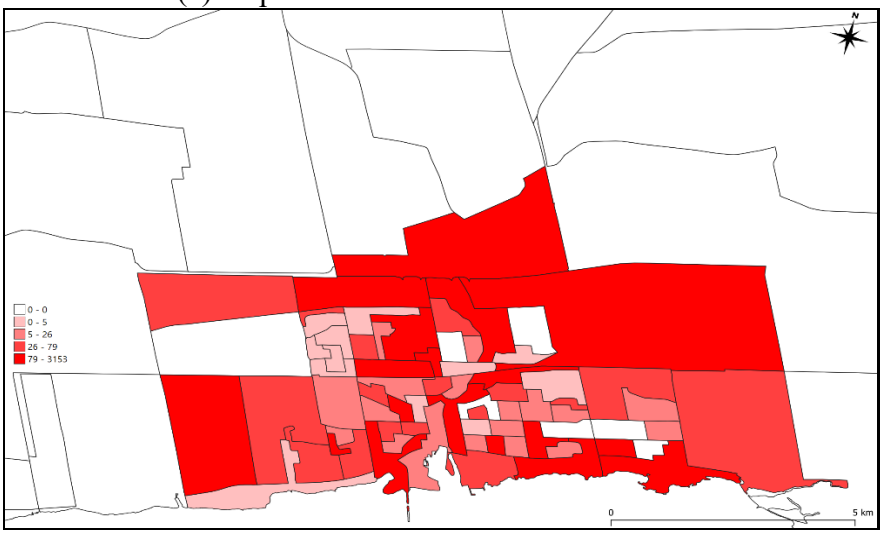
(a) RT 11 Stops (b) ODT pickup and drop-off Stops

Figure 2 RT11, ODT stops overlaid on DAs

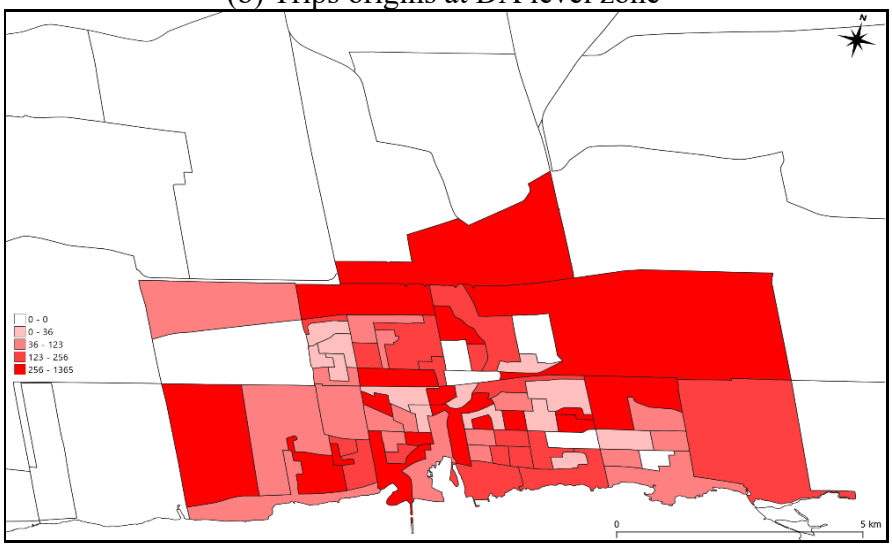
Figure 3 presents the spatial distribution of the trips at dissemination areas (DAs) level which shows the variation of concentration of trips (3a), origins (3b) and destinations (3c) of the trips from the end of September to the end of May 2019. The total number of trips were mapped and projected on to the DA level zones map using QGIS package. In addition, origins and destinations of the trips were projected separately to analyze their distribution across the area. The top ten concentrated zones (based on number of trips made) were selected and their demographic characteristics were evaluated. The average population density of these zones (990 per square kilometer) found to be higher than that of the total population density (205 per square kilometer) of Belleville area. The percentage of working age (15-64 years) individuals in these zones was found to be 66%, which is higher than that of the average for Belleville (63%), with the average median income (after tax) of $48,272 and the average household size of 2 persons. Which suggests that most of the people living in these zones are working and belong to middle income class. Furthermore, there are 9% individuals whose primary language is not English and are non-Caucasian. This group can include students from other countries who are studying and also working as shift workers. Loyalist College is located 1.6 kilometres from the Bay of Quinte on Wallbridge-Loyalist road with the neighborhood of student's residences which include five medium rise buildings and four townhouse blocks.



(a) Trips concentration at DA level zones



(b) Trips origins at DA level zone



(c) Trips destinations at DA level zones

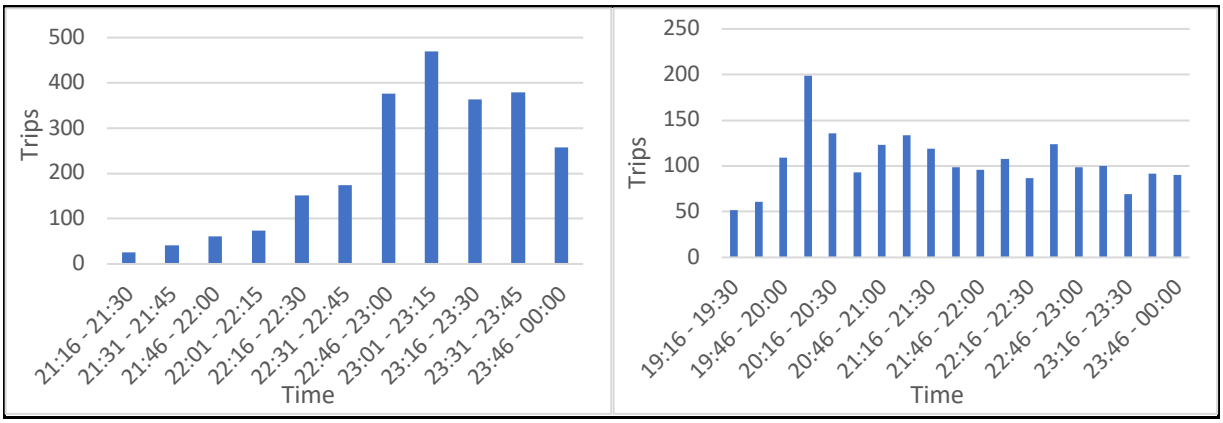
Figure 3 Spatial distribution of ODT trips at DA level (Sep 2018-May 2019)

Individual Level Analysis

Here we used the 3 months data (October-December 2018) of trips booked through the ODT app. No details on the users of other booking methods (i.e. call in centre, ad hoc riders) were available. It was observed from the individual level data that overall ODT bus service has been used for various different purposes for instance, work, shopping, education, health and leisure. Specifically, most of the top users have the same origin and destination pattern and same timings for most of their trips. The trip distance for top users of ODT ranges from 3.7 km to 7 km.

Temporal trip distribution

The temporal trip distribution was also carried out for ODT service which runs from 9:00pm to 12:00am on weekdays and from 7:30pm to 12:00am on weekends as shown in the Figure 4. This shows the highest trip demand for the time slot of 11:00pm to11:45pm for weekdays and 8:00pm to 8:30pm on weekends. It may be due to the work-to-home trips as mentioned in the previous section. Most of the top users who have the same origin and destination for their work trips requested to be picked up after 10:30pm for weekdays and 8:15pm on weekends.



(a) Weekdays (b) Weekends

Figure 4 Temporal trip distribution

Supply and Level of Service Analysis

Table 3 represents the fleet size (FS) of ODT buses for the months of October 2018 till March 2019. It can be seen that the fleet size of 3 (number of buses per day) was most commonly used overall for these months except for the month of October where fleet size of 1 and 2 was frequently used. Initially, when ODT was introduced on 18 September 2018, the fleet size of 1 or 2 was enough to meet the trips demand, however when the trips demand significantly increased over the Christmas season in November and December 2018, fleet size also increased to 3 and 4. For later months (January to March 2019) when the demand became stable (see Figure 5b), the fleet size started to become stable too.

Ride matching/Trip assignment analysis

From the point of view of responsiveness and reliability, the performance of the ODT system was found to be significantly high, as only a small number of trips (2%) couldn't be assigned from the total trip requests. Table 4 shows the trips assignments analysis for 3 months data from October to December 2018. It indicates the greater number of trips (71%) were booked through ODT app as compared to the bookings through call-in center (7%) and walk on riders

(21%). However, the percentage of the assignment of trips for walk on riders is higher (85%) than the trips booked by ODT app (30%) and call-in center (26%). This is due to the fact that walk-in (ad hoc) riders were present at the stop and picked up without an advance booking. The Pantonium ODT system is also serving the walk-in (ad hoc) riders who didn't book their trips in advance.

TABLE 3 Fleet size of ODT

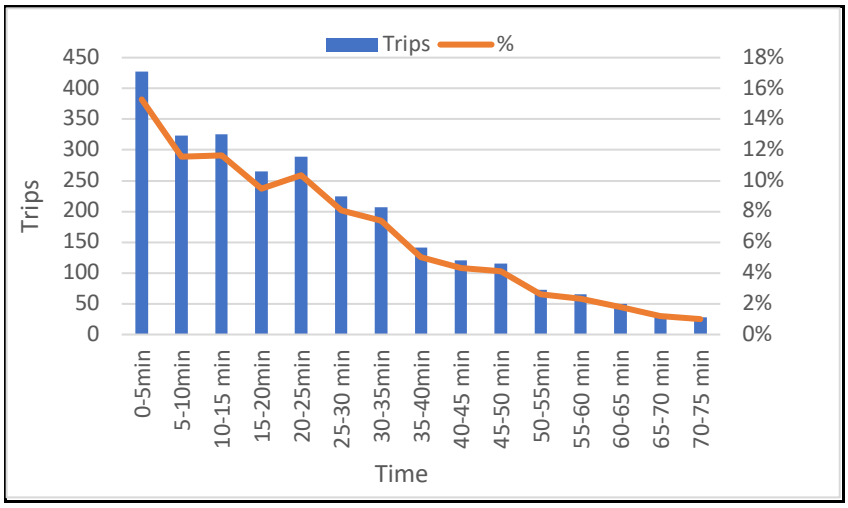
Fleet Size (FS)	Oct	Nov	Dec	Jan	Feb	Mar
1	18	0	0	0	0	0
2	11	6	3	3	7	9
3	1	24	23	25	20	22
4	0	0	1	1	0	0

The cancellation of trips by ODT app users was found to be higher (68%) as compared to call-in bookings (66%) and walk on riders (14%). Cancelled trips include the trips which were either cancelled by the rider, the rider didn't show up, or the driver did not properly board the rider in the driver app once the rider alighted the bus. Cancellations of trips through ODT app is higher because initially people were getting familiar with the app and they requested the same trip more than once in many cases. Also, people who booked their trips 1 or 2 days before the requested time for pick up, cancelled it if they changed their travel plan.

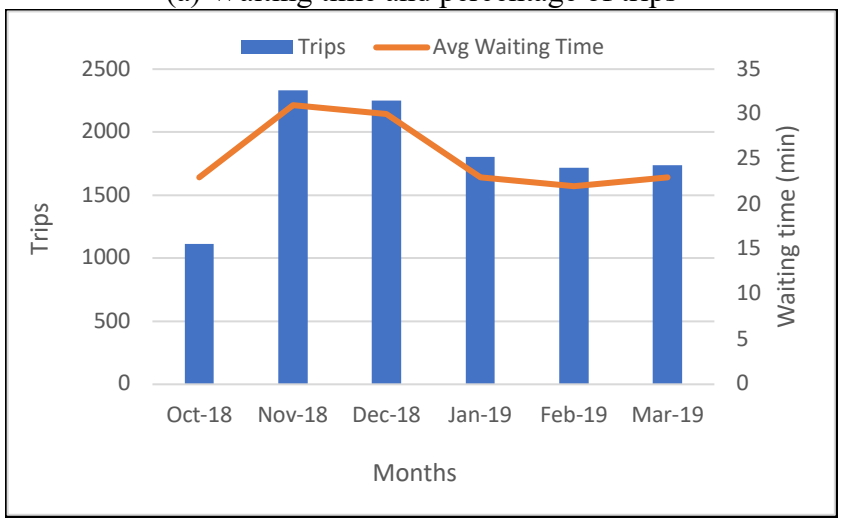
TABLE 4 Trips Assignment Analysis (October-December 2018)

Booking methods	Total trips	Assigned	Cancelled	Not Assigned
Call-in center	342	91	228	23
On Demand Transit app	3437	1037	2346	54
Walk on/Anonymous	1009	863	142	4
Total	4788	1991	2716	81

Figure 5 (a) shows the waiting time which is the difference between the actual arrival time of bus and the time requested by rider to be picked up. As mentioned above the ad hoc riders would be picked up if they are present at the stop without prior booking of trip, their waiting time will be 0, therefore their data was not included in calculating the waiting time. Collectively 39% trips were found where riders waited for 0-15 minutes and 28% trips with the riders waited for 15-30 minutes. This is satisfactory in relation to the tolerance time given by the riders while booking their trip with ODT. Where 48% of users gave the waiting tolerance time of 15min and rest 30 min. Although the wait time of 30 minutes for 28% trips seems higher, people are still using it due to its pre-scheduling option, flexibility in routing and convenience in pick up and dropping off locations. The previous fixed route (RT 11) late night buses had the time gap of 30 minutes. The main disadvantage of RT 11 was that it didn't cover high demand zones in the area due to its fixed route as shown in the Figure 2(a).



(a) Waiting time and percentage of trips



(b) Waiting time and trips demand

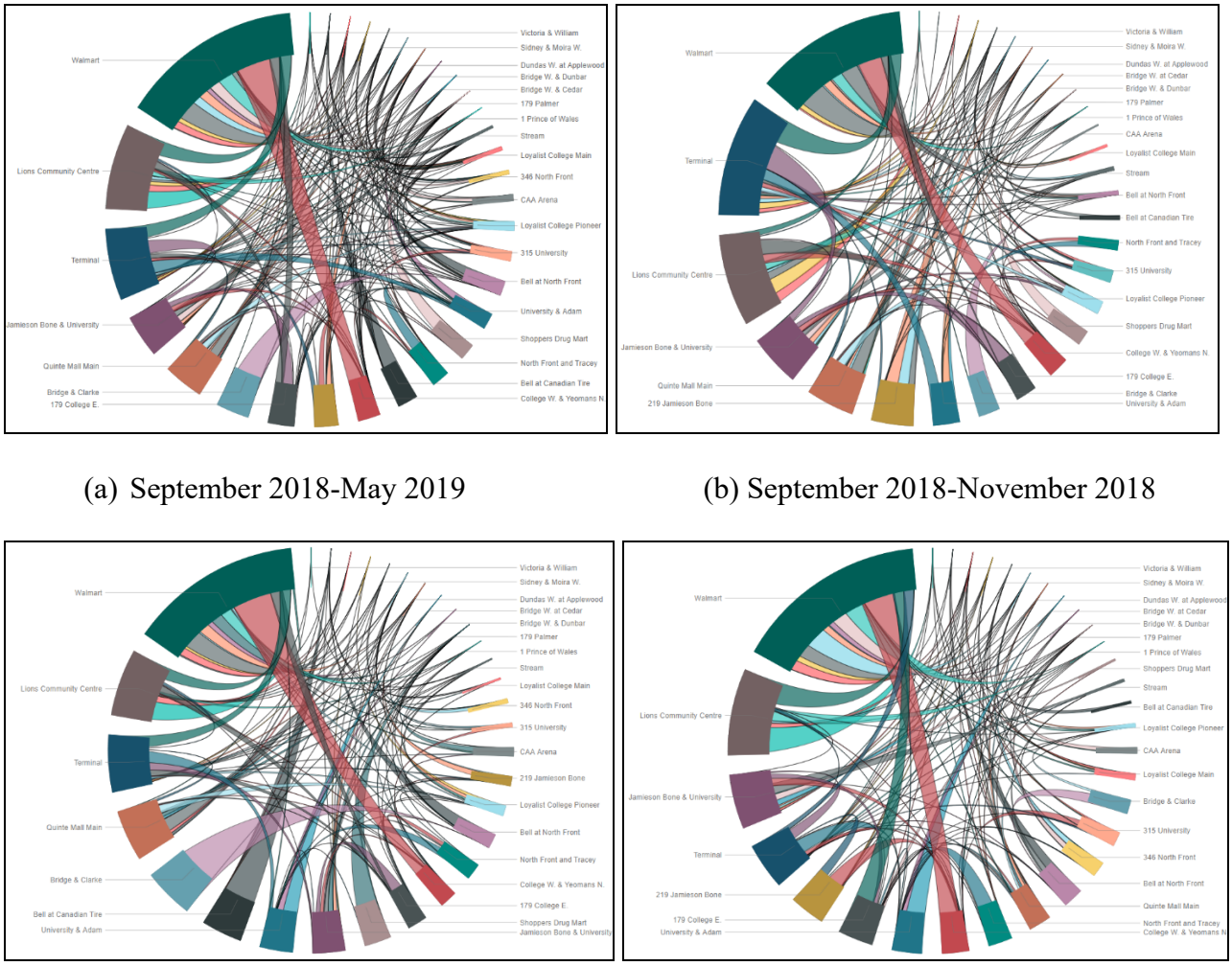
Figure 5 Waiting time analysis

Figure 5 (b) shows the relationship between the average waiting time and trips demand per month for the data from October 2018 till March 2019. For the first few months (October-December), there is variation in the number of trips for the waiting time window between 21min to 28min which is within the limit of most of the users' given tolerance time. Gradually, when the users become familiar with the ODT system, the average waiting time and the number of trips become consistent in the later months.

Origin-Destination Analysis

Figure 6 represents the origin-destination pattern for the total of 14,132 number of trips collected from 17 Sep 2018 till May 2019. For the purpose of OD analysis, 20 most frequently used stops (pickup and drop off) were selected for three data sets as shown in the figures below. Figure 6 (a) shows the overall origin destination pattern for the time period of 9 months (Sep 2018-May 2019). It shows that Walmart (Supercentre in Belleville) was the most frequently used stop, followed by Lions Community center, Terminal (near to intercity bus terminal) and Jamieson Bone and University (industrial area). Walmart is the largest retail superstore in Canada with 411 stores and also the largest employer. It is one of the most used places for the buyers and employees. Most of

the trips generated at Walmart ended at the stops of College W. and Yeomans N., Sidney street and Moira W., 1 Prince of wales, Terminal and 179 Palmer stops.



(a) September 2018-May 2019 (b) September 2018-November 2018

(c) December 2018-February 2019 (d) March 2019-May 2019

Figure 6 OD pattern for ODT stop

Excluding Terminal, all other stops are near to single-family residential areas or apartment buildings. This suggests that these trips were made either by employees or shoppers to travel to their homes. Lions Community centre organizes activities and concerts in the evenings, which leads to the trip generation at this location. While for the months of September to November 2018 (See Figure 6b), Walmart was followed by Terminal (instead of Lions community center) in terms of pickup stop usage frequency. The destinations of these trips started at Walmart were same as in the Figure 6(a). While the higher number of trips started at Terminal were ended at Jamieson Bone and University (industrial area) and at Walmart.

The sequence of the first 4 stops (in terms of usage frequency) for the months of December 2018-February 2019 is almost the same as it was for the entire duration (September 2018-May 2019) except that Quinte Mall stop replaced the Jamieson Bone and University stop (see Figure 6c). It might be due to the holiday season in December when most of the trips were made for

shopping and recreation in malls. This is also apparent in the Figure 6(c) where all the trips starting at Bridge and Clarke (residential area) end at the same destination of Bell at North Front (restaurants and shopping area). Figure 6(d) shows that the usage frequency of Loyalist College main is higher for the months of March 2019 to May 2019 as compared to the other months. Also, the stop of 219 Jamieson Bone (industrial area) was used more frequently in the months of March to May 2019 and became one of the five mostly used stops as shown in Figure 6(d). In summary the most frequently used stops remain same in the sequence except some of them changed in different months.

CONCLUSION

This study presented the analysis of supply as well as demand factors of the ODT provision in the City of Belleville and examined the impact of these factors both in terms of space and time at zonal and individual level. Various datasets were employed to carry out the broad analysis on ODT operations, including trips and GPS data over 9 months (September 2018-May 2019), trips users' data over 6 months (October 2018-March 2019) and stops data over 3 months (October 2018-December 2018). This work is expected to be insightful for the planning and design of ongoing ODT projects. The policy makers and experts can examine the impact of supply and demand factors to make ODT system more effective.

The analysis focused on exploring the spatio-temporal demand, supply and level of service and origin-destination pattern. In addition, the socio-demographic characteristics of the highly concentrated zones of ODT trips were examined. At DA level analysis, the higher number of ODT trips were created from the zones with higher population density; higher percentage of people belong to working age group (15-65years) and fall into the category of middle-income class. The individual level analysis indicates that most of the top users of ODT service have the same pattern of movement, travelling for the same origin and destination at the same timings (between 11:00pm-11:45pm) which suggested that their trips were work related trips (work to home). This will lead to better decisions about the fleet size during these durations. The number of drop off locations were found to be higher than the number of pickup locations, which indicates that people use other means of transportation in the morning to go to work and used ODT at night to travel back to home. It also indicates that in addition to frequent users (same O-D trips), there are significant number of trips (46%) that are made by infrequent users who travel with diverse O-D patterns. It leads to the conclusion that providing the bus service only to frequent users for the particular time slot will not be viable solution as it will fail to accommodate the higher percentage of trips demand made by infrequent users. Regarding the stop's usage frequency, it can be concluded that Terminal has been used as a "first mile solution" by commuters travelling from Belleville centre to the neighbouring location where they may live. Results indicate the interaction between supply and demand factors. When the demand increased in the months of November and December, the waiting time also increased to 30 minutes. To cater to the high demand the fleet size was increased which ultimately made the trip demand and waiting time stable in the later months. It will be useful to analyse more data (rest of the months of 2019) in future to further observe the interaction between supply and demand factors.

According to Belleville Transportation Master Plan (2014), both the population and employment are predicted to increase by roughly 24% and 32 % respectively between 2011 and 2031, which will increase the transit mode share by 13%. Provision of ODT system on a broader scale is one of the most suitable solution to meet the needs of Belleville city in future, which can

provide the same level of service as provided by ride-hailing (Uber) to a wider sociodemographic (i.e. higher to low-income groups) at lower cost.

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