Fort Erie On-Demand Transit Case Study

Bonnie Powell, Colin Endsley, Stanley E. Young, Andrew Duvall, Josh Sperling, and Rick Grahn

National Renewable Energy Laboratory

NREL is a national laboratory of the U.S. Department of Energy
Office of Energy Efficiency & Renewable Energy
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January 2023

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List of Acronyms

CO_2	carbon dioxide
NREL	National Renewable Energy Laboratory
ODT	on-demand transit

Executive Summary

Rural and smaller-sized communities in North America face unique mobility challenges due to their low population density, lower public transit spending per capita compared to major cities, and a high reliance on private vehicles. In recent years, communities such as Fort Erie, Ontario, have restructured or advanced their public transit systems using on-demand services. Fort Erie is a relatively sparsely populated region of 32,901 residents, spread across a land area of 166 square kilometers (64 square miles), for an average population density of 198 residents per square kilometer (514 per square mile). In October 2021, the town implemented a mobility-on-demand system integrated with smartphone software to replace its fixed-route community bus system, which consisted of four buses with three routes, each with a roughly 1-hour, one-way loop. The new service utilizes a fleet of six minivans, two of which are retrofitted with wheelchair-accessible ramps. The system may require that a passenger requesting a standard van walk up to 400 meters (a quarter mile) to their pickup location to optimize vehicle routing while providing origin-to-destination service. The on-demand system proved effective in providing service, eclipsing pre-pandemic ridership by 40%, decreasing greenhouse gas emissions per ride by 63%, and decreasing the cost to the town per ride by 29%. This report documents both the previous system and the new system in terms of routes, ridership, costs, fuel, and other notable system parameters. This work is part of an ongoing series of case studies on providing small communities with on-demand, right-sized vehicle service coupled with a smartphone application.

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Introduction

In October 2021, Fort Erie, Ontario, replaced its fixed-route system of four buses with an on-demand service that utilizes an operational fleet of four standard minivans plus two handicap-accessible minivans. The town made the change during the COVID-19 pandemic, following research into ridership and rider satisfaction conducted over the previous 3 years and after witnessing other similar pilot deployments. The Fort Erie request for proposal stated:

> "…the goal [is] to be the lead in On-Demand Transit service delivery in the Niagara Region that will bring equal access to transit for all the permanent residents, seasonal residents and visitors alike. This new service will also offer those users who may normally apply for the Specialized service another option for transport within Fort Erie." [1]

Fort Erie Transit partnered with the Toronto-based software company Pantonium and local company Regional Limousine to meet all the requirements for changing to on-demand service. Pantonium offers a software package and smartphone app that handles routing, payment, driver dispatching, and real-time scheduling to manage a fleet similar to common transportation network companies such as Uber and Lyft. Regional Limousine was contracted to start operating the deployed system by providing vehicles, drivers, and staff for a dispatch office that allows users to book rides via telephone. One of Fort Erie's old buses and one of the on-demand vehicles are shown in Figure 1.

Figure 1. Fort Erie Transit bus (left) and one of the accessible on-demand minivans (right).

Photos from the town of Fort Erie

Methods and Organization

This study was motivated by a desire to explore and document the impacts of Fort Erie's successful transition from fixed-route transit using diesel buses to on-demand transit (ODT) using light-duty minivans. Recognizing that the Fort Erie transition had not been previously documented in the published literature, this work was also motivated by prior efforts exploring a nearby on-demand pilot in Innisfil, Ontario [3]. The National Renewable Energy Laboratory

(NREL) team collaborated with Fort Erie Transit and its partners to collect information, present an overview of the on-demand transit service's implementation, and analyze impacts with respect to cost, energy, emissions, ridership, and customer satisfaction. This is one of a series of case studies conducted by NREL on the implementation of unique mobility services for rural transportation.

The research team performed interviews with Fort Erie transit and Pantonium through virtual calls and email. Fort Erie provided data on both the previous fixed-route bus system and the on-demand system, including ridership statistics, vehicle fuel consumption, vehicle kilometers traveled, rider survey results (for on-demand only), and background documents. The NREL team reviewed these documents along with publicly available resources. Pantonium, under agreement with Fort Erie, provided vehicle dispatching information, pickup/drop-off statistics, and routing information for a more detailed analysis of vehicle coverage and operations.

The paper is organized into the following sections:

- **Background** provides a thorough description of the Fort Erie community, as well as its legacy fixed-route transit system.
- **Implementation of the Fort Erie On-Demand Transit System** discusses the process of transitioning from the fixed-route system to the on-demand system with a fleet of smaller vehicles, as well as the motivations behind the decision.
- **Analysis and Results** compares and contrasts the fixed-route and on-demand systems from various perspectives, including cost, fuel use, emissions, accessibility, and customer satisfaction, which other communities can consider if exploring similar on-demand systems in the future.
- **Discussion** and **Conclusions** review the findings in light of additional factors impacting the Fort Erie system and its future outlook. These sections also consider the potential for the Fort Erie on-demand mobility system to be replicated and/or built upon in the United States.

Background

The Fort Erie Transit Service Area

Fort Erie, with a population of 32,901, spans 166 square kilometers (64 square miles) and has a population density of 198 people per square kilometer (514 people per square mile) [2]. The town also has approximately 10,000 seasonal (summer) residents. Due to its low population density, traffic congestion was not reported as an issue in interviews with employees of the town of Fort Erie. By comparison, major Canadian cities like Toronto have population densities close to 4,000 people per square kilometer (10,360 people per square mile). Fort Erie has distinct population centers with large stretches of open space in between. According to interviews with town employees, it is known as a "community of communities"; small neighborhoods are interspersed with large swatches of farmland, as shown in Figure 2. This characteristic posed a significant challenge to Fort Erie Transit.

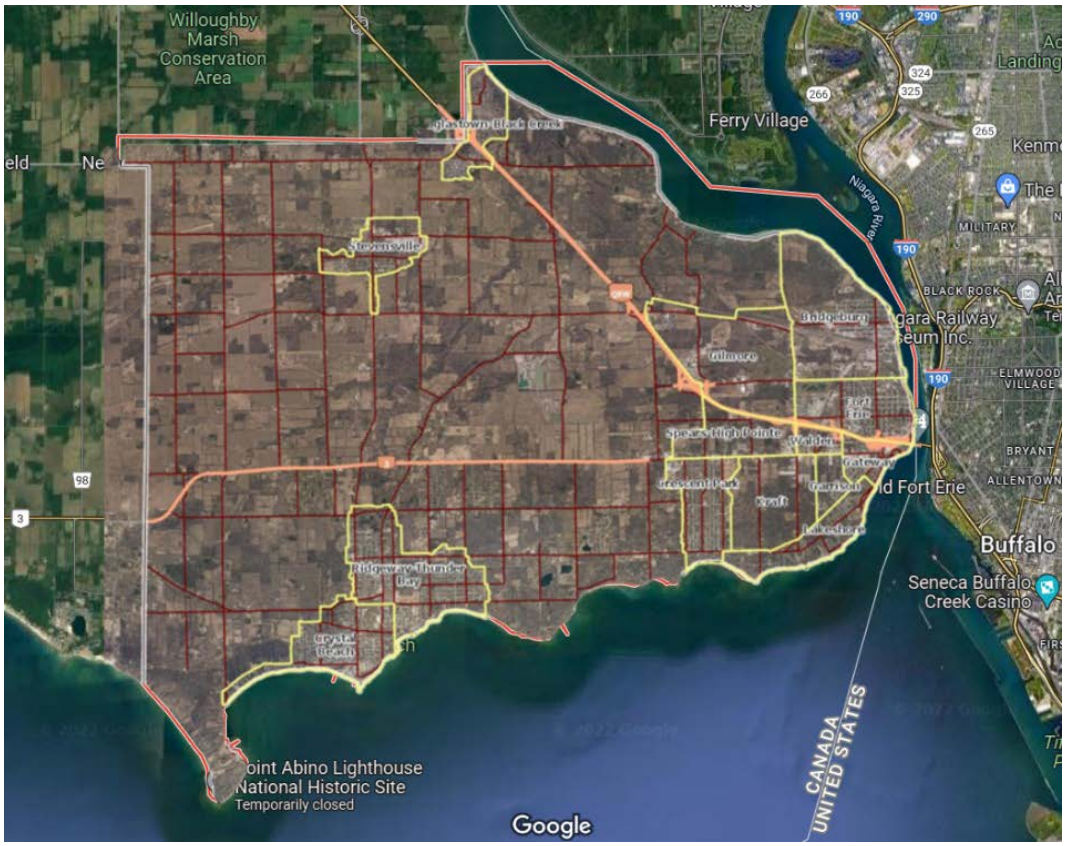


Figure 2. The town of Fort Erie, with population centers outlined in yellow. All other areas are considered rural Fort Erie.

Image from the town of Fort Erie

Previous Fixed-Route Transit Services

Information on the prior fixed-route system was acquired through interviews and review of materials provided by employees of the town of Fort Erie. Formerly, Fort Erie was served by three fixed-route transit lines and four buses. The large buses were owned and operated by a private company. Each bus line connected a handful of semi-distant communities to social destinations and goods/services. For some of the bus lines, this resulted in long ride times and low demand. Fort Erie conducted a transit study in 2011 that led to a shift away from predominantly "flag stop" service (where the bus did not stop unless a customer signaled to the driver by raising a flag from the road or a passenger requested to stop once boarded) to a system with more infrastructure—i.e., transit stops. Transit stops are proven to improve passenger safety and provide a more pleasant transit experience. The study was followed in 2016–2017 by a reevaluation, which led to more routes being added to the single conventional fixed route. A diagram of the previous bus system and its routes is shown in Figure 3.

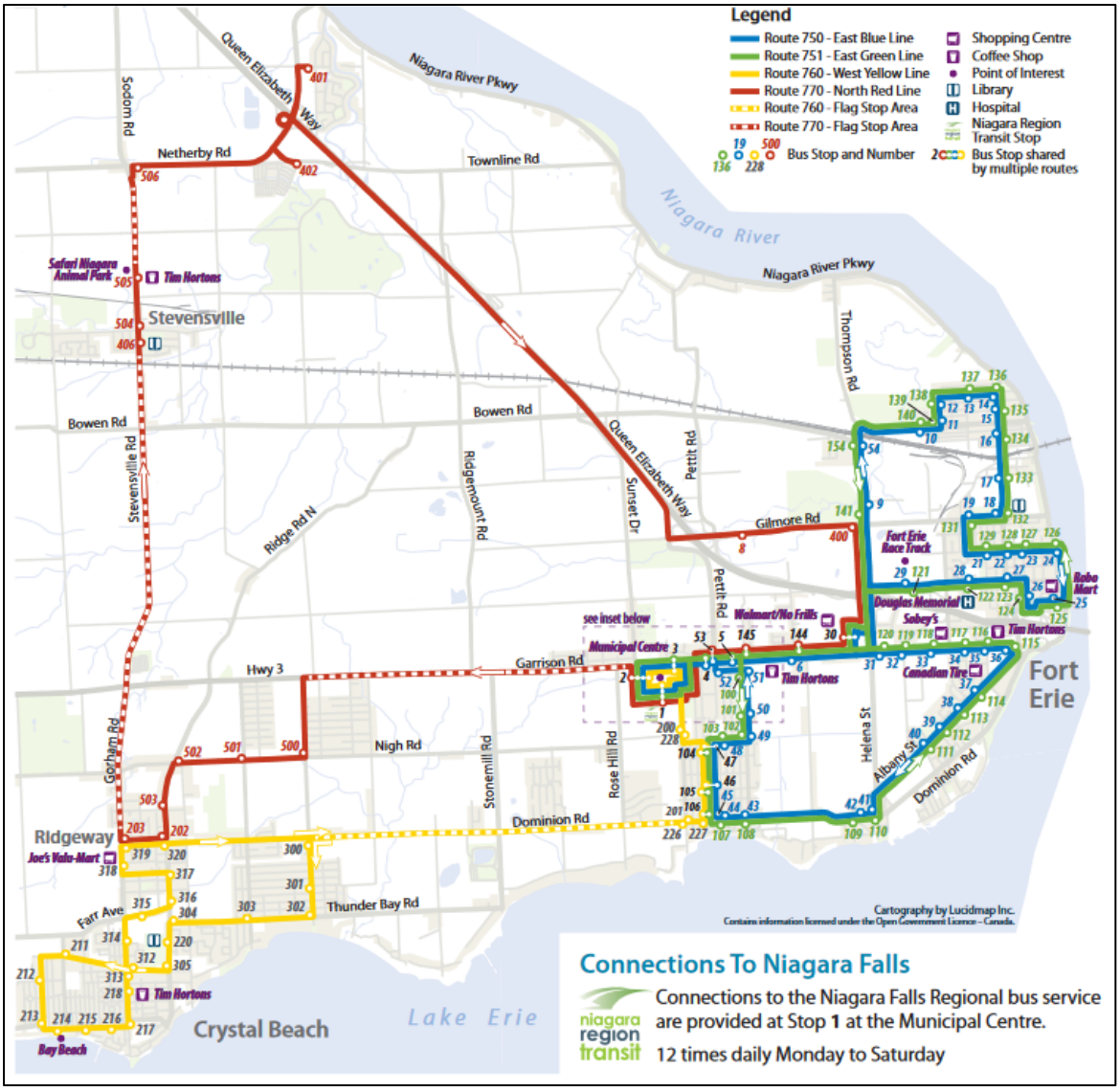


Figure 3. Detailed fixed bus routes.

Image from the town of Fort Erie

The fixed-route transit service operated four bus lines, with bus service available from 6 a.m. to 9 p.m. Monday through Saturday (excluding 10 annual statutory holidays). Thirty-foot buses manufactured by ElDorado, each with 27–29 seats, were used. Each bus had two wheelchair-capable spots as well as low floors with ramps.

The North Red Line (#770) routed through the Stevensville and Ridgeway communities and the outlying northern neighborhoods, connecting them with the Municipal Centre and other bus lines. The North Red Line had two flag stop regions: east/west along Garrison Road and north/south along Stevensville Road. The North Red Line was 35.1 kilometers (21.8 miles) long with 21 stops and was the least efficient route, costing the town $88 per ride in 2019. The entire fixed-route system cost an average of $24 per ride in the same year. Inefficiencies that led to the high costs included low ridership and low utilization of routes.

The West Yellow Line (#760) connected the Crystal Beach and Ridgeway neighborhoods to the Municipal Centre plus a stretch down Dominion Road. This road was a flag stop area, as indicated by the hashed yellow/white color in Figure 3. The #760 bus route made 38 stops along a 29.4-kilometer (18.3-mile) route in addition to the flag stop stretch.

From June to September, Fort Erie's ~30,000 residents absorb an influx of an additional 10,000 part-time residents. The beaches are a popular destination during these months. Tourists tended not to use the local fixed-route buses, however, opting for personal transportation instead.

The East Blue (#750) and East Green (#751) routes ran in opposite directions from the Municipal Centre toward the Peace Bridge area, through Old Fort Erie and by the Fort Erie Racetrack. The two lines passed the Walmart Supercenter, which was reported as being a popular rider destination. These buses completed a 27.6-kilometer (17.1-mile) loop every hour, making 53 stops along the way. Single rides for all routes were $3, day passes (unlimited rides for 1 day) were available for $6, and 30-day unlimited access was available for $90.

Fort Erie Transit has been soliciting feedback on their fixed-route system and analyzing potential updates to their system for more than 10 years. In 2011, the town conducted a transit study that outlined multiple actions, including ridership data generation and adding more transit stops. The study also left room for a "made in Fort Erie" solution at the discretion of management.

According to records kept by the town of Fort Erie, the fixed-route bus system had low ridership (which was exacerbated during the COVID-19 pandemic), leading to a high cost per ride for the town. Also, residents in the outlying regions did not have reasonable access to the public transit system. Buses carrying fewer passengers on the less popular routes consumed as much fuel as those serving more riders in the busier regions. The diesel buses and their associated noise levels regularly traversed the more populated communities, leading to complaints from residents.

Implementation of the Fort Erie On-Demand Transit System

To address the concerns raised with the fixed-route bus system, in 2019, Fort Erie Transit began to consider alternatives to their existing system, including first-/last-mile solutions and hybrid/electric fleet vehicles. The town conducted research in 2019 and 2020, and on January 11, 2021, the town council approved the transition to an on-demand system using smaller vehicles, specifically minivans. They determined that first-/last-mile solutions would not provide benefit in Fort Erie's geographical context and that electric minivans were not yet readily available for an initial system deployment. The new on-demand system began operating on October 4, 2021. When transitioning from the fixed-route system to the on-demand system, Fort Erie had a 2-week overlap when both systems were in service.

Other communities have adopted similar on-demand systems with various business models. The town of Innisfil, Ontario, partnered with Uber in 2017 for an effective outsourced ODT system [3]. According to interviews with employees of the town of Fort Erie, Fort Erie considered such a partnership, but there are few Uber drivers in the Fort Erie area. The town was also concerned that Uber drivers would travel to adjoining areas with greater populations where they could make

more money, decreasing the reliability of the public transit service. Fort Erie desired a service exclusively for their town, with dedicated drivers and vehicles.

From an analysis of passenger counts on the fixed-route buses, Fort Erie found that there were, on average, between four and six rides given per hour on the most used (Blue) route, and less than one ride per hour on the least used (Red) route. This made smaller vehicles, such as minivans, an attractive option. Fort Erie investigated electric and hybrid options, but due to pandemic supply chain and cost issues, ultimately procured standard internal combustion-powered Dodge Grand Caravans. The vehicles had immediate availability and were able to handle the region's winter driving conditions.

The booking, dispatching, and routing software of the on-demand system and an associated smartphone app are provided by the company Pantonium. The smartphone app uses a proprietary algorithm and is similar to common transportation network company apps, from which customers can request a ride and track the vehicle's location ("On Demand Transit – Rider App"; see Figure 4).

To ensure equity in the service, the town council approved the inclusion of a customer service desk where rides can be booked via standard telephone (often referred to as "dial-a-ride"). This service desk is managed by Regional Limousine. Rides can also be scheduled via a webpage.

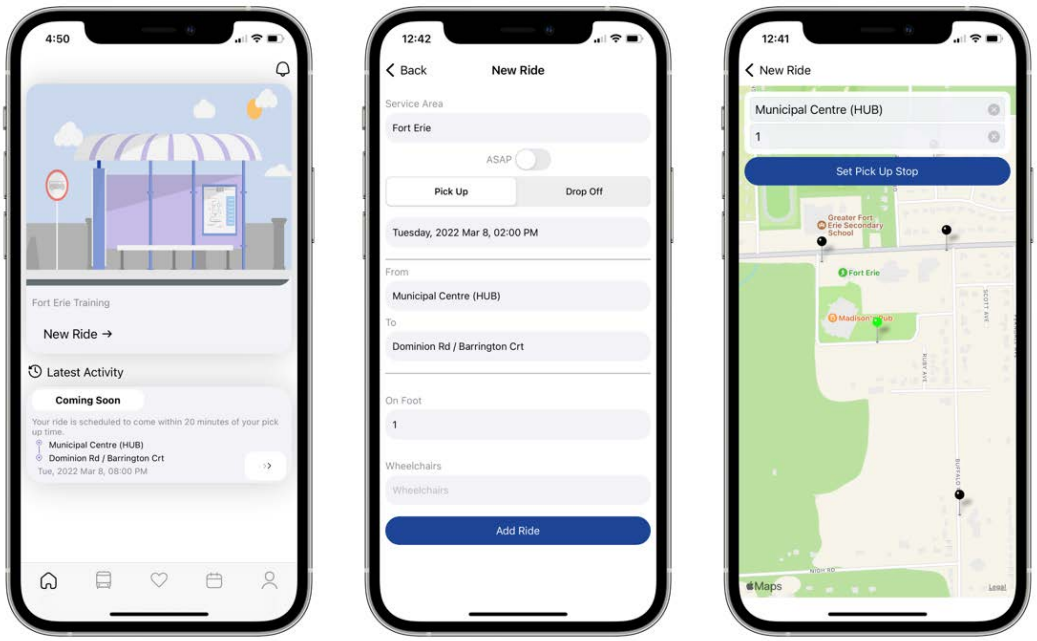


Figure 4. Fort Erie's On-Demand Transit – Rider App [4]. From left to right, screenshots show a home screen with the latest activity, scheduling a new ride, and setting a pickup spot.

Images from the town of Fort Erie

Operation of the ODT system was contracted to Regional Limousine. They own and manage a dedicated fleet of minivans and drivers, as well as the customer service phone line. Bus drivers from the previous fixed-route system were retrained to work in the new on-demand service using

minivans. Fort Erie pays Regional Limousine an annual fee for an agreed number of service hours.

A ride can be booked either in advance or for as soon as possible (much like ride-hailing services). If the customer uses the app, the location of the minivan servicing the call is displayed in real time. Fort Erie provides direct service to a few popular stops where passengers can board without booking ahead, such as the local Walmart. If a customer is at one of these locations and sees a Fort Erie Transit vehicle with space available, they can board it without a prior reservation.

When booking, customers will either be instructed to walk to a nearby stop to board, or the minivan will provide curb-to-curb service. This depends on the customer's location. Inside of a population center (see Figure 2), where there is greater walkability and existing transit stops from the fixed-route system, customers must board from a transit stop or designated point of interest. Outside of a population center, the minivan will provide curb-to-curb service at a customer's location, and the customer will not be instructed to walk to a designated stop. This is due to limited walkability (such as sidewalks) outside of population centers. If a rider requests the accessible vehicle due to accessibility needs, they are picked up at their location regardless of whether they are in a population center or not. Whether booked through the smartphone app, webpage, telephone call, or ad hoc access (such as at the Walmart), the routing algorithm is designed to be "greedy," picking up as many passengers as will fit in the van while minimizing stops and drive time.

For service anywhere in the 170-square-mile area, a ride costs the customer $3 (the same as a single-ride bus fare in the prior system). There are multiple payment options. Each van is equipped to accept cash, debit, credit, and smart cards with preloaded passes. Smart cards can be reloaded with the driver or online.

Analysis and Results

Fort Erie Transit tracks ridership, fuel costs, and vehicle kilometers traveled. This allows for an objective analysis of the on-demand system's impact on ridership, operational costs, and emissions, as compared to the legacy bus system. The town also performed a ridership survey in 2022 asking riders about their satisfaction with the new system. The dispatching software collects trip-level data, including latitude and longitude waypoints of each minivan in service, number of passengers, and ride and wait times.

Ridership

The COVID-19 pandemic had devastating effects on transit providers around the globe, and Fort Erie was no exception. According to monthly ridership records kept by the town of Fort Erie, during the pandemic, ridership on Fort Erie Transit dropped to an average of about 1,800 rides per month, down from 3,000–4,000 monthly rides pre-pandemic. The ODT program, which consisted of six vans initially, resulted in ridership tripling within the first 6 months of implementation. Ridership surpassed pre-pandemic levels in March 2022 and reached an all-time high of 5,326 rides in June 2022. Ridership in a 3-month pre-pandemic period (April–June 2019) was exceeded by 40% in April–June 2022. Total ridership trends over the last 5 years are shown in Figure 5 using data provided by the town of Fort Erie and Pantonium.

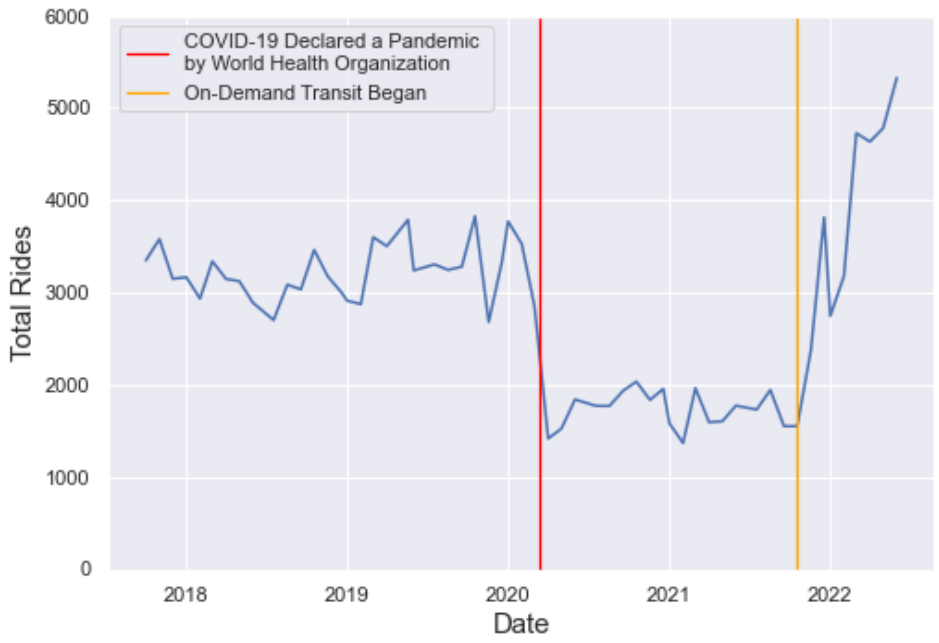


Figure 5. Total monthly ridership before and after the on-demand system was instituted (October 4, 2017, to June 30, 2022)

Peak Usage

Peak times for the on-demand system were between 10 a.m. and 3 p.m., with the highest usage occurring around 2–3 p.m., as shown in Figure 6. In comparison, the peak usage for fixed-route trips in 2019 was slightly earlier, between 11 a.m. and 12 p.m. In the analyzed 9-month ODT period, 11 trips began a few minutes before the opening hour of 6 a.m., and 31 trips began just after the closing hour of 9 p.m. These trips were binned into the 6 a.m. and 8 p.m. pickup hour categories, respectively. No data currently exist to indicate trip purpose.

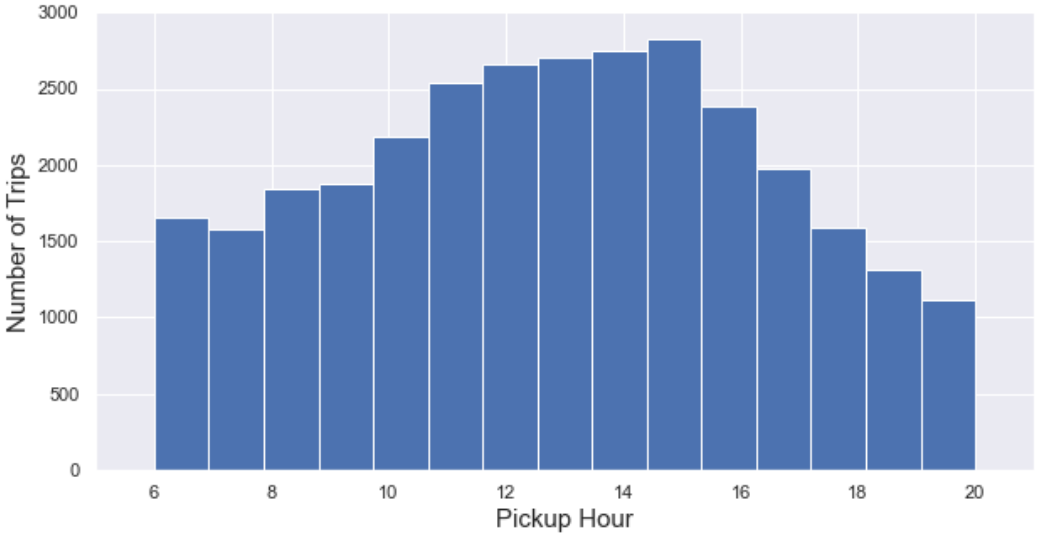


Figure 6. Number of trips at different operating hours of the day, for all trips from October 4, 2021, to July 19, 2022

To meet increasing rider demand, the town council approved the purchase of three additional Grand Caravans in May 2022 [5]. Of the total fleet of nine minivans, seven seat five passengers each. The remaining two minivans can accommodate two wheelchair-using passengers each, in addition to three non-wheelchair-using passengers. Four of the nine vans are used continuously throughout the service day; two are deployed for 5 hours per day, during peak times only; and one van remains on standby and is only deployed when needed. The final two vans are backups in case of maintenance or other issues. If all nine vehicles are used, the total capacity is 45 passengers. During operations, the maximum number of ride requests rarely exceeded 30 within any 30-minute time period (or 66% of total capacity). Because average in-vehicle ride times were under 14 minutes, vehicle supply was assumed to be sufficient for the designed service.

Wait and Ride Times

Wait times reflect a system that is used in multiple ways—through scheduling in advance, scheduling for pickup as soon as possible, or ad hoc boarding (no scheduling). Wait times were negative for approximately 14% of total trips, likely because the rider scheduled the ride in advance, requested an estimated pickup time, and the driver arrived early. These wait times were changed to zero for this analysis. An additional 6,000 trips (19%) had a wait time of zero, and the trip was inputted by the driver (as opposed to documented by the app or dispatch office), likely indicating an ad hoc boarding from one of the locations where users do not have to schedule the ride in advance. These identified walk-on boardings were excluded from the wait time analysis since it is unknown how long the customer was waiting.

The average wait time for trips taken between October 4, 2021, and July 19, 2022, was 10 minutes and 35 seconds. Although not directly comparable, each fixed-route bus service ran in a loop for approximately 60 minutes. This means a fixed-route rider had to plan their travel around the bus schedule or risk waiting up to 60 minutes. Wait times for the on-demand system were lowest in the mornings and at night, and highest from approximately 4–5 p.m. (Figure 7). All box and whisker plots show a box extending from the first quartile to the third quartile, with a line at the median and the whiskers extending to 1.5× the interquartile range. Approximately 1.7% of observations fell outside of the 1.5× interquartile range, which is a threshold commonly used to define outliers. These outliers remained in the analysis but were removed visually from Figure 7 to avoid overly distorting the box and whisker plots themselves.

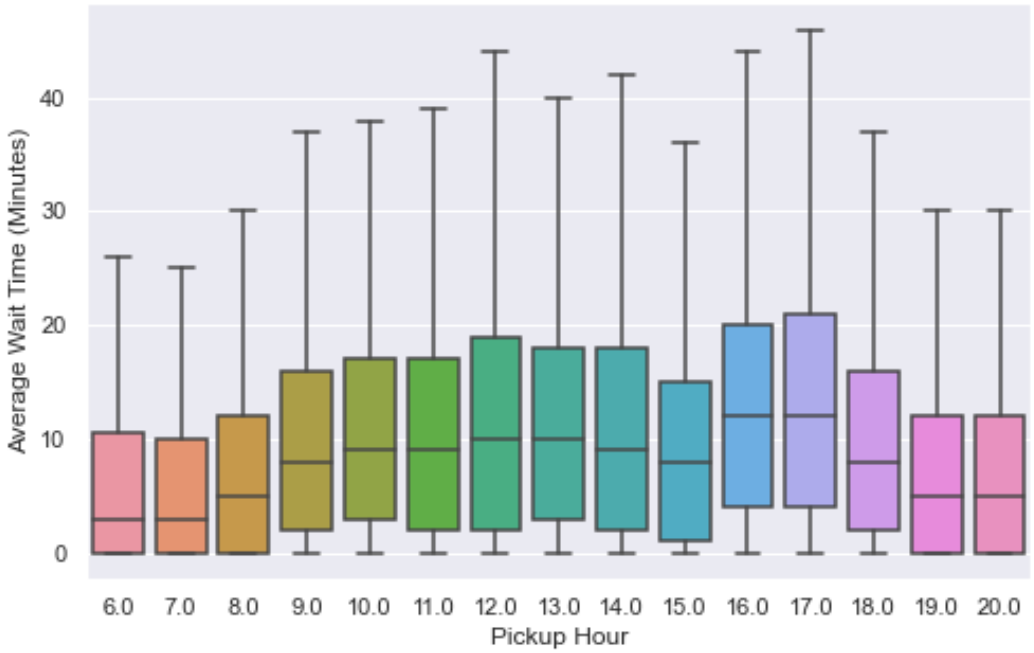


Figure 7. Average wait time for each operating hour of the day, for completed trips between October 4, 2021, and July 19, 2022. Outliers defined by values outside of the 1.5× interquartile range are not shown in the plot.

However, wait times for trips with a passenger using a wheelchair were higher than the average trip wait times. In the analyzed time frame, 557 trips occurred with a passenger using a wheelchair. The average wait time for these 557 trips only was approximately 14 minutes and 4 seconds, compared to 10 minutes and 31 seconds for the remaining 30,435 trips with no passengers using a wheelchair. This may demonstrate that since there are fewer accessible vehicles in the fleet, accessible vehicles need to travel farther to reach a passenger or finish completing a trip before picking up a new passenger. Average wait times for trips with a passenger using a wheelchair by pickup hour are shown in Figure 8.

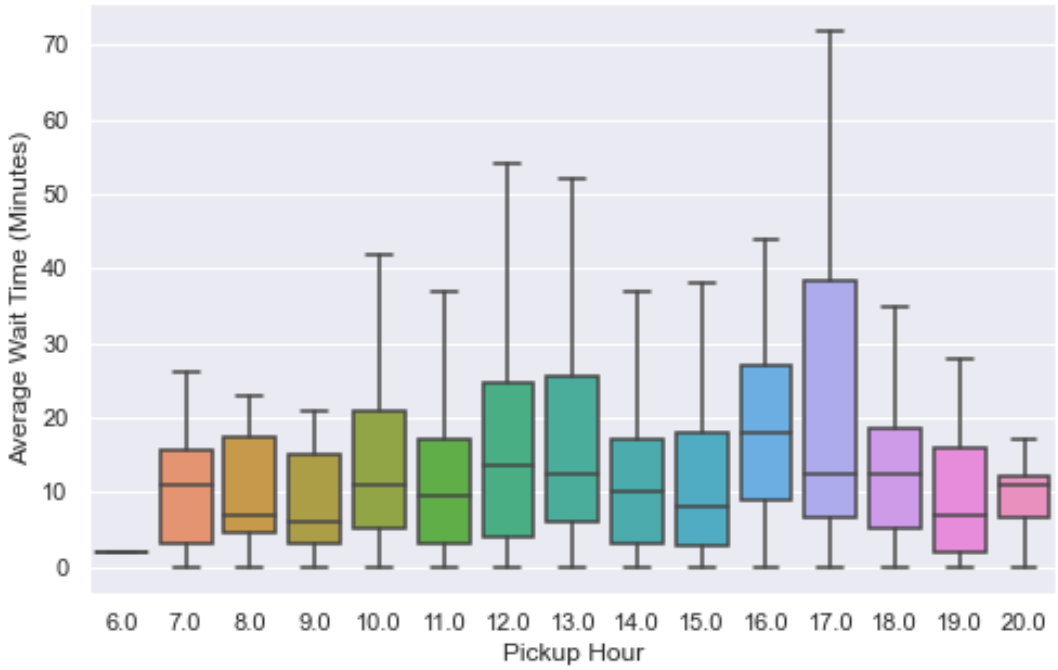


Figure 8. Average wait time for each operating hour of the day, for completed trips with a passenger using a wheelchair, between October 4, 2021, and July 19, 2022. Outliers defined by values outside of the 1.5× interquartile range are not shown in the plot.

The mean ride time was 13 minutes and 33 seconds, and it remained constant throughout most of the day, with slightly longer ride times early in the morning and in the late afternoon, and the shortest ride times in the evening (Figure 9). The ride time was defined as the time between when the vehicle arrived at the pickup location and the drop-off location. Approximately 3.7% of observations fell outside of the 1.5× interquartile range, which is a threshold commonly used to define outliers. These outliers remained in the analysis but were removed visually from Figure 9 to avoid overly distorting the box and whisker plots themselves. Average ride time with and without these outliers differed by less than 1 minute. The average ride times for trips with passengers using wheelchairs were very similar to trips with no passengers using wheelchairs—13 minutes and 22 seconds and 13 minutes and 34 seconds, respectively. Trips with passengers using wheelchairs had fewer and less extreme outliers with respect to ride time, with a maximum recorded ride time of 68 minutes. Although there were no data for direct comparison with the fixed-route system, each route loop took approximately 1 hour from start to finish.

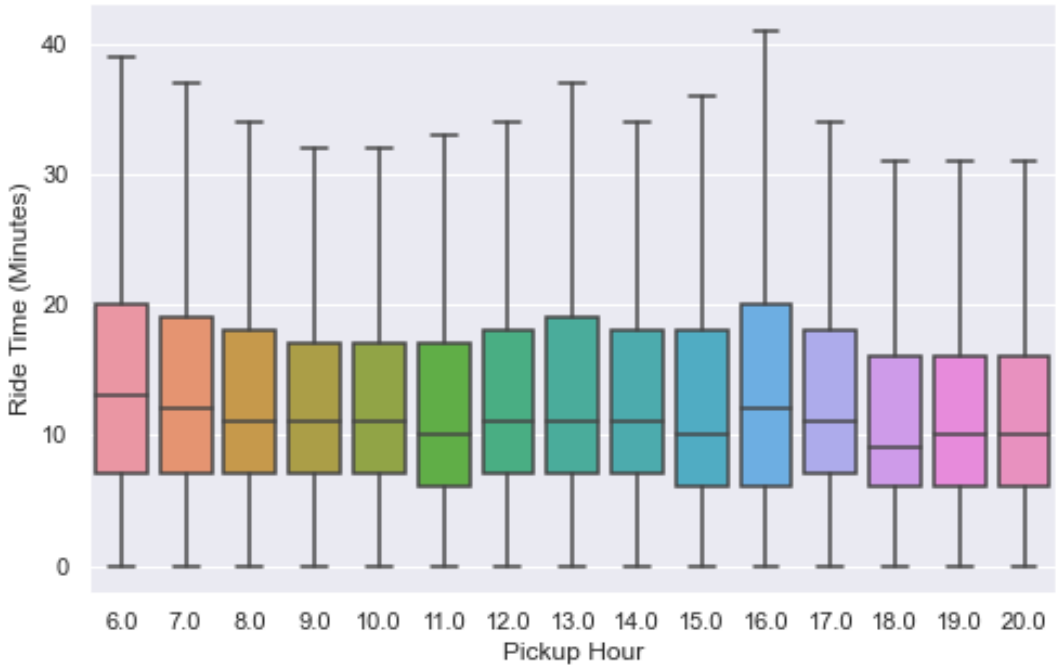


Figure 9. Average ride time for one trip for each operating hour of the day, for completed trips between October 4, 2021, and July 19, 2022. Outliers defined by values outside of the 1.5× interquartile range are not shown in the plot.

Spatial Accessibility

The shift to on-demand service is the latest effort by Fort Erie to find a "made in Fort Erie" solution suited to the unique challenges facing Fort Erie planners. According to the 2016 *Town of Fort Erie Transit Route and Service Plan*, approximately 70% of community residents had reasonable access to the fixed-route bus system (defined as living within 400 meters of a bus stop) [6]. By switching from a fixed-route service to an on-demand service, Fort Erie Transit nearly doubled its service area and fully captured the remaining 30% of the population. Figure 10 shows the areas served by the old bus system and the current on-demand system.

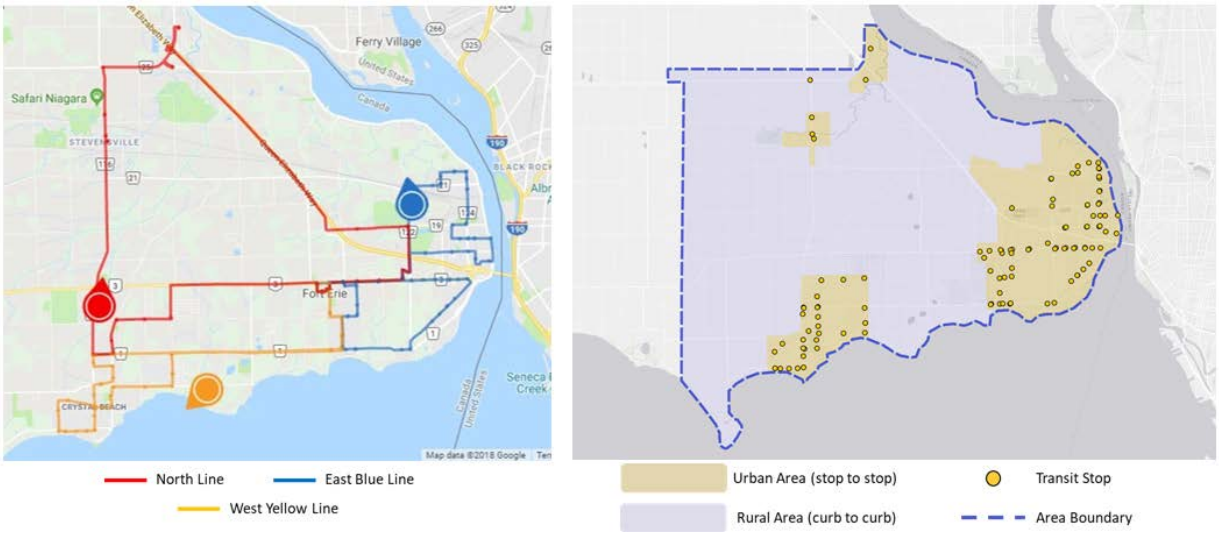


Figure 10. Fort Erie service expansion. The diagram on the left is the old fixed-route bus system, and the diagram on the right is the new on-demand system that now services the entire town.

Image from the town of Fort Erie

An analysis of vehicle GPS data shows that the on-demand system is indeed used throughout the entire Fort Erie community, demonstrating a vastly improved level of accessibility and equity compared to the sparse coverage of the prior fixed-route system. A route heat map was generated and confirms that although trips were concentrated in population centers such as the southeast corner of the town, trips passed throughout the community (Figure 11).

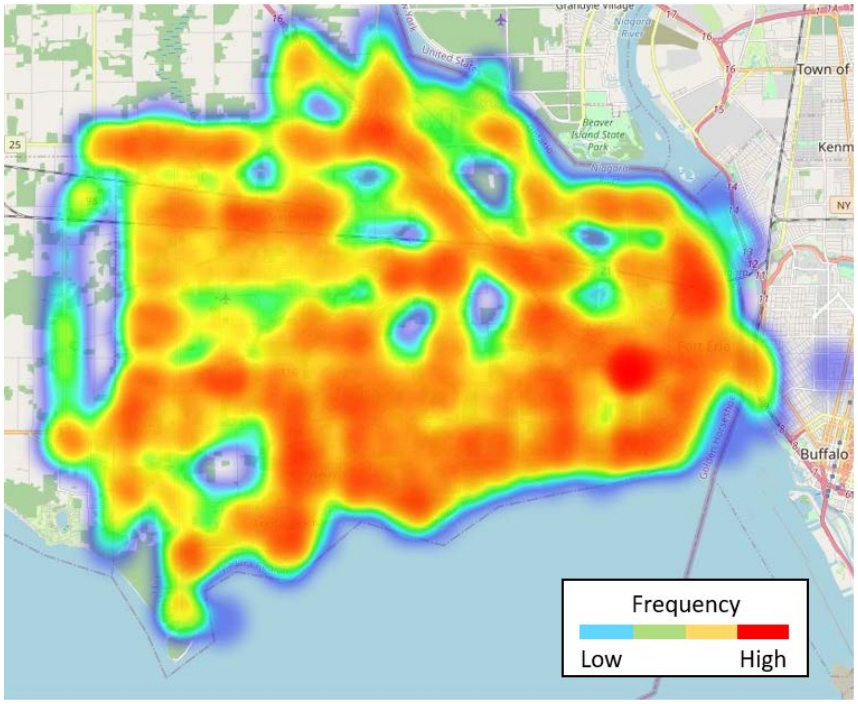


Figure 11. A heat map showing where vehicles providing trips traveled, using latitude and longitude coordinates recorded every 30 seconds for all ODT trips from October 4, 2021, to July 19, 2022. Red indicates high-frequency corridors, and green and blue indicate lower-frequency corridors.

Pickup and Drop-Off Locations

Pickup and drop-off locations are distributed across the entire town. To make use of existing infrastructure and to optimize vehicle routing, a passenger requesting a standard ride from a population center in the app will be instructed to walk to a nearby transit stop, typically less than 200 meters (0.12 miles) but sometimes up to 400 meters (0.25 miles), to board the on-demand minivan. In rural areas outside of Fort Erie's population centers (where walking is hazardous due to obstacles such as large ditches or lack of sidewalks), curb-to-curb service is provided. In addition, when any rider requiring specific accessibility accommodations requests the accessible vehicle, they are picked up at their location, regardless of their rural/population center classification. For over 60% of trips between October 2021 and July 2022, prior transit stops were used as both pickup and drop-off locations, as shown in Figure 12. Of the remaining trips, 35% involved boarding/alighting at points of interest, and approximately 4% were at customer addresses.

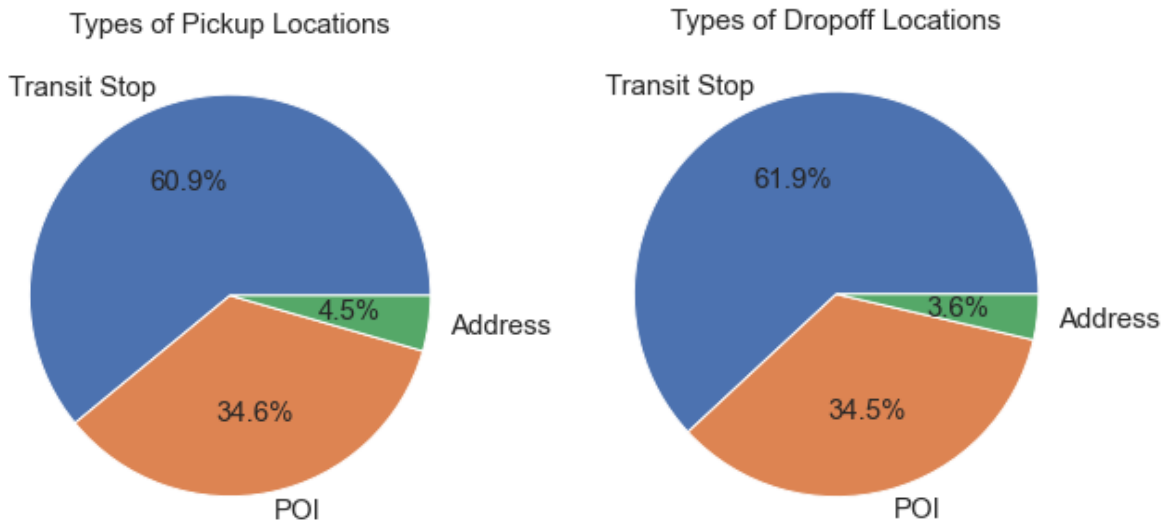
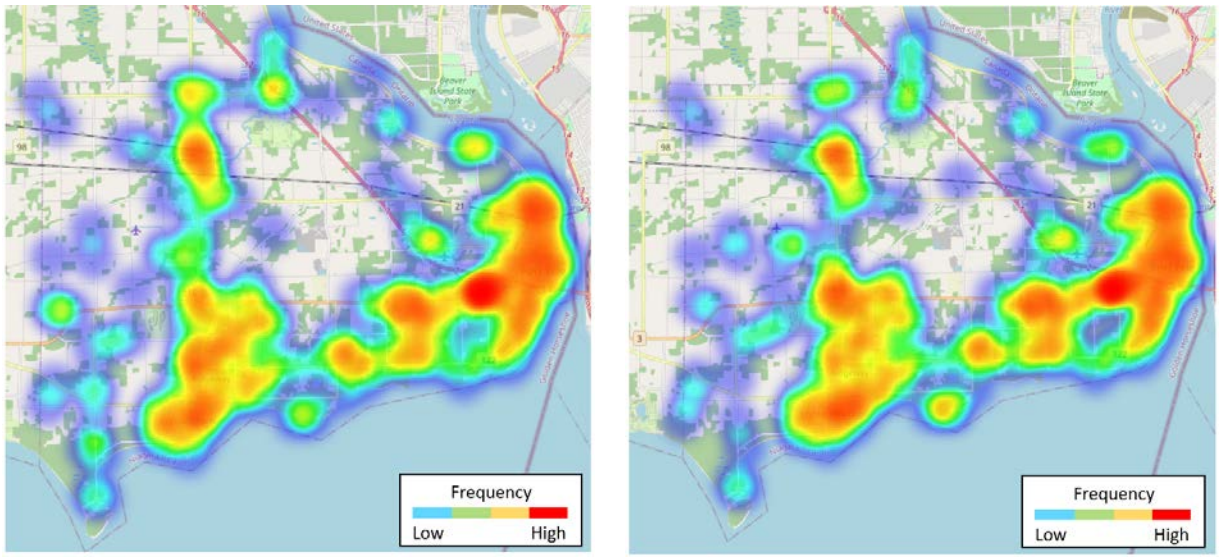


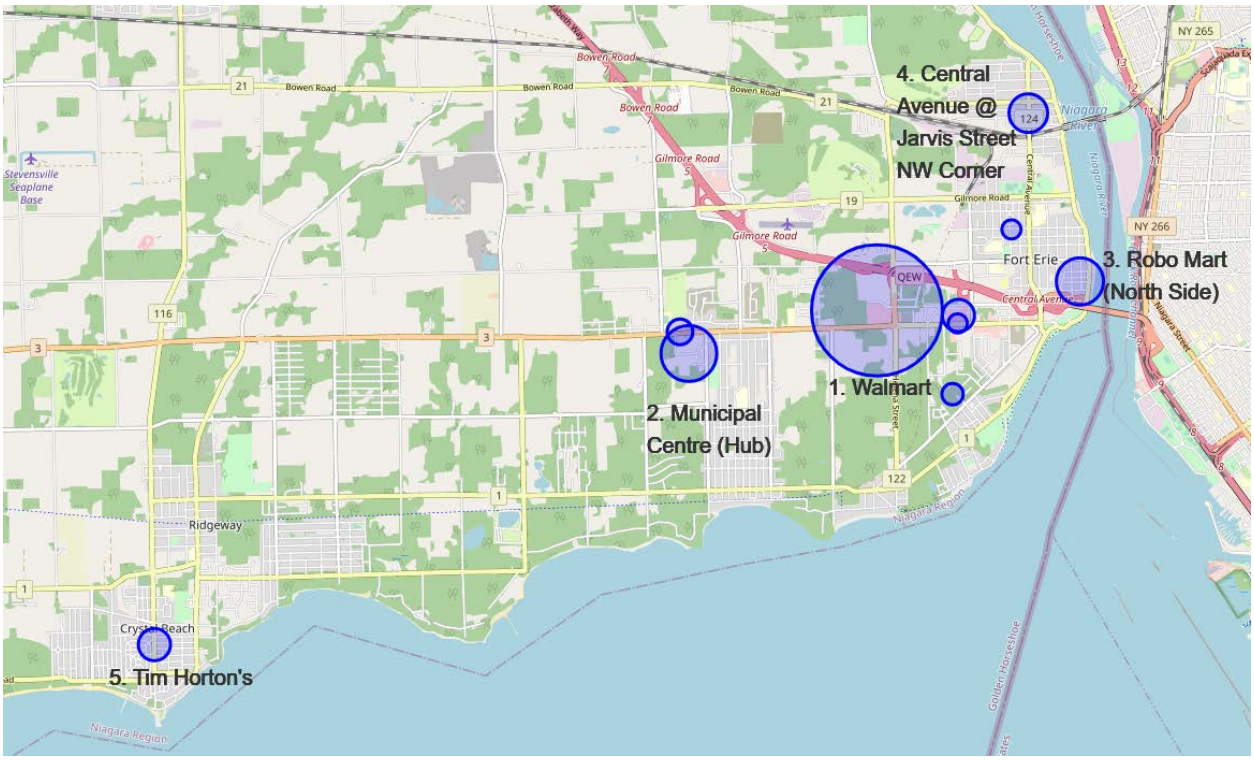
Figure 12. Percentage of trips at different types of pickup and drop-off locations, including a transit stop, specific address, or point of interest (POI), for all rides from October 4, 2021, to July 19, 2022

Figure 13 shows heat maps for all origins and destinations. The most popular pickup and drop-off location was the Walmart transit stop, making up over 10% of pickups and nearly 9% of drop-offs. The top 10 origins and destinations are shown in Figure 14. All 10 are transit stops in the Fort Erie and Crystal Beach population centers.

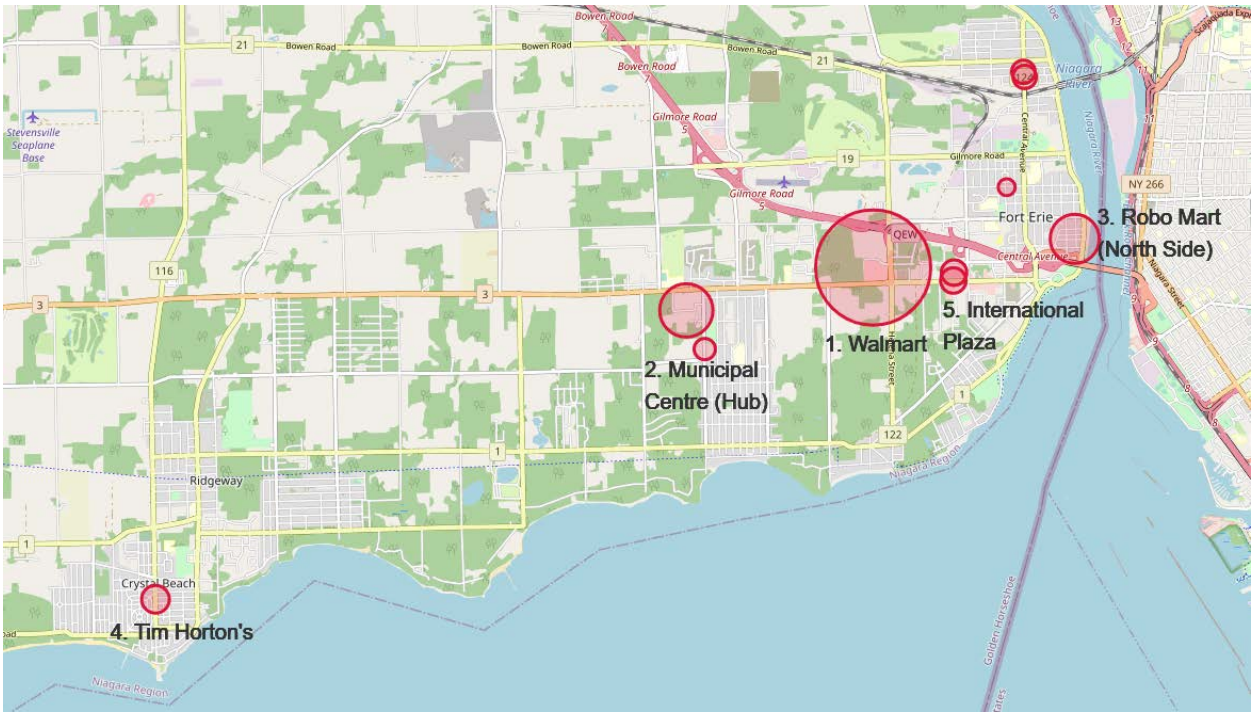


Pickup Locations Drop-Off Locations

Figure 13. Heat maps showing pickup and drop-off locations for all ODT trips from October 4, 2021, to July 19, 2022. Red indicates high-frequency locations, and green and blue indicate lower-frequency locations.



Top 10 Pickup Locations



Top 10 Drop-Off Locations

Figure 14. The 10 most popular pickup (top) and drop-off (bottom) locations for trips taken between October 4, 2021, and July 19, 2022. The size of each circle corresponds to its prevalence.

Accessibility for Those With Wheelchairs, Bicycles, or Young Children

Two of the minivans in Fort Erie's current fleet are wheelchair-accessible, as shown in Figure 1. The middle seats of these vans were removed to accommodate equipment for a ramp and wheelchair loading. The fixed-route buses, in comparison, were also each equipped with two wheelchair-accessible spots. Since the advent of the on-demand system, 557 trips have been provided for passengers in wheelchairs, representing 1.8% of all trips. However, as outlined above, the average wait time for accessible vehicles was approximately 4 minutes longer than non-accessible trips. Ridership data for wheelchair users in the fixed-route system were not available. Passenger data collected in the ODT system were only broken down by those who used a wheelchair and those who did not. Data on other disabilities such as vision, hearing, or developmental disabilities were not available.

Child car seats can be used if provided by the passenger; however, use of car seats is not required. According to interviews with town of Fort Erie employees, if there is an infant in the vehicle and a car seat is not provided, the driver must modify the route to avoid highways. This is an internal policy and relies on drivers to update their route accordingly—it is not incorporated into the dispatching software. It may result in a slightly longer route. Fort Erie asks that riders who would like to install a car seat request the wheelchair-accessible van because more time is built into the pickup time for these vehicles. Passengers can also bring strollers and load them into the cargo area in the back of the van. Bikes can be mounted on bike racks in the rear, and passengers can store a modest amount of goods (comparable to what one would carry on a traditional bus) behind the rearmost seat, if necessary. Bicycle racks were also available on the fixed-route buses.

Operating Costs

According to interviews with employees of the town of Fort Erie, the town's annual budget for the fixed-route buses was $1.4 million.[1] The proposed budget for the on-demand system was $950,000, due mainly to anticipated decreases in operating costs from decreased fuel usage. An increase in demand resulted in the expansion of the system (additional vehicles and more drivers), which led to the system budget increasing to $1.4 million, which was the original budget for the fixed-route bus system. All budgets included contracts with outside companies who owned and operated the vehicles. However, because the on-demand system is serving more rides at the same cost as the fixed-route bus system, the per-ride operational costs have decreased. The city-provided funding goes toward operations and subsidizing the cost of rides. A single ride costs the customer $3 (the same as in the fixed-route system) and costs Fort Erie approximately $17, as reported by Fort Erie Transit. In comparison, Fort Erie Transit reported the average cost to the town for the fixed-route system in 2019 as $24 per ride. A key finding is that although the overall cost of the ODT system is the same as the previous fixed-route service, the new system is serving more users and providing more trips.

[1] All costs are in Canadian dollars.

Another major advantage of the current on-demand system is the amount of data that are automatically collected from each ride. These data are crucial to Fort Erie as they evaluate the most cost-effective strategy to scale their public transit system.

As ridership continues to increase, Fort Erie plans to evaluate various strategies for sustainable growth, which may include additional on-demand service or hybrid on-demand and fixed-route service, with fixed routes targeted to serve high-frequency trips.

Fuel and Emissions

The town of Fort Erie provided data on annual fuel and kilometers traveled for 2018, 2019, and 2020. Aggregate fuel and kilometers traveled for three additional time periods (January–September 2021, October–December 2021, and January–March 2022) were also provided. These data were proportioned to a per-month basis in Figure 15 and Figure 16. Concurrent with the deployment of the on-demand system (which simultaneously increased ridership and expanded access), operational costs, such as the cost of fuel, decreased on a per-passenger-trip basis. This is due to more fuel-efficient vehicles, as well as the reduction in vehicle kilometers traveled and high ridership. Decreased fuel consumption has led to reduced emissions. Figure 15 shows how average fuel consumption per ride decreased after on-demand service began.

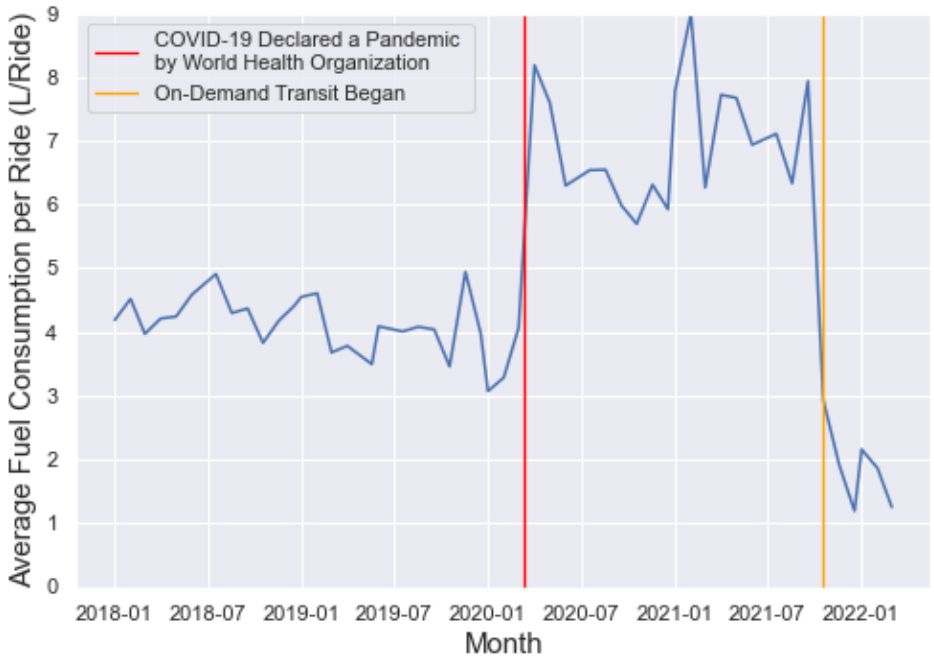


Figure 15. Average monthly fuel consumption per total monthly riders (October 4, 2017, to May 1, 2022)

With the switch to on-demand service, a linear relationship between ridership and fuel consumption has emerged. As ridership increases, so does fuel consumption. In the previous fixed-route system, fuel consumption was relatively static and independent of ridership. The scaling of fuel consumption with ridership makes it possible to estimate the point at which the total fuel consumption would equal that of the previous fixed-route transit system; this is illustrated in Figure 16. The blue line represents monthly fuel consumption derived from data

provided by Fort Erie Transit from January 2021 to March 2022. Ridership data were provided by the town of Fort Erie on a monthly basis. The steep decline in fuel usage beginning in October 2021 corresponds to the implementation of the ODT service. A linear extrapolation of on-demand service monthly ridership is shown using a green dashed line. At approximately 8,000 monthly rides, the fuel consumption for the on-demand service would surpass that of the fixed-route system. If each of these rides was by a different person, this would represent engagement of riders equal to 25% of Fort Erie's population, an extremely high utilization rate for public transportation.

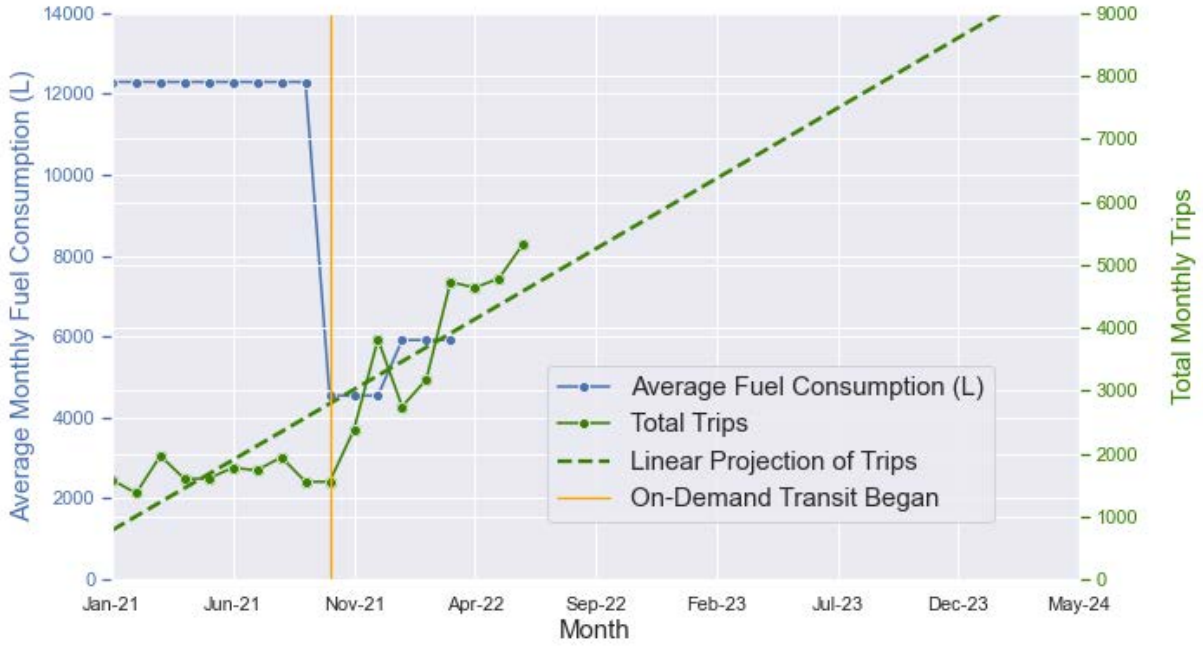


Figure 16. Correlation between monthly ridership and average monthly fuel consumption

In addition to total system-level fuel reduction and a per-passenger-trip fuel reduction, fuel consumption on a per-passenger-kilometer basis also reduced by nearly 52%, as shown in Figure 17. In other words, the new system transports a passenger the same distance using half the fuel. Fuel consumption per passenger-kilometer was calculated using annual fuel and distance traveled data for the fixed-route system and aggregate fuel and distance traveled data from October 2021–March 2022 for the on-demand system.

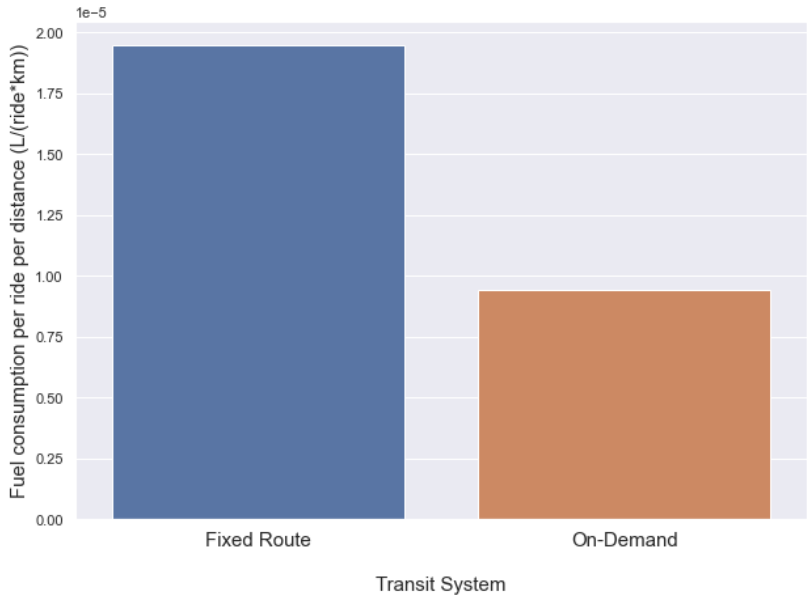


Figure 17. Fuel consumption on a per-passenger-kilometer basis. Fixed-route system data are from 2020, and the on-demand system data are from October 2021–March 2022.

Emissions decreased proportionally with the reduced fuel consumption. Using the aggregate fuel data provided by Fort Erie, the research team estimated the emissions associated with a 6-month period during the fixed-route system and a second 6-month period during the on-demand system using Equation 1:

$$Metric\ tons\ of\ CO_2 = Avg\ fuel\ consumption\ (L) * CO_2\ Emission\ Coefficient\ \left(\frac{kg}{L}\right) * \frac{1\ metric\ ton}{1000\ kg} \quad (1)$$

The NREL team used a carbon dioxide (CO_2) emission coefficient of 2.69 kilograms of CO_2 per liter of diesel burned and 2.32 kilograms of CO_2 per liter of gasoline burned [7]. Table 1 summarizes the differences between the two systems, including emissions per kilometer and emissions per ride.

Table 1. Distance Traveled, Fuel Consumed, and Carbon Dioxide Emissions for Half of 2019 (Fixed-Route System) and a 6-Month Period From October 2021–March 2022 (On-Demand System)

Year	Time Period	System	Total Rides	Km (miles)	Fuel, Liters (gal)	Avg L/100 km (gal/100 mi)	Emissions kg CO_2; CO_2/km; CO_2/ride
2019	6 months [a]	Fixed-route	19,784	205,976 (127,988)	79,402 (20,976)	38.55 (16.39)	213,590; 1.04; 10.80
2021–2022	6 months [b]	On-demand	18,381	180,908 (112,411)	31,373 (8,288)	17.34 (7.37)	72,785; 0.40; 3.96

[a] Annual 2019 data divided by two, because only annual fuel consumption data were available for the fixed-route system.

[b] October 2021–March 2022.

Emissions per kilometer from the fixed-route bus system were more than two times greater than from the minivans in the on-demand system. This is primarily due to the better fuel economy of the smaller vehicles. The observed fuel consumption per 100 kilometers and the manufacturer's specified fuel consumption of the buses used in the fixed-route service and the minivans in the on-demand service are given in Table 2. Note that the fuel consumption of the Dodge Caravan was observed to be 47% higher than the manufacturer fuel consumption. This difference may be explained by the idle time spent waiting for passengers. In contrast, the ElDorado bus consumed less fuel than the manufacturer-reported fuel consumption.

Table 2. Fuel Consumption of Fixed-Route Bus and On-Demand Minivan, According to the Manufacturer and Over the 6-Month Time Period Outlined in Table 1

Vehicle	Manufacturer Fuel Consumption, L/100 km (gal/100 mi)	Observed Fuel Consumption, L/100 km (gal/100 mi)	Percent Difference
ElDorado 30-foot bus	48.08 (20.41) [a]	38.55 (16.39)	−20%
Dodge Caravan	11.76 (5.0) [b]	17.34 (7.37)	+47%

[a] Estimated based on 2009 STURAA test performed by Pennsylvania State University [8]

[b] Combined city and highway [9].

There is potential to further reduce emissions by using hybrid or battery-electric vehicles, including CO_2, particulate matter, and volatile organic compounds that contribute to the formation of ozone and smog. The hypothetical impacts of different types of minivans employed for the on-demand service were estimated. The CO_2 emissions associated with the Dodge Caravans (traditional gasoline vehicles) were used as the baseline, as outlined in Table 1. Two scenarios were evaluated: hybrid all-wheel-drive Toyota Siennas and plug-in hybrid Chrysler Pacificas. We assumed that all Dodge Caravans were replaced with one of these vehicles in the scenarios. CO_2 emissions per ride reduced 44% and 68% for the traditional hybrid and plug-in hybrid vehicles, respectively (Figure 18).

Fully electric vehicles have the potential to further reduce emissions, although there are currently no battery-electric minivans on the market. Using a comparable battery-electric vehicle and assuming a conservative range of 140 miles, 94% of vehicle journeys could be served with battery-electric vehicles without mid-journey charging. A vehicle journey is a sequence of trips (pickups and drop-offs) reported by the dispatching software company, with an average of three journeys per van per day and most journeys starting and ending at the dispatch office. It is also likely that battery-electric vehicles could serve all vehicle journeys if battery range constraints were considered in the matching and routing algorithm from the onset.

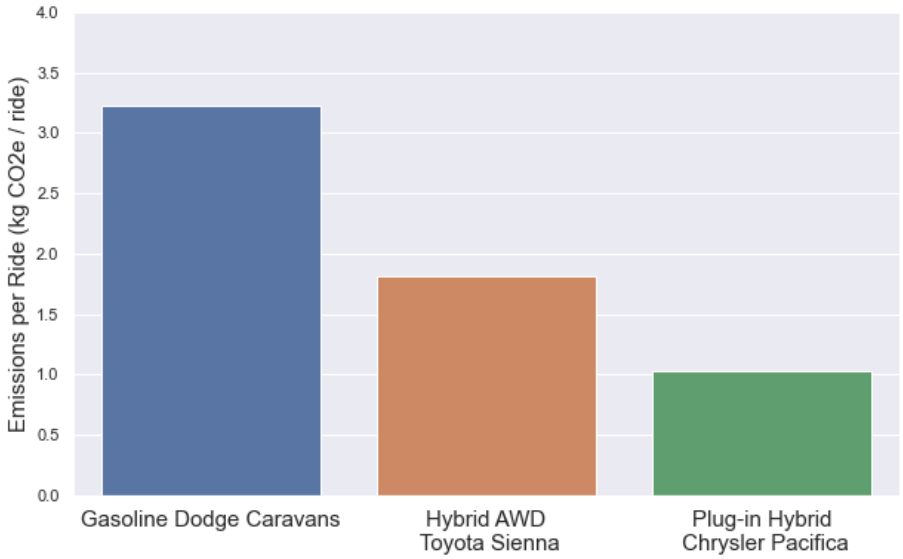


Figure 18. Estimated emissions per ride for the baseline case (Dodge Caravans) and two hypothetical scenarios where all vehicles are replaced with hybrid all-wheel-drive Toyota Siennas or plug-in hybrid Chrysler Pacificas. Both upstream and tailpipe emissions are included, using an electricity grid mix for Buffalo, New York [9].

Customer Feedback

The town of Fort Erie performed a survey using onboard paper survey cards in April and May 2022. The questions and response options are included in Table 3. The response rate was not collected. Preliminary results include findings regarding rider satisfaction, vehicle cleanliness, driver helpfulness, where the respondent heard about the service, and any open-ended comments. These preliminary results include responses from 46 riders. The most common way riders heard about the service was word of mouth, followed by "transitioned from fixed-route bus," as shown in Figure 19.

Table 3. Survey Questions and Response Options From an Onboard Survey Performed in April and May 2022

Survey Questions	Response Options
Was your trip satisfactory?	Yes, No
Was your driver helpful?	Yes, No
Was the vehicle clean?	Yes, No
How did you hear about Fort Erie On-Demand Transit?	Billboard, Online, Radio Ad, Transitioned from Fixed-Route Bus, Word of Mouth, Other, No Answer
What is your overall satisfaction with this service? (1–5 Rating)	1–5 Rating, with 5 being the most satisfied and 1 being the least satisfied
Open Comments	Free response

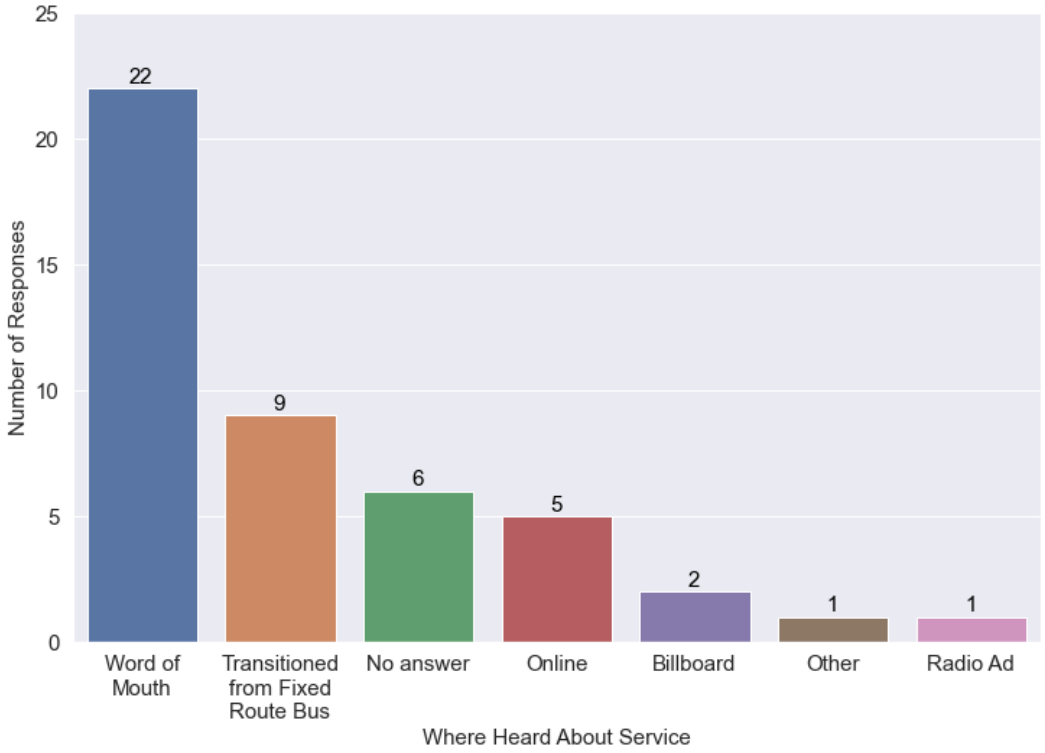


Figure 19. Preliminary results from onboard comment cards, collected April and May 2022, show how riders heard about the on-demand system. The total sample size was 46 respondents.

On a scale from 1 to 5, 84% of respondents rated their overall satisfaction with the trip as either a 4 or 5, with only two 1 and 2 ratings out of 46 surveyed.

Discussion

Fort Erie's on-demand system has significantly altered public transit use in the community. Such rapid change has had widespread benefits. The on-demand system moved more people using less fuel, with CO_2 emissions on a per-ride basis reduced by over 60%. Public transit is now available to every resident of the town of Fort Erie, and according to anecdotal experience expressed in interviews with employees of the town of Fort Erie and preliminary results from a small survey showing over 90% of respondents stating their trip was satisfactory, customer satisfaction is high. Customer satisfaction is also reflected in increased ridership. Wait time averaged about 11 minutes overall and 14 minutes for wheelchair-accessible rides, and ride times averaged around 14 minutes in the new system. No data were available for the fixed-route system, but the bus route's frequency was approximately once per hour. Accessibility for wheelchair users and those with bicycles was still provided, and the service provides greater independence—including for those who did not have access to transit before, the unbanked, those without smartphones, and those with disabilities. Less burden on parents to transport high school students to jobs and other activities was also noted.

Another benefit of the on-demand system is the valuable data collected by the dispatching software. Passenger counts, pickup and drop-off locations, dates and times of rides, and GPS

routes are all now available to Fort Erie for ongoing analysis, enabling them to track the success of their system and develop a business case for adding a fixed route (or other hybrid business model) in addition to the on-demand vans. The data can also help inform decisions such as increasing (or decreasing) vehicle capacity and adding vehicles, as was done in May 2022 when the purchase of three additional vans was approved.

In interviews with key stakeholders, Fort Erie reported a few operations issues with passengers. Most notable is the issue of passengers scheduling rides and then not showing up at the pickup location. This occurs for almost 12% of trips. Passengers who do not officially cancel their rides lead to "ghost stops" and wasted operating costs. "Deadheading"—circulating without any riders—may also occur between passenger drop-off and traveling to the next passenger pickup. Opportunities for optimizing routing and allocation of vehicles based on demand prediction could further reduce inefficiencies and costs. Inefficiencies will ultimately exist—similar to empty buses under the fixed-route system—but can be minimized if the system only serves actual demand. Overall, the on-demand model with minivans leads to minimum deadheading. Although it is difficult to enforce ride cancellations without discouraging passengers from using public transit entirely, fees could be instituted to discourage such behavior, as is done in ride-hailing applications.

Some passengers were resistant to the change involved in the new system, according to interviews with employees of the town of Fort Erie, although survey results showed that this resistance decreased over time. The new system had a learning curve for both drivers and passengers. In an interview with key stakeholders, organizers of the ODT system emphasized the importance of driver training. The same drivers who previously drove the fixed routes were switched over to the new system, which brought challenges, such as needing a greater navigation knowledge of the entire Fort Erie area [10]. One early key lesson learned was the importance of having more one-on-one training with the drivers to enable a smooth transition, as well as providing avenues for drivers to provide feedback to enable continuous improvement.

One of the drawbacks of using minivans rather than buses during the COVID-19 pandemic, according to interviews with stakeholders, was travelers having to be within closer proximity to one another. However, significant safety protocols were put in place to mitigate the risks.

Another issue with the on-demand system is its scalability. Fort Erie is growing, with a 7.1% increase in population from 2016 to 2021 (almost 2% higher than the national average) [2]. Although an on-demand system is more flexible and responsive to changes in demand, it is important to continuously evaluate the on-demand system and consider adding fixed routes in certain areas if demand allows. Other communities seeking to implement similar systems must carefully consider whether a fully on-demand system is right for them, or if a hybrid or fixed option may better suit their demand.

Looking Ahead

The 2022 rider survey revealed that word of mouth and prior use of the fixed-route system were the most common ways riders learned about the on-demand system. Fort Erie is actively working on expanding ridership, especially among young riders and summer tourists. The town may need to advertise and perform outreach to these specific groups. However, ridership has been increasing since on-demand was instituted.

As mentioned above, the Fort Erie council recently approved the purchase of three additional vehicles due to increased ridership. The town also anticipates a rise in summer tourism, rebounding from the pandemic.

A Niagara-wide public transit system (referred to as the "transit consolidation service plan") is coming January 1, 2023. This involves consolidating Niagara and Fort Erie's public transit systems. Fort Erie Transit anticipates little impact to the on-demand system following the consolidation, with no customer-facing changes.

On the funding side, Fort Erie Transit anticipates a budget increase within the next couple of years due to increased ridership and potential service expansion. Fort Erie is considering expanding from 6 days of service per week to 7. This would put Fort Erie Transit in line with other transit services in the area, such as Niagara, which currently operates a 7-day-per-week transit service. Expanding service end times from 9 p.m. to 11 p.m. is also being considered.

Future Opportunities

According to the Federal Transit Administration National Transit Database, as of August 2022 [11], there were 128 public transit agencies in the United States actively reporting to the Federal Transit Administration with service areas of less than 500 people/km^2 (1,295 people/mi^2) operating fixed-route bus systems. Collectively, these 128 transit systems complete approximately 272 million unlinked passenger trips per year, on average, and have service populations of about 76.8 million. If all these systems were replaced with on-demand systems and right-sized vehicles (and saw similar ridership increases and fuel reductions as Fort Erie), approximately 1.7 million metric tons of CO_2 emissions could be avoided annually, with more residents served. This is equivalent to removing approximately 367,000 internal combustion engine passenger cars from the road for an entire year, in addition to the societal benefits of expanding transit access beyond population centers [12].

Conclusions

On-demand transit is emerging in rural and smaller-sized communities as a valued mobility service solution for locations in which traditional transit is not viable or not accessible to all, and as a promising inclusive alternative to traditional fixed-route bus transit services. An initial analysis 8 months after Fort Erie's implementation of an on-demand system demonstrates expanded access, increased ridership, decreased operating costs, and reduced emissions. While the service is not a profit-generating business, it has been noted as affordable, at $3 per trip (with subsidies), as well as cost-effective, with a lower operating cost on a per-ride basis relative to the fixed-route service that it replaced. In the era of transit operations during the pandemic, during which many locations have experienced reduced ridership, cuts to service, and other challenges, the on-demand system in Fort Erie is an anomaly and a success story for what other communities could consider for their services in the future.

This analysis also revealed the importance of the data that Fort Erie is collecting and using to assess the system's performance over time. Scalability is a key topic for Fort Erie Transit as ridership continues to increase, and iteration of system parameters will be necessary to ensure the continued success of the system as it grows. Detailed ridership data acquired over time, including

rider pickup and drop-off locations and times, can be used by Fort Erie to ensure that on-demand remains the best system for the area.

The potential for other communities to learn from and adapt the Fort Erie ODT system may present opportunities to transfer knowledge and successes. This is a critical component of the modernization and expansion of public mobility options and the reduction of private car dependence in small communities. This work will also help meet the needs of the growing number of people who are unable to drive themselves. Providing public mobility options, especially for older or disabled segments of the population, will enable people to live independently for longer by maintaining their ability to get to medical care and other crucial destinations.

Public mobility in small communities has been challenging for traditional transit. The use of smaller vehicles combined with a dynamic logistics platform for scheduling, routing, and data collection is proving to be an essential tool for effective mobility service in small communities.

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