DOES MICROTRANSIT PERFORM WELL IN THE US? AN EVALUATION OF TECHNOLOGY-ENABLED DEMAND-RESPONSE TRANSIT

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ABSTRACT

This paper explores emerging microtransit pilot programs in the United States, which represent a technological upgrade of traditional demand-response transit (DRT) in the hope of appealing to more rider groups. Published data and interviews with agency planners show that microtransit in the U.S. adopt two major service models, On-Demand Transit (ODT) and Ridehail (RH). ODT services are a modern version of dial-a-ride transit, most of which are operated with in-house labor of the transit agency or by existing bus service contractors. In contrast, RH services resemble rideshare products of transportation networking companies (TNCs) and are mostly outsourced. Data show that microtransit costs more per trip than the average fixed-route bus for all pilot studies and labor contracting structure is the most important factor in cost-effectiveness. Successful microtransit does provide quality transit access but are unlikely to achieve significant mode shift or environmental benefits.

BIOGRAPHICAL SKETCH

Zhiyue (Tim) Wang is an undergraduate student in the urban and regional studies program at Cornell University. Their academic field of interest encompasses urban mass transit planning and travel behavior research. Being from mountainous southeastern China, Wang deeply appreciates how accessible urban transport systems enable upward mobility and quality of life improvements for individual residents and drive regional economic growth. They invests time and effort in visiting and studying world-class transit systems in cities like Shanghai, Tokyo, and London, and wishes to work as part of the global movement in bringing quality and equitable transit to increasingly car-centric cities in today's world.

I dedicate this thesis to all transit workers and agency staff who keep our cities moving every day, efficiently and sustainably.

ACKNOWLEDGMENTS

I would like to express my sincere gratitude to the service planning teams at TCAT and King County Metro. This work would not have been possible without their knowledge of the microtransit planning process and unique insights into the factors that help shape a successful pilot program.

I must also say thank you to Dr. Nicholas Klein for his academic support and encouragement that are indispensable for my completion of this thesis, and to Dr. Zakhary Mallett, who helped broaden my vision of empirical research and practice in transportation planning.

I also owe a debt of thanks to my friends and roommates Edward Guo, Yucheng Zhang, Frank Hu, and Guo Jing for offering me critical support and guidance as I navigated through my four years of undergraduate studies in Ithaca, NY.

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LIST OF ABBREVIATIONS

ADA: Americans with Disabilities Act

COVID-19: Coronavirus Disease 2019

DRC: Demand-Response Connector

DRT: Demand-Response Transit

GHG: Greenhouse Gas

FM/LM: First-Mile/Last-Mile

FRT: Fixed-Route Transit

FTA: Federal Transit Administration

NTD: National Transit Database

NYSERDA: New York State Energy Research and Development Authority

RH: Ride-Hailing

TCAT: Tompkins Consolidated Area Transit

TCRP: Transit Cooperative Research Program

TNC: Transportation Networking Company

VMT: Vehicle Miles Traveled

WAV: Wheelchair Accessible Vehicle

PREFACE

The study presented in this thesis was inspired by post-pandemic transit planning and innovation in small urban and suburban transit agencies. As a transit enthusiast and advocate, it was disturbing to see transit ridership collapse further in travel markets that were already heavily car-centric pre-pandemic. Still, learning about the innovative strategies that agencies across the U.S. were attempting gave me encouragement and hope for the future of small city transit. I sincerely wish this study is helpful, even if just slightly, to transit agencies looking to evaluate and improve their family of services.

Introduction

An increasing number of transit agencies are experimenting with microtransit services in the recent decade. Most of these pilot programs aim to modernize the traditional dial-a-ride service model by improving trip request and dispatch technologies. While still accepting ride requests by phone calls, microtransit relies on mobile applications to efficiently collect requests from riders and process them using computerized scheduling systems (NASEM, 2010, p. 39). This set of technology enables transit operators to remove the need for advanced trip reservations and instead take requests in real-time, which could expand the market for on-demand transit service from groups with special needs to the general public.

Despite the positive outlook, transit agencies have faced numerous challenges as they plan and operate microtransit pilots: the flexible routing and schedule take away the reliability of a fixed-route service as most or all stops are served on-request only. Depending on trip availability and wait time, this mechanism may make spontaneous travel more difficult and could complicate travel planning for riders. In some cases, DRT has led to lower ridership when it replaced a low-performing fixed-route service operating in the same area or failed to expand ridership while service area and hours significantly increased. Microtransit's low ridership issue could further limit its cost-effectiveness and environmental sustainability. Microtransit carry fewer riders per hour but still require similar operating expenditure on vehicle and labor, in addition to greenhouse gas (GHG) emissions generated. While "right-sizing" the vehicle could reduce fuel costs and emissions, this option is dependent on an agency's access to small-size vehicles, either in their own fleet or through partnerships with private transportation companies.

Mixed outcome from current microtransit pilots raise questions about the real value microtransit provided to riders. In this paper, I explore the following questions: How are microtransit programs operated across the U.S.? To what extent do microtransit pilots fulfill their objectives, and what institutional, geographic, or service characteristics likely enable success? To answer these questions, I review the service provision and performance of 18 microtransit programs across the United States, combining metrics from conventional transit evaluation frameworks and industry standards for new mobility services.

In the following sections, I present a definition of microtransit and discuss the pilot programs' goals and assumptions using agency documents, journal articles, and research reports. Based on these sources, I suggest an evaluation framework for microtransit focused on pilot programs' common objectives and corresponding performance metrics. This is followed by an empirical analysis of microtransit in the U.S., consisting of a general, quantitative analysis of 18 programs and two detailed case studies. I end the paper by summarizing main findings from the general review and case studies and attempt to answer the research questions. I also present recommendations for transit agencies looking to improve existing microtransit services or planning for new ones.

Microtransit: Definition, Goals, and Assumptions

Transportation scholars and practitioners have used various terms to describe transit services that do not follow a fixed route or schedule, includingn "on-demand," "demand-response," "flex," and "micro." These names reflect the new pilots' unique characteristics – they often utilize smaller shuttle buses or vans, follow flexible or free routing, and organize operations according to real-time demand. I use *microtransit* as an umbrella term to describe modernized demand-response transit programs that emerged as transportation networking companies (TNCs) like Uber and Lyft brought computer-based, dynamic routing, and trip assignment systems to the transit industry. I define microtransit, based on specifications developed by Eno Center for Transportation, as shared transportation services operated by public transit agencies or their contractors that utilize computer-based routing systems to determine flexible routing and on-demand schedules (Westervelt et al., 2018, p. 3).

Since 2010, a significant number of U.S. transit agencies have been switching to on-demand service models in areas where missions of public transportation are difficult to fulfill with traditional fixed-route transit (FRT). Jarrett Walker's influential work on goal-setting for public transportation proposes two basic categories of transit routes – coverage-oriented and patronage-oriented services (2008). Depending on local travel patterns, microtransit might have a competitive edge over FRT in providing coverage-based service, as flexible routing and scheduling allow microtransit to precisely respond to real-time requests in an area where overall demand is low and spatially dispersed. The orientation toward providing basic lifeline services in low-density neighborhoods implies that microtransit alone is unlikely to generate significant ridership compared to other transit modes (Volinski et al., 2019). Nevertheless, microtransit may still help promote system-wide ridership if they function as first-mile/last-mile (FM/LM) connectors to trunk bus routes or rapid transit. In a system where FRT depends on multiple local feeder services to attract riders, microtransit provides important support to FRT performance and can help sustain higher level of service on those routes.

Empirical research and case study reports on microtransit show that transit agencies utilize microtransit in three principal settings: 1) to provide coverage service to unserved or underserved neighborhoods, 2) to improve first-mile/last-mile access to FRT, and 3) to replace underperforming fixed-route bus routes (Hansen et al., 2021; Volinski et al., 2019). Transit agencies may also initiate microtransit programs as test cases for partnering with TNC or to experiment with trip-routing technologies – the FTA Mobility on Demand program (MOD), for example, aims broadly to improve mobility through "leveraging innovative technologies and facilitating public-private partnerships" (Transit Center et al., 2020, p. 7).

These use cases hint at underlying goals and expectations transit agencies have for microtransit. First, microtransit is expected to provide better connectivity compared to similar fixed routes, especially in a transit market where demand is spatially dispersed. Neighborhood coverage routes and feeder routes that run on fixed routes and schedules often suffer from long headways and circuitous routing, which limit ridership and further restrict the operational resources invested in the service (Higashide, 2019). Agencies replace low-performing bus routes with microtransit in the hope of serving areas with existing, dispersed demand (Westervelt et al., 2018, p. 16). By tailoring each trip to real-time requests, microtransit could decrease waiting times and onboard travel time for individual riders.

Another important assumption behind microtransit pilots is lower operational costs. According to a national survey of agencies operating microtransit routes, making services more cost-efficient in low-density areas is among the top reasons for experimenting with the new model (Volinski et al., 2019, p. 15). The dual mandate for transit to both provide lifeline service and increase transit ridership and mode share is an enduring dilemma for agencies serving suburban and rural markets. Rather than choosing between sustaining a low-performing service or eliminating the service entirely, pioneering agencies like King County Metro opt to operate microtransit as a low-cost alternative for FRT in low-demand areas (King County Metro, 2021b). By optimizing each run to real-time demand, microtransit enables agencies to use smaller vehicles to serve larger areas and reduce waiting time for requested trips, creating a coverage service that is financially feasible.

Finally, potential environmental benefits are pursued by transit agencies that utilize microtransit as FM/LM connectors. By making trunk-line transit routes more accessible and convenient to use, microtransit may attract drivers to use transit instead of the automobile and reduce overall VMT (Gifford et al., 2021, p. 2; Yarrow, forthcoming, p. 9). This enables the reduction of air pollution and greenhouse gas emissions related to automobile reliance.

Toward a Common Evaluation Framework

The three goals discussed above can be seen as hypotheses that transit agencies hope to test out in experimenting with novel microtransit programs. While each pilot program has its unique goals, they share the objectives of improving service usefulness, increasing efficiency and financial management, and making local travel more environmentally sustainable. A generalizable evaluation framework for these pilots should focus on the extent to which these hypothesized benefits are attained in practice, and relate those successes and failures to the service characteristics of specific pilots. Such a framework can not only inform the feasibility of integrating current programs into an agency's regular service portfolio but also help operators who are looking to enter the microtransit market better plan for new services.

Current research on microtransit emphasizes evaluating specific pilot programs and generalizable findings are rare, possibly due to the high variability across microtransit operations. Among the limited literature on microtransit evaluation, Transit Center et al. (2020) propose general goals and specific metrics to evaluate federally-funded Mobility on Demand programs, based on common performance metrics used by public transit agencies and private transportation providers. They identify nine goal areas for technology-enabled mobility programs; among these, four are especially relevant to public microtransit services: increasing transit connectivity, achieving planning goals (travel behavior changes), improving financial management, and gaining customer satisfaction. Research on transit agencies' expectations for microtransit performance echo these proposed metrics – Hansen et al. (2021) worked with Capital Metro (Austin, TX) to explore service metrics that agency staff deem the most important in determining the success of a microtransit pilot. They similarly highlight metrics that demonstrate service usefulness (waiting time, trip duration, and completed trips), environmental sustainability (shared rides and transfers to FRT), operational- and cost-effectiveness, and rider satisfaction.

To produce a generalizable evaluation framework for microtransit in the U.S., I matched performance metrics proposed in literature to the three major use cases of microtransit discussed in the previous section (See table 1). The four objectives follow a logical order from describing a service's span and frequency (objective one) to measuring benefits produced by unit time and expenditure (objective two), contribution to lower GHG emissions (objective three), and the overall rider experience (objective four). For each objective, I selected multiple performance metrics that complement each other and have the best data availability. Still, I acknowledge two limitations of this framework that necessitated changes during analysis.

Table 1. Microtransit Objectives and Performance Metrics

Metric	Data Type	Description
OBJECTIVE 1: TEMPORAL AVAILABILITY		
1a. Waiting Time or Headway	Average	Average duration between trip request and actual boarding time **or** duration between two scheduled vehicle runs for services with a planned cycle time
1b. Weekly Hours of Service	Average	Average number of hours in a week for which service is available
1c. Completed Trips	Percentage	Percentage of completed trips out of all requested trips
OBJECTIVE 2: EFFECTIVENESS		
2a. Operational Effectiveness	Average	Number of boardings per vehicle revenue hour
2b. Cost-Effectiveness	Average	Average cost per passenger ride
OBJECTIVE 3: ENVIRONMENTAL SUSTAINABILITY		
3a. Mode Shift	Percentage	Percentage of microtransit riders previously using single-occupancy vehicles (SOVs)
3b. Transfer to FRT	Percentage	The percentage of passenger trips involving a transfer to or from a fixed-route transit ride
OBJECTIVE 4: CUSTOMER SATISFACTION		
4a. Rider Satisfaction	Average	Trip rating out of five or percentage of satisfied riders in a surveyed group

First, the completed trips metric (1c) was meant to go beyond the scheduled level of service, which is captured by metrics 1a and 1b, and measure how reliable the microtransit was in fulfilling rider requests. The proportion of completed trips are often lowered by trip cancelations due to rider no-show, limited vehicle capacity and/or availability, trip requests that violate service policy, etc. Unfortunately, I discovered during data collection that except for a few services that used trip planning systems similar to conventional ride-hailing, most agencies did not have completed trips data available. Thus, I dropped the metric in the following analysis sections.

The other problematic metric was rider satisfaction (4a). Besides the data availability issue similar to the one discussed above, rider rating for microtransit are surprisingly consistent across all types of programs. This pattern is echoed by a TCRP report on microtransit and indicates a serious self-selection issue in rider surveys (Volinski et al., 2019). Because agencies could only examine satisfaction among current riders, this first precludes people who could have used the service but did not, due to low service level or quality. In particular, microtransit that replaced FRT could have lost previous riders due to the service change, which is not reflected in the rider surveys. Riders who “tried out” the service but decided not to continue using it are also likely excluded in the data. These two issues severely limited the value of a rider satisfaction metric. Thus, it is excluded in analysis that follow.

Data

This study combines a quantitative assessment of microtransit service provision, performance, and effectiveness with qualitative understanding of transit agencies’ experience and takeaways gained in planning and operating microtransit. These approaches produced two major sets of data used to document, analyze, and evaluate innovative microtransit programs, which are outlined below.

Statistics on Service Availability and Performance

Microtransit

To construct data for cross-sectional analysis of microtransit pilots across the US, I identified these services and obtained key availability and performance metrics through several research reports and a general literature search. I started by examining three case studies from the Federal Transit Agency's Mobility on Demand program (MOD) that utilizes technology-enabled microtransit to improve transit access (Gifford et al., 2021; Miller et al., 2021; Parks & Moazzeni, 2020). These programs focus on data collection and project evaluation, and create consistent documentation of pilot goals and performance. I then examined case studies in three reports dedicated to microtransit services and selected pilots with data available at least for evaluating the first two objectives of microtransit: temporal availability and effectiveness (APTA, 2021; Volinski et al., 2019; Westervelt et al., 2018).

I complemented information on microtransit pilots discovered through this method using project evaluation reports, whenever such resources were available, and collected data corresponding to the evaluation framework summarized from the literature. Due to the national scope of this review, I narrowed my focus to service connectivity and effectiveness and searched for data on weekly hours of service, waiting time, rides per revenue hour, and cost per passenger ride. The search yielded 24 microtransit programs in the US, from which 18 programs with at least two available service metrics were selected for analysis.

Most of the service performance and trip data for the two case studies were obtained from respective project reports as cited in the text. Additional daily ridership data for Tconnect was requested and obtained from TCAT.

Agency Information and FRT Performance

I benchmarked the effectiveness of each microtransit program using the performance of fixed-route buses operated by the same agency. I calculated effectiveness measures for fixed-route buses using 2019 data from the National Transit Database (NTD) to see how microtransit compares to conventional services and verify whether microtransit achieved goals to increase service, reduce costs, and improve sustainability (FTA, n.d.). I also proxied the general transit market type served by a transit agency using population size data on census-defined primary urbanized areas (UZA).

Planning and Operation

To conduct quantitative data analysis on the two case study programs and understand microtransit planning and operation from the transit agency's perspective, I interviewed four transit agency staff from TCAT and King County Metro who were involved in planning and evaluating microtransit programs. I conducted the interviews in semi-structured formats, with a few pre-determined questions that outlined the structure and objectives for the conversation. The interviews lasted between 30 minutes and an hour, during which I asked questions about 1) the project concept and goals and how they changed over time, 2) planning and operational difficulties, especially when collaborating across agencies, and 3) methods and outcomes of project evaluation. I took detailed notes during the interviews and organized them under each question or theme for future reference.

Limitations

There are several limitations to my research. Though I strived to obtain consistent, representative data for each microtransit program and analyze them responsibly without over-generalizing on particular observations, the small sample size, limited data availability, inconsistent data collection methods, and the subjective nature of analyzing based on a small number of case studies may bias my findings.

Microtransit is a new service model experimented with by a limited number of agencies in the US, most of which are major organizations with the staff and budget to implement such pilots. Furthermore, a narrow field of research so far has documented and addressed microtransit planning and operations, which limited the number of programs examined in this study to only 18. This small sample size made it impractical to employ robust statistical methods such as multivariate regression and restricts the generalizability of my findings for practice. Instead, I focused on descriptive statistics with specific understanding of service characteristics and institutional contexts of each pilot.

A second limitation of my analysis is data availability issues, which manifest in missing entries for waiting time and cost-effectiveness measures and the general unavailability of mode shift and FRT transfer ratio for most of the reviewed programs. I mitigated this issue by first determining that metrics under the first two objectives (temporal availability and effectiveness) are the most critical for evaluating all programs, while objective three (environmental sustainability) will be used for case studies only. I then filtered the initial 24 programs by allowing for a maximum of two missing data entries for objectives 1 and 2. This yielded 18 programs for analysis with mostly complete data, except for wait time, where only 11 programs reported such data.

Third, the majority of microtransit services reviewed in this study were operating as pilots with dedicated funding separated from general operating funds, which means that consistent data such as those reported to the NTD are not available. Data collected from reports and agency documents cover different time periods and utilize inconsistent measuring standards. The most common time span issue arises from whether data was collected from a specific evaluation period (such as a six-month pilot period) or was the latest available data from long-term services. Because only one type of these data is available for most programs, confounding factors such as periodic variation in transit ridership or the COVID-19 emergency may bias the analysis.

Data standards also differed across agencies, particularly for the wait time and effectiveness metrics. Wait time is either calculated as an average from actual trip data or derived from the scheduled cycle time of the service. The latter method tends to exaggerate the average wait period because the cycle time is a maximum period that a vehicle could spend picking up and dropping off passengers. Average wait periods are likely shorter for programs with capacity above demand, because the vehicle spends some time idling at the terminal for most trips, during which it could respond to ride requests faster than scheduled. Agencies also calculate operational effectiveness (rides per hour) differently, by dividing total ridership either by vehicle revenue hours or driver hours. The latter approach includes deadheading and yields lower effectiveness. Lastly, the cost-effectiveness metric (cost per passenger boarding) is mostly consistent except for a small number of programs, such as LA Metro's Via to Transit, that report *subsidy* per passenger boarding by incorporating fare revenue into the calculation. Subsidy per passenger boarding can make programs appear cheaper than those using strictly total operating cost as the numerator.

A final note in research limitation concerns the case study part of this empirical analysis, where I attempted to explore how institutional structure, the local transit market, and other contextual factors impacted microtransit success. I prioritized the depth of analysis by focusing on only two case studies, which are selected to each exemplify the two prevailing service models (detailed discussions follow in the next section). Still, I acknowledge that the nature of case-based analysis restricts generalizability, especially as microtransit is still a new concept without consistent service standards. I make every effort to note instances where findings are generalized in the sections that follow.

Microtransit Programs in the US

This section provides a quantitative analysis of microtransit services studied in scholarly articles, independent evaluations, and self-evaluation reports published by transit agencies. This review is not intended to be comprehensive as the data covers only programs where published research exists. Still, it captures pilot programs that drew the most attention from academia and public agencies and are most likely to influence policy and planning of transit agencies looking to enter the microtransit market. The 18 sampled microtransit pilots were operated by 17 agencies across among nine different states, and the two states with the highest numbers are California (six) and Texas (three). The list of microtransit programs and their performance metrics are summarized in table 2, where data sources are also noted in the last column.

Service Models

The 18 tech-enabled microtransit programs reviewed in this section utilize two major service models. On-Demand Transit (ODT), defined as flexible routes "with one or more scheduled transfer points that connect with a fixed-route network (NASEM, 2010, p. 5)," include programs created by upgrading trip planning technology of dial-a-ride and paratransit services. Transit agencies typically partner with technology providers to develop mobile applications for trip requests and, in some cases, utilize real-time route planning systems to improve the efficiency of the trip planning process.

The vehicle and labor used for ODT programs clearly show their connection to paratransit – among the 13 agencies operating ODT, three did so through their existing paratransit service provider while three others seeked for new contracts. The common characteristic among these contractors is that almost all were involved in paratransit and dial-a-ride operations, which allowed them to use the same vehicle fleet and labor for microtransit while applying their experience in operating other demand-response services (Volinski et al., 2019). Besides contracted services, five agencies provide ODT using in-house labor and vehicle. This approach allowed agencies to follow existing work rules for drivers operating microtransit and avoid issues in union negotiations (Volinski et al., 2019). However, following work rules for fixed-route operation could also reduce flexibility in adjusting service level – in the case of the VTA FLEX, this resulted in an oversupply of bus drivers during the pilot (Westervelt et al., 2018). In addition to avoiding labor conflicts, direct operation also enabled agencies to utilize transit shuttles in their existing fleet – the AC Transit Flex was operated using 16-seat vehicles that were purchased but never put into service, while the Santa Clara VTA refurbished retiring vehicles for use by microtransit (Westervelt et al., 2018). These agencies were able to reduce capital investment and contracting costs by tapping into underutilized assets.

Table 2: Microtransit Program Summary

Agency	Program Name	Scheduled Hours of Service per Week	Mean Waiting Time (min)	Rides per Revenue Hour	Cost per Ride	Source
Alameda-Contra Costa Transit District	Flex	70	22.5	3.0	$ 71.00	Westervelt et al. (2018); Urgo (2018)
Capital Metro (Austin, TX)	Pickup	65	11.9	3.7	$ 17.42	Hansen et al. (2021); Lynch (2018)
Denver RTD	Call-n-Ride	71	-	3.8	$ 21.84	Volinski (2019)
Houston METRO	DRT Flex Zones	98	-	2.4	$ 28.65	Volinski (2019)
Tompkins Consolidated Area Transit	Tconnect	20	30	1.5	-	Yarrow (forthcoming); Champion Bus (n.d.)
Kansas City Area Transportation Authority	RideKC Micro Transit	84	15	2.7	$ 20.00	APTA (2019; 2021)
Kitsap Transit	SK Ride	52	-	3.7	$ 35.68	Volinski (2019)
Monterey-Salinas Transit	MST On Call	-	-	4.0	$ 13.44	Volinski (2019)
Napa Valley Transportation Authority	On-Demand	61	-	2.6	$ 17.00	Volinski (2019)
Central Florida Regional Transportation Authority (LYNX)	NeighborLink	84	-	3.3	$ 12.60	Volinski (2019)
Salem Area Mass Transit District (Cherriots)	Connector	78	30	3.3	-	Volinski (2019); OSTI, n.d.
Santa Clara Valley Transportation Authority	FLEX	75	7.5	0.4	-	Westervelt et al. (2018)
King County Metro	Ride2	45	5	1.7	$ 46.00	King County Metro (2020)
Dallas Area Rapid Transit	GoLink	75	9.3	2.5	$ 16.37	Parks & Moazzeni (2020)
LA Metro	Via to Transit	118	9	1.7	$ 23.09	Volinski (2019), Brown (2021); Miller et al. (2021)
Utah Transit Authority	UTA On-Demand	98	12	1.4	$ 25.28	Macfarlane (2021); UTA Innovative Mobility Solutions (2020)
King County Metro	Via to Transit	138	8.5	3.9	$ 11.90	Gifford et al. (2021)
Hillsborough Area Regional Transit Authority (HART)	Flex	116	-	3.5	$ 10.00	Volinski (2019)

The rise in transportation network companies (TNCs) and partnerships between transit agencies and these private firms enabled an alternative service model. Labeled *Ride-hail* (RH) in this study, these services occur through public-private partnerships where agencies pay using either in-house budgets or public funding to utilize contracted vehicles, labor, and technology for the entirety of the microtransit program (Gifford et al., 2021; Miller et al., 2021; UTA Innovative Mobility Solutions, 2020). RH programs resemble pooled ride-hailing services such as UberPool and Lyft Shared, but differ from the private options in their focus on improving connectivity to local transit hubs. Microtransit operating under the RH model are also subsidized by transit agency budgets and/or external grants, giving it comparable affordability to a regular bus ride (Patel et al., 2022). One clear motivation for transit agencies to utilize the RH model is the added capacity brought by a private provider, including contracted drivers and their fleet of small-sized vehicles suitable for microtransit operations (Grossman & Lewis, 2019). RH services are also more flexible to area and level of service adjustments due to different driver contracting practiced by private providers (King County Metro Planner #1, March 2023). The last four programs in table 2 (gray background) utilize the RH model and, with the exception of HART, all partner with the private mobility company Via Transportation for operations and trip planning technology.

One special case in the programs reviewed is Dallas Area Rapid Transit's GoLink service, which started as a DRC service using dedicated vehicles but saw the addition of an RH option providing subsidized Uber and Lyft trips to and from rail transit stations (Parks & Moazzeni, 2020).

Temporal Availability: Hours of Service and Waiting Time

Hours of service per week varied greatly across the programs, partly due to the fact that some services operated on weekdays and/or during peak hours only. While King County Metro's Via to Transit program provided the longest service span at 138 hours across 7 days of the week, the agency's previous commuter-oriented pilot, Ride2, operated for less than 50 hours of service per week. Looking across the sample of microtransit pilots, more traditional ODT programs operated for a median of 70.5 hours per week which reflects service that mainly focused on weekday commute and midday hours (See figure 1). On weekends, most ODT services had later starting time and provided some level of evening service. The schedule of a typical ODT service, Vine Transit's Calistoga Shuttle, is shown in figure 2 as an example. In comparison, RH programs provided a higher median number at 115.5 hours, which enables daily, full-time service from early morning to late night hours.

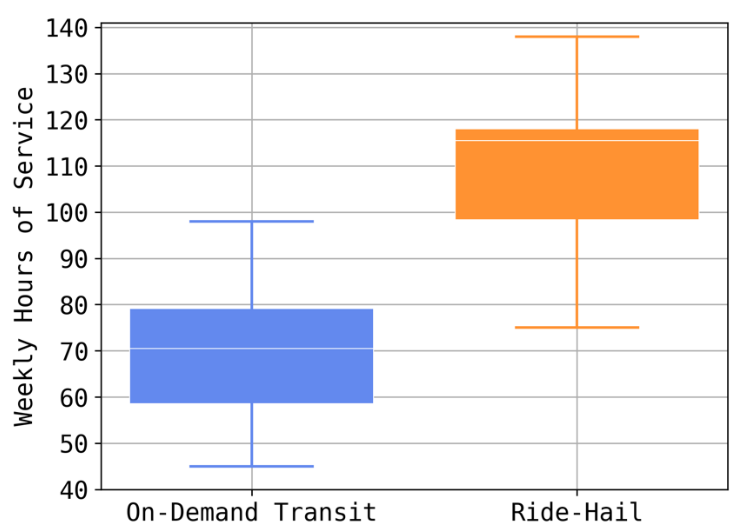
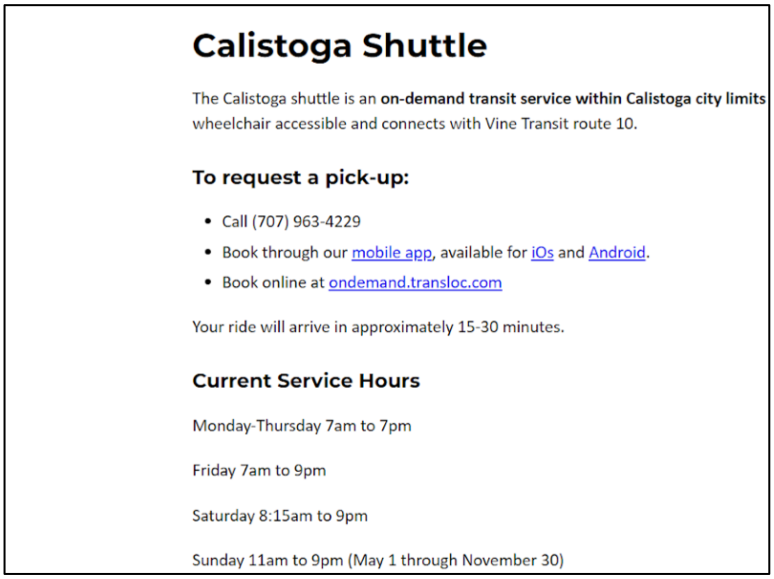


Figure 1. Hours of Service by Service Model



Calistoga Shuttle

The Calistoga shuttle is an **on-demand transit service within Calistoga city limits** wheelchair accessible and connects with Vine Transit route 10.

To request a pick-up:

- Call (707) 963-4229
- Book through our mobile app, available for iOs and Android.
- Book online at ondemand.transloc.com

Your ride will arrive in approximately 15-30 minutes.

Current Service Hours

Monday-Thursday 7am to 7pm

Friday 7am to 9pm

Saturday 8:15am to 9pm

Sunday 11am to 9pm (May 1 through November 30)

Figure 2. Vine Transit Flex Service Hours
Source: https://vinetransit.com/routes/calistoga-shuttle/

For the 11 programs that do report average wait time or scheduled headways, these measures are used to indicate the average frequency of service (See figure 3). While the majority of microtransit services reviewed had a wait time at or below 12 minutes, four ODT services had numbers between 15 and 33 minutes. Among these four services is the AC Transit Flex, which was created to replace two low-performing suburban bus routes. Agency staff aimed to match microtransit frequency to previous fixed-route buses that ran hourly services, leading to a limited number of vehicles operated and an average cycle time of 45 minutes (Westervelt et al., 2018).

<u>Effectiveness: Ride per Revenue Hour and Cost per Ride</u>

After discussing indicators of temporal service availability, I now turn to two key measurements of service effectiveness, defined by Iseki as the "level of consumption for a unit of an input" to operate transit services (2016, p. 5). In the context of microtransit operation, this ratio can be measured by passenger boardings per vehicle revenue hour (*rides per hour*) or operational cost per passenger boarding (*cost per ride*). While the rides per hour metric evaluates outcome relative to unit transit service produced, the cost per ride metric captures external factors that vary across regions and are mostly out of the transit agency's control, such as varying labor and fuel costs.

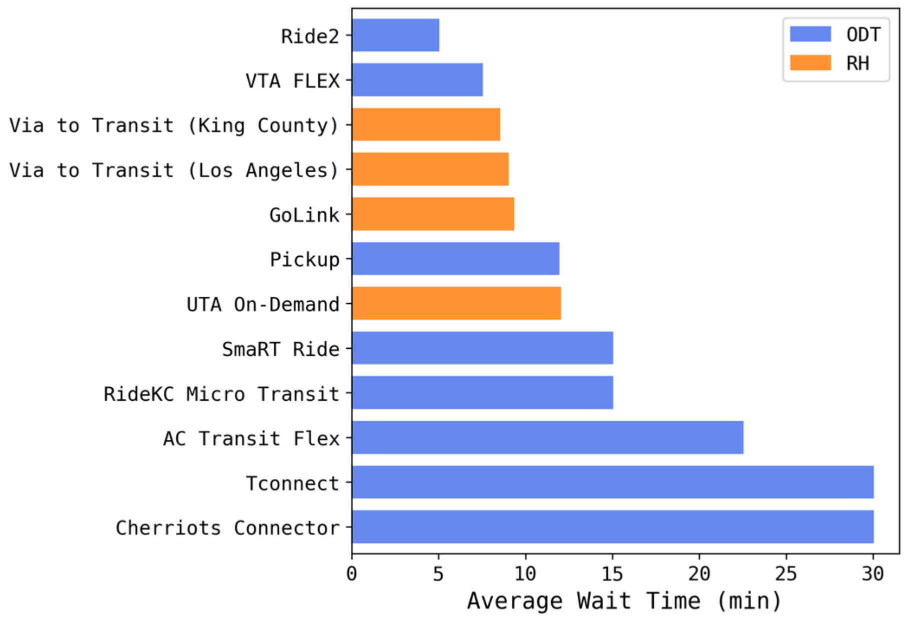


Figure 3. Wait Time Distribution

Among the 18 microtransit programs reviewed, rides per hour vary from 0.4 to 4.0 with an average of 2.7 rides per hour. This relatively close distribution contrasts with the large variety in service models and temporal availability. For example, while the program with the best availability and operated under the RH model, King County Metro's Via to Transit, had a high effectiveness at 3.9 rides per hour, that number is not much different from several high-performing ODT programs that have much lower temporal availability, such as Denver RTD's Dial-n-Ride (3.8) and the Capital Metro Pickup (3.7) (See table 2). Overall, programs with above-median hours of service have a slight edge in effectiveness, serving 2.8 rides per hour compared to 2.6 for programs with below-median service spans. A similar correlation is observed between wait time and effectiveness: programs with below-median wait times generate on average 3.1 rides per hour, 0.5 higher than services with longer wait times (See table 3).

The operational effectiveness of microtransit is consistently below fixed-route buses operated by their respective agencies (See figure 4): SK Ride and MST On-Call performed best relative to FRT, achieving nearly one-fourth of the average hourly ridership of fixed-route services. The rest of the pilots served between 2% and 21% of hourly rides on fixed-route buses in their area. This large disparity between microtransit and FRT holds regardless of the size of the metro area where a transit agency operates. In fact, when comparing agencies serving the larger 8 metro areas in the 17-agency sample to those serving smaller cities and suburbs, microtransit effectiveness is slightly lower on average in more populated metro areas, despite their significantly higher fixed-route effectiveness (See table 3).

This pattern of low operational effectiveness across regions corresponds to the common use cases for microtransit, i.e., replacing low-performing FRT, expanding service to low-density neighborhoods, and providing FM/LM connection, which all focus on extending coverage and maintaining a minimum level of service instead of generating significant ridership. Agencies reason that by using demand-response technologies and smaller vehicles, the microtransit model limits operational expenses and justifies providing a basic level of service even if the operational effectiveness is low (Volinski et al., 2019, p. 29).

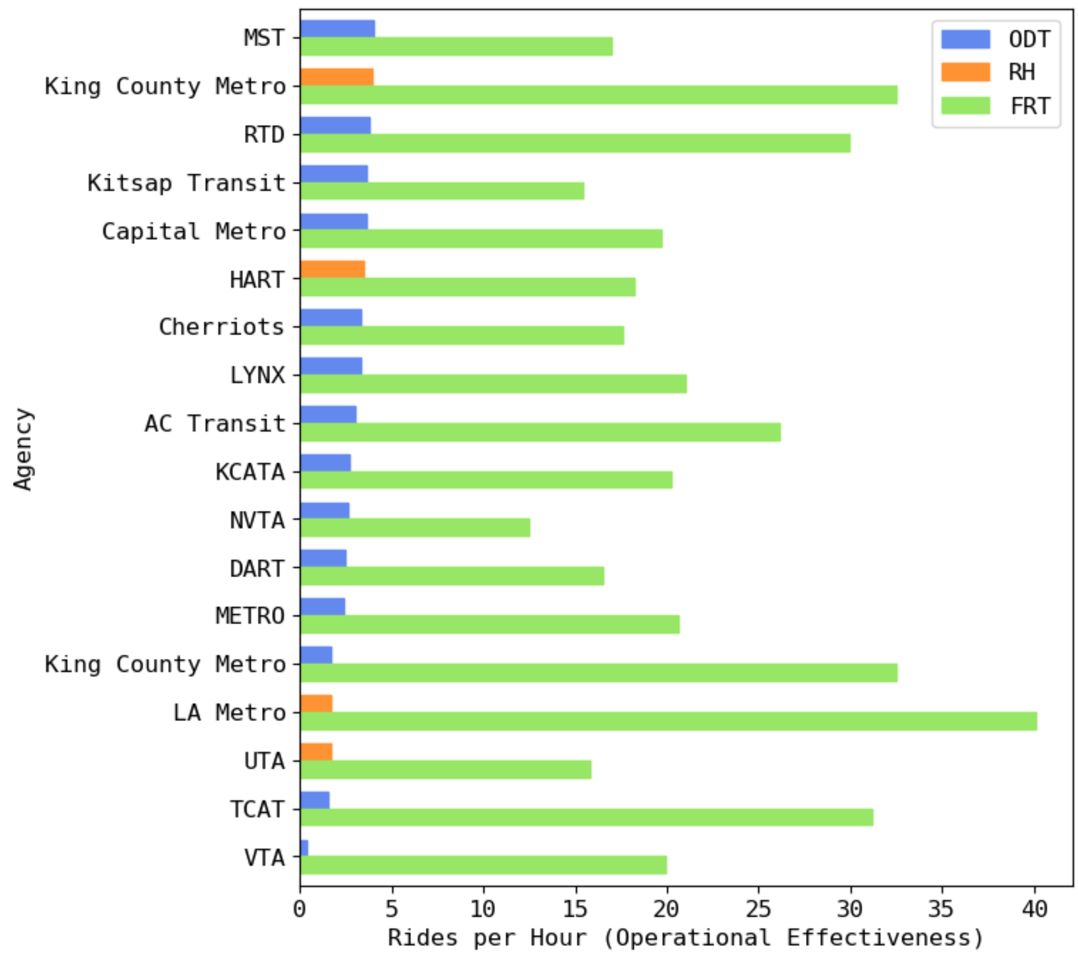


Figure 4. Microtransit and FRT Operational Effectiveness

Table 3. Average Operational Effectiveness by Urban Area Population

Urban Area Population	Count	Operational Effectiveness (Mean Rides per Hour)	
		Microtransit	Fixed-Route Bus Transit
Above Median (exclusive) 1,664,496 < x < 12,150,996	8	2.5	26.3
Below Median (inclusive) 53,661 < x < 1,519,417	9	2.9	19.0

To better capture these cost-saving aspects of microtransit and draw comparisons to fixed-route operations, I next present the unit cost per passenger boarding for the 14 programs that report such information. The majority of microtransit services cost between $10 and $30 per ride, with a median of $20 (RideKC Micro Transit). Similar to patterns in operational effectiveness, the variation in costs across services has little connection to service hours or wait time. Still, it is worth noting that RH services were on average less costly ($16.86) than ODT services ($27.27), and that the four most expensive services all used the ODT model. The small sample size makes any extrapolation premature, but this connection does show that ODT services in this sample are more susceptible to high costs.

To gauge the cost-effectiveness of each microtransit program relative to fixed-route buses operated by the same agency, the unit costs of microtransit and corresponding FRT are plotted in figure 5, with the dashed line indicating equal costs. Among the 14 programs analyzed, three managed to operate at or below 2 times the average cost of their parallel FRT (MST On Call, HART Flex, and Via to Transit (King County)). In these three programs, the MST On Call operated in one of the smallest urban areas in this sample, which had a relatively expensive FRT system costing the agency $9.29 per ride. Microtransit only exceeded that average by less than 50%, making it a finacially viable program especially if the service is improved to attract more riders. The other service worth noting is Via to Transit (King County), which was able to rein in costs by adjusting its level of service throughout the day thanks to the partnership with a private transportation company. The service had high per-hour ridership and achieved one of the lowest absolute costs, making its effectiveness comparable to that of FRT in a large metro transit system like King County Metro.

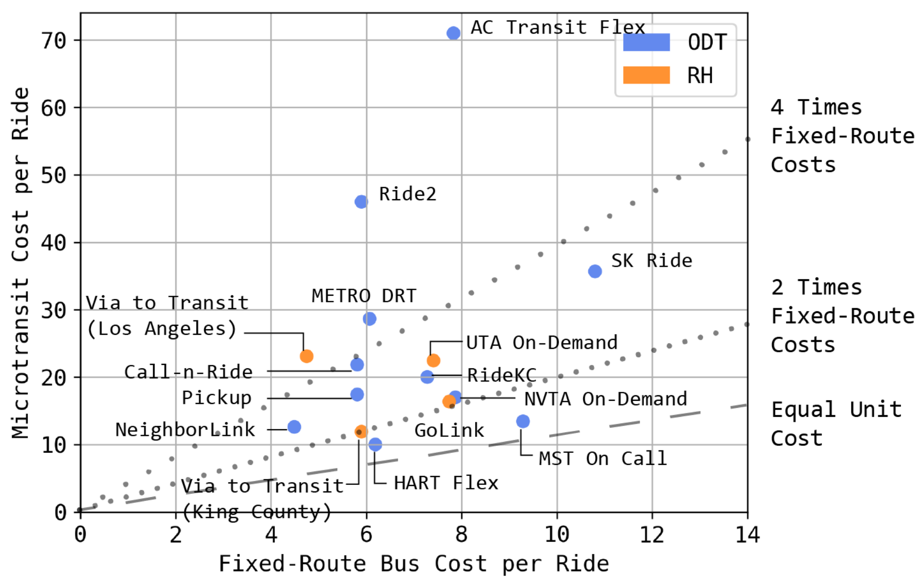


Figure 5. Cost per Ride of Microtransit vs. Fixed-Route Buses

Still, the majority of microtransit programs (11 out of 14) cost over two times per ride compared their parallel FRT system. One cohort of these more costly programs are ODT services operating in large metros, including Ride2 (King County), AC Transit Flex, and Houston METRO DRT, which had the highest cost per ride in the sample. Large metro services can also appear costly if the parallel fixed-route system is highly effective, such as those in Los Angeles, Denver, and Kansas City. Although these agencies' microtransit pilots had moderate absolute costs of around $20 per ride, they still appear much more expensive when situated in the respective agency's family of services.

In summary, temporal availability and service effectiveness metrics show contrasting patterns among the 18 microtransit programs reviewed in this section. Availability metrics show wide variations across programs with the RH model providing consistently higher availability, especially for service span. One possible explanation for this pattern is that all four RH programs operated in some of the largest metro areas and provided connections to a quality FRT network, creating greater demand for travel across the week. RH services operated more frequently and for longer periods also due to fewer work rules and lower labor costs in the private sector – using contracted services likely gave agencies higher flexibility to increase or reduce geographic area served and vehicles and labor resources invested in the service (Westervelt et al., 2018)

The variation in effectiveness measures, especially rides per hour, is less predictable across programs with different service models and availability. For both ODT and RH programs, ridership was relatively low compared to fixed-route buses of the same agency, reflecting the limited patronage of microtransit irrespective of service availability. Still, the demand-response nature and smaller vehicle size of microtransit, especially RH services, meant that these programs still had the potential to reduce expenses.

Case Studies

The preceding review of microtransit programs has shown some preliminary patterns between service model, temporal availability, and effectiveness. Despite this, several questions remain regarding details in the planning and operating process of microtransit: What motivated agencies to improve traditional dial-a-ride service or provide a ride-hailing option in partnership with TNCs? Were there factors beyond service model and temporal availability that influenced service effectiveness? Were environmental concerns part of the rationale for implementing microtransit, and to what extent had agencies achieved this objective? To address these questions, I next present findings from four interviews with agency staff familiar with the King County Metro Via to Transit and TCAT Tconnect programs.

Case Study 1: Tconnect

The Tconnect pilot was a first-mile/last-mile microtransit service operated by Tompkins Consolidated Area Transit (TCAT) in New York State. Throughout the pilot, Tconnect used one 24-seat cutaway bus for weekend-only service between Ithaca Mall, a local shopping and transit hub, and several rural neighborhoods that were underserved by FRT (Yarrow, forthcoming). The pilot replaced a fixed-route shopper service, Route 77, with a demand-response zone significantly expanded from the original route (see figure 6). Tconnect operated entirely using in-house resources and aimed to provide connectivity both to shopping destinations and to the rest of the TCAT network, exemplifying the ODT service model. The only part of pilot that involved outsourcing was the trip request and planning system, which was contracted to a local technology startup named UrbanMobility. Major characteristics of the Tconnect service are presented in table 4.

Table 4. Tconnect Service Characteristics

Agency	TCAT *(Tompkins Consolidated Area Transit, Inc.)*	Primary Urban Area Population	53,661
		Fleet Size	52
Program	Tconnect	Service Model	Directly-Operated Demand-Response Connector (DRC)
		Main Use Cases	First-Mile/Last Mile Connection Fixed-Route Replacement
		Service Area (Size)	Lansing and Etna (15.2 sq. mi)
		Vehicle	One 30-foot, 24-seat cutaway transit shuttle
		Service Span	Sat & Sun 7:35 AM - 12:30 PM and

			1:35 PM - 6:30 PM (19.6 hrs per week)

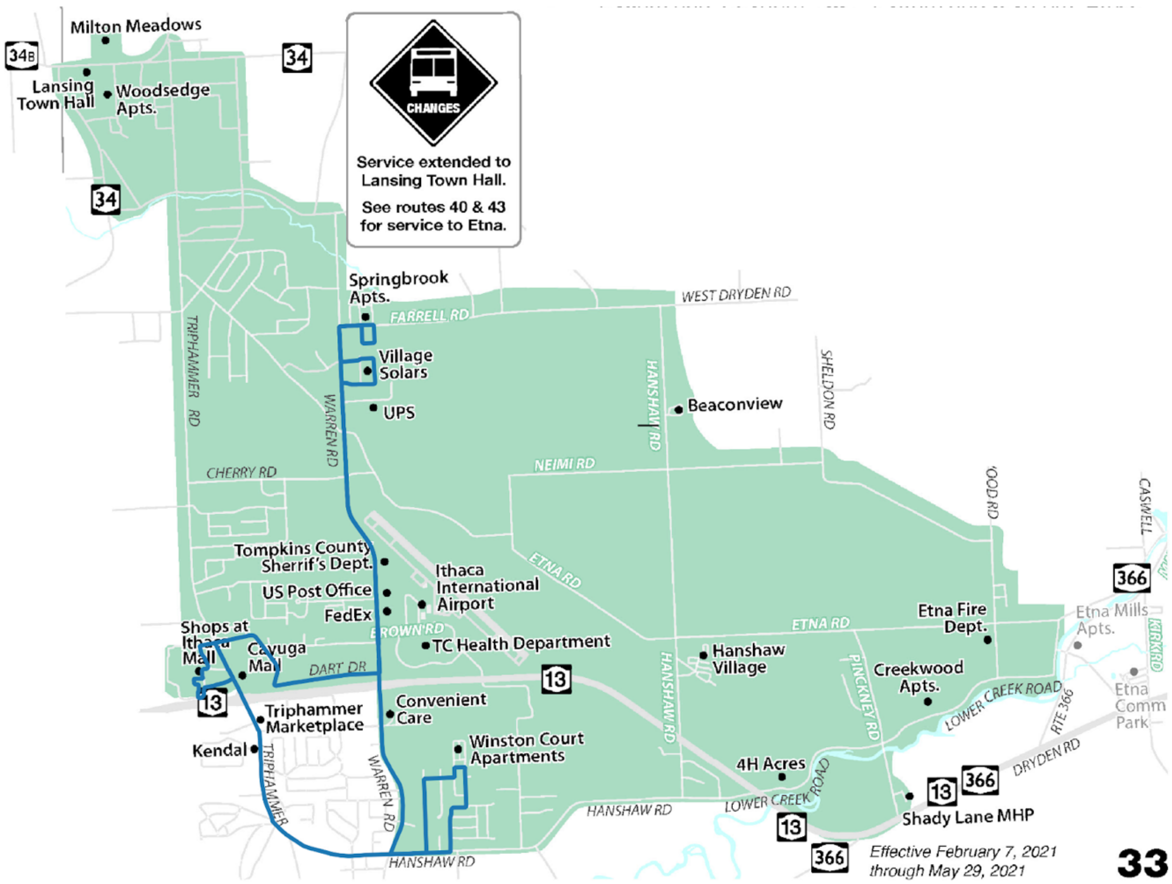


Figure 6. Tconnect Service Area and Original Fixed-Route

Source: adapted from TCAT Ride Guide (Spring 2021)

<u>Project Evolution</u>

The service was first conceived when Gadabout, TCAT's subcontractor for paratransit services, showed interest in improving the efficiency of its service by encouraging more rural riders to transfer to fixed-route bus services (TCAT Planner #1, February 2023). Gadabout reasoned that microtransit is a feasible FM/LM option for connecting riders in low-density neighborhoods to FRT, which could reduce the demand for long-distance, point-to-point paratransit trips while also improving access for regular riders (Yarrow, forthcoming, p. 10). Gadabout and TCAT agreed that the paratransit operator would be responsible for providing labor and its ADA-compliant fleet of transit shuttles, while TCAT would work on community outreach and facilitate transfers between Tconnect and fixed-route buses. The project gained support of New York State's Energy Research and Development Authority (NYSERDA) and received a grant of $260,000 to provide microtransit services to residents "who live outside of reasonable walking distance [of local bus stops], enabling them to travel anywhere within TCAT's service area (TCAT, 2020)." TCAT's project team selected the Dryden area for the initial pilot and aimed the service at weekday commuters who travel to and from Ithaca, the county's employment center.

The COVID-19 emergency in Spring 2020 resulted in delayed deployment of Tconnect and necessitated changes to the service model. Most importantly, the loss of commuting ridership forced TCAT to pause plans for weekday services in Dryden and reorient resources to serve weekend shopping trips, as weekend ridership was less impacted by remote work (Yarrow, forthcoming). Tconnect also lost access to Gadabout's bus operators, many of whom were volunteer drivers that preferred not to work during the pandemic. Tconnect eventually rolled out services in two phases: Phase A moved forward with a new weekend service while Phase B involved the implementation of the original commuter service in Dryden. Due to the short operating period and minimal ridership of the Phase B service, this study focuses on analyzing planning and operations for Phase A, which ran for a 20-month period from August 2020 to May 2022.

Temporal Availability

Being the single weekend-only service in the 18 microtransit pilots reviewed, Tconnect had the shortest weekly hours of service at 20 hours but did provide a long daily service span compared to commuter-oriented services that provided limited or no off-peak service (e.g. SK Ride, AC Transit Flex, Pickup, Ride2). On the other hand, TCAT did not collect wait time data but did indicate that the service followed a 60-minute cycle time. Considering the limited rides Tconnect serve per vehicle trip, I assumed most trips did not exceed the cycle time and estimated an average waiting time of 30 minutes. The use of a single vehicle, necessitated by low travel demand, placed Tconnect on the higher end of the scale for wait time.

To get a complete picture of services in the Tconnect demand-response zone, weekday service availability on TCAT fixed-routes 36, 37, and 31 are shown in table 5 for each of the six areas served by Tconnect on weekends. Weekday fixed-route service featured consistently longer service hours compared to Tconnect, as both early morning and late-night services were available. Despite this, low demand on these rural and suburban routes resulted in long service headways, which were further reduced by short runs that only served parts of the route. Except for Lansing Town Hall and Hanshaw Village, other locations in the area received less fixed-route service on weekdays compared to the weekend Tconnect service (10 trips). In other words, Tconnect did provide a higher level of service during the day compared to its fixed-route counterparts.

Table 5. Tconnect and Parallel Weekday Service

Weekend Service (Tconnect)	
Daily Hours of Service	9.8 (7:35 AM – 12:30 PM; 1:35 PM – 6:30 PM)

Estimated Waiting Time (min)	30					
Weekday Service (Fixed-Route)						
Areas Served by Tconnect	Triphammer Rd	Lansing Town Hall	Warren Rd	Winston Court	Hanshaw Village	Etna
Route	36	36, 37	37	31		
Daily Hours of Service	13	13	12	15	16	16
Estimated Waiting Time (min)	60	37	47	66	38	56

Source: TCAT Late Fall 2019 Ride Guide

Operational Effectiveness

During the 21 months that Tconnect Phase A service was in operation, revenue hours per day were mostly kept unchanged except for one extra hour added to the original 9-hour schedule in November 2020. In contrast, ridership per revenue hour showed two distinct phases: for the first five months, ridership varied between 0.5 and 1.2 with a mean of 1.0 per revenue hour; ridership abruptly increased in February 2020 to 1.9 and kept a higher average at 1.6 rides for the rest of the pilot period (Yarrow, forthcoming; see figure 8). This pattern was correlated with an expansion of the Tconnect service area to include Lansing Town Hall and the Milton Meadow housing complex, the latter being one of the four major trip origins after the service expansion (see the top-left cluster in figure 7). As weekend TCAT service did not exist in these locations prior to Tconnect, this apparent increase in ridership represents latent demand that was unserved and implies that Tconnect enabled some riders to make weekend trips that were previously limited to weekdays.

While the successful service expansion shows Tconnect did match the demand of its rider group, the program's overall operational effectiveness was only 5% of that achieved by TCAT fixed-routes (1.5 vs. 31.2 rides per hour) – among the sample of 18 microtransit programs, this ratio is low relative to the average of 13.5%. Trip data and interviews with agency staff imply three potential barriers to higher effectiveness (TCAT Planner #1, February 2023; TCAT Planner #2, March 2023). First, the large distances among major trip origins limited the competitive edge of a demand-response service. During service planning, TCAT staff identified serving carless and low-income neighborhoods as an important goal of the Tconnect program and conducted substantial outreach to these groups of potential riders. Spatially, the outreach efforts focused on residents of low-income apartment complexes who have much lower car-ownership rates than the rest of the county (Yarrow, forthcoming). This prediction of the market for Tconnect was confirmed during operations – all five major trip origins shown by trip data imply use by the target rider group. On the other hand, service pick-up and drop-off were limited outside of these locations, which contradicts the goal of microtransit to serve dispersed destinations. Instead of picking-up riders along each service run the vehicle had to spend more time traversing between distant destinations, limiting the number of boardings per revenue hour.

Besides ridership, total revenue hours operated also had a significant impact on operational effectiveness of Tconnect. As the microtransit program replaced a fixed route that used to operate in the area, it is possible to make a comparison between these two services' output and ridership levels. Automatic people counter records show that in 2019, the previous fixed-route service generated an average of 108 rides per month, which was slightly lower than the average monthly ridership on the Tconnect (121 rides). In contrast, revenue hours for the FRT are much shorter due to Saturday-only operation and a total of five trips operated a day compared to 10 trips for Tconnect. Running for just over 13 hours per month, the FRT service generated similar ridership to that generated by nearly 82 hours of operation of Tconnect. This resulted in a quite surprising disparity between the two services' operational effectiveness – the fixed-route served on average 8.0 riders per hour, compared to below 2 rides per hour for Tconnect.

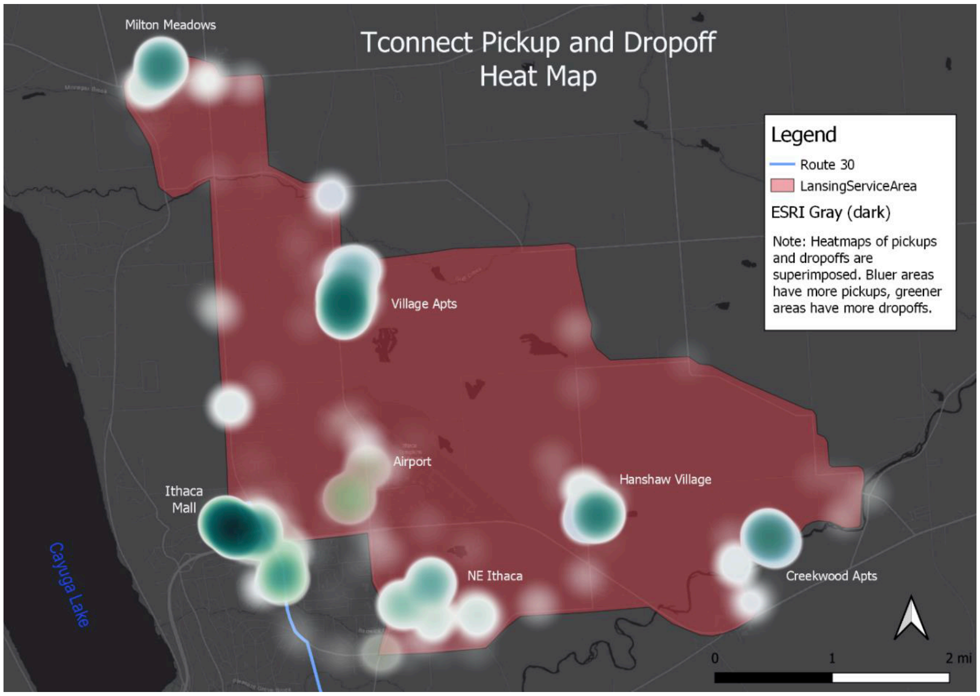


Figure 7. Heatmap of Tconnect Pickup and Dropoff Locations
Source: Yarrow, forthcoming

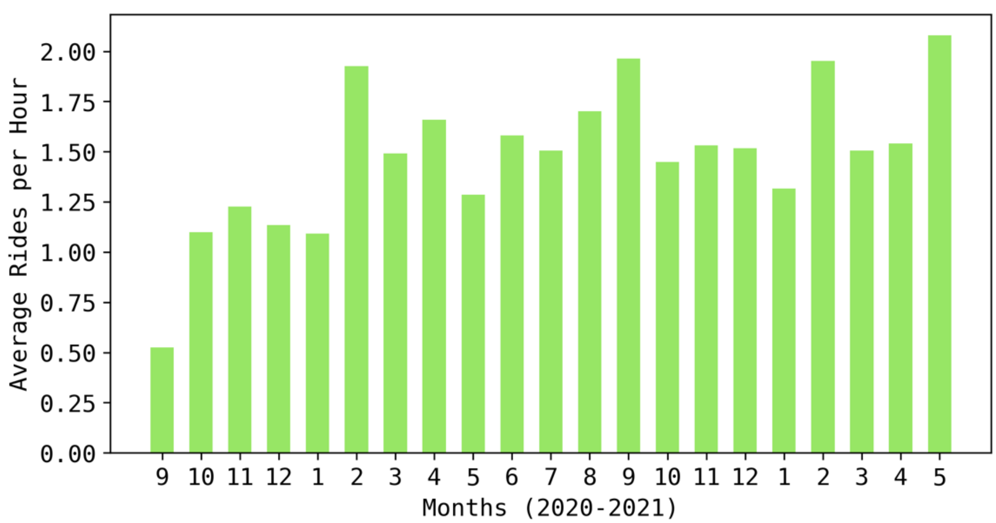


Figure 8. Tconnect Monthly Average Rides per Revenue Hour
Source: Yarrow, forthcoming

Interviews with agency staff also showed another factor causing increased revenue hours for Tconnect – when operating a fixed-route bus, TCAT was able to implement through-running between Route 77 and other routes originating from the Ithaca Mall stop (TCAT Planner #1, February 2023). This means that for just over half of the 7.25-hour service span, the driver and vehicle were assigned to a different route to improve operating efficiency. This mechanism was removed after the service shifted to an on-demand model, as the Tconnect vehicle is "on-call" throughout its 9.8-hour service span and could not be used for other services even in absence of trip requests. This limitation in operating flexibility compounded the increased service hour of Tconnect and led to low operating effectiveness of the microtransit program.

Cost-Effectiveness

Tconnect's low operating effectiveness apparently limited its cost-effectiveness, as operating costs rise with more revenue hours invested in the service. During interviews, TCAT staff mentioned that they did not perform a cost-allocation for the Tconnect program, thus precluding a precise calculation of the cost-effectiveness measure (TCAT Planner #1, February 2023). Still, cost per ride could be estimated using data on total revenue hours, ridership, and total project funding. The total funding was allocated to Phases A and B of the pilot assuming equal costs per revenue hour across the two service areas. Cost per ride was then estimated for Phase A service using the total ridership figure. The results are shown in Table 6 and as part of the cost-effectiveness diagram in Figure 9.

Table 6. Cost-Effectiveness Calculations for Tconnect

Total Project Funding: $260,000		
	Phase A (Lansing-Etna Weekend Service)	Phase B (Dryden Weekley Service)
Total Revenue Hours	1,710.4	2,074.5
Estimated Total Cost	$117,500	$142,500
Total Ridership	2,540	-
Cost per Ride	$46	-

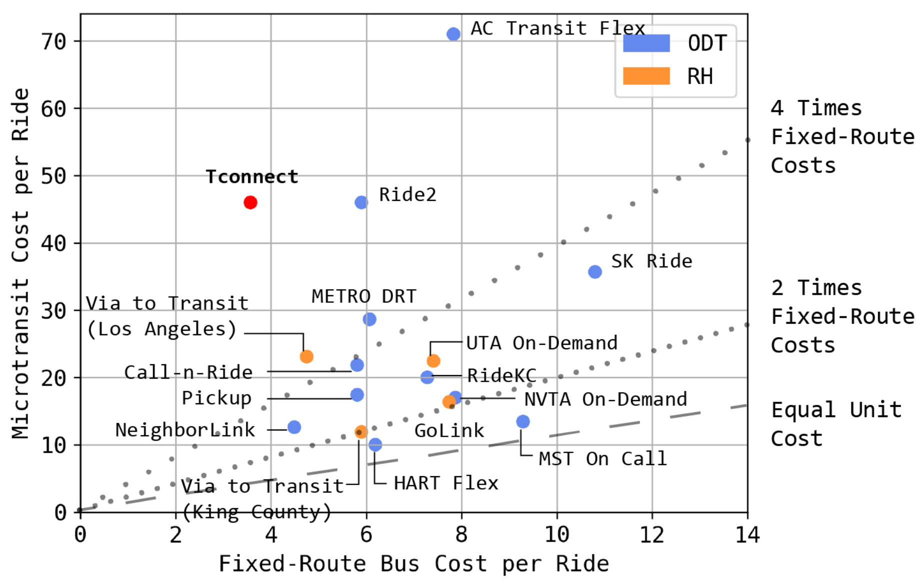


Figure 9. Locating Tconnect in the Cost-Effectiveness Graph

The estimated cost per ride for Tconnect was relatively high at $46 dollars, the same as Ride2 (King County Metro) and ranks second highest among the 18 programs reviewed in this study. The estimated cost was also significantly higher than that of parallel paratransit services for TCAT's network at $27.17. One apparent cause of Tconnect's high per-unit cost wasis the vehicle size – at 24 seats, the transit shuttles were a poor match to the per-hour ridership generated by Tconnect, implying that the vehicle was used for less than 1/10 of its capacity on most trips. This mismatch of vehicle size to ridership was directly related to the change in operator from Gadabout to TCAT due to pandemic disruptions. Given the limited funding and short-term nature of the Tconnect program, the only option left to TCAT was to select the smallest vehicle in their fleet for microtransit. Another directly-operated program reviewed in this study, the VTA FLEX, also faced this dilemma as it utilized vehicles the agency already owns that had a capacity similar to the Tconnect shuttles (Westervelt et al., 2018). VTA identified high operating costs of its 26-seat shuttles as a primary reason leading to the closure of the pilot.

Another potential factor causing high per-trip cost of Tconnect was the upfront payment for developing the trip planning system and the HyperCommute mobile application. Although TCAT did not disclose the exact amount, the project team worked closely with UrbanMobility, the technology provider, and in-house bus operators to test the app for a two-month period just before the COVID emergency (Yarrow, forthcoming). This work was repeated in the summer of 2021, when the app was redesigned based on rider feedback. This intensive app development process was key to improving the user experience but also placed additional cost on the service, especially because the pilot was only active for under two years.

Environmental Sustainability

Imagined as an FM/LM solution, the Tconnect pilot was tasked with not only providing local accessibility, but also bringing riders to TCAT's extensive fixed-route network and facilitating higher transit mode share. By providing quality transit connections to local destinations and the rest of the TCAT network, Tconnect was expected to encourage shift away from single-occupancy vehicles and improve environmental sustainability of transportation in Tompkins County. The Tconnect project team paid special attention to mode shift and sustainability as this was also the principal goal of the NYSERDA grant that financed the pilot (Yarrow, forthcoming).

I assessed two performance metrics, *FRT transfers* and *mode shift*, to examine the proportion of Tconnect trips that were direct versus connecting trips, and analyze potential environmental benefits. I utilized responses from an onboard rider survey conducted in spring 2022 to identify whether Tconnect was used as a feeder service or for direct trip to destination. The survey asked respondents to select from a list their top destinations while traveling on Tconnect. Agency staff then processed the responses to identify locations that are within the catchment area of Route 30, the most patronized TCAT route that provided transfers with Tconnect. I identified five major destinations from the data, which were then categorized by whether it was covered by the Tconnect service area ("local"), can be reached by transferring to the Route 30 ("FRT transfer"), or fall in neither of the two categories ("other and unidentified", See table 7).

Table 7. Tconnect Trips by Type of Destination

Type of Trip	**Destination**	**Percentage**
FRT Transfer 27%	Kendal (senior housing complex)	3%
	Downtown Ithaca, and rest of the Route 30 corridor	24%
Local 69%	Ithaca Mall and immediate shopping area	52%
	Other shopping destinations	14%

	Ithaca Post Office	3%
Other and Unidentified 3%	Recreation and others	3%

Source: Yarrow, forthcoming

According to the rider survey, most Tconnect trips (69%) ended in the local service area, the majority of which were trips heading for the Ithaca Mall. This trend reflects that Tconnect served a similar function as the previous fixed-route shopper service Route 77 by connecting riders to major shopping destinations. In contrast, a smaller but significant portion of riders (27%) headed for locations along the Route 30 corridor, showing that Tconnect did provide a viable connection to the fixed-route network to neighborhoods that had no previous weekend service. Agency staff estimated that an extra 5 miles of passenger distance traveled on transit was made possible by each transfer trip on Tconnect, which amounted to 3,429 miles for the entire pilot (or 35% of total PMT on Tconnect; Yarrow, forthcoming). Still, the relatively small proportion of FRT transfer trips reflects that weekend travel demand in Lansing and Etna was limited outside of shopping trips – although the Route 30 provided frequent service to major employment and retail centers such as Cornell University, Collegetown, and Downtown Ithaca, trip volumes were small, especially considering the low overall ridership generated by Tconnect.

While survey data confirmed that Tconnect provided viable FRT connections, they only amounted to improved sustainability if the trips were previously made on more energy- and/or emission-intensive modes, including driving alone and using ride-hailing services. Data on this issue paints a less optimistic picture for Tconnect: 70% of respondents said their Tconnect trips replaced transit and walking trips (Yarrow, forthcoming). Ride-hailing accounted for 20%, indicating a small percentage of potential mode shift from car-based travel to Tconnect. A second survey conducted in the final months of the pilot also shows limited potential for mode shift: 87% of survey respondents had been riders on TCAT fixed-routes, and while 20% were from households owning private vehicles, there was less than one vehicle per household member in all cases. It is clear that for the most part, Tconnect functioned as a lifeline service for transit-dependent riders – important for elevating access equity – but was not effective in attracting choice riders or improving environmental sustainability.

Case Study 2: Via to Transit

Via to Transit was an urban microtransit pilot operated using the ride-hail model and through a partnership between two regional transit agencies, King County Metro and Sound Transit, and a private transportation provider, Via Transportation. Whereas the Tconnect pilot connected only to bus transit, Via to Transit operated around five light rail stations that were also served by bus routes, thus enabling multi-modal connection (Gifford et al., 2021). Via provided the technology (trip planning tools and user interface), vehicles (standard vans and wheelchair-accessible vehicles), and contracted drivers to operate the service. A brief summary of service characteristics is shown in table 8.

Table 8. Via to Transit Service Characteristics

<table>
<tr><td rowspan="5">Agency</td><td colspan="2">Primary Urban Area Population (Seattle, WA)</td><td>3,059,393</td></tr>
<tr><td rowspan="2">King County Metro</td><td>Mode</td><td>Bus, Trolley Bus, Demand-Response, Vanpool, Streetcar, Ferry</td></tr>
<tr><td>Fleet Size</td><td>2,350</td></tr>
<tr><td rowspan="2">Sound Transit</td><td>Mode</td><td>Commuter Bus, Light Rail, Commuter Rail, Street Car</td></tr>
<tr><td>Fleet Size</td><td>357</td></tr>
</table>

Program	Via to Transit	Service Model	Contracted Ridehailing (RH) Service
		Main Use Case	First-Mile/Last Mile Connection
		Service Area (Size)	Southeast Seattle: Mount Baker, Columbia City, Othello, and Rainier Beach stations Tukwila International Boulevard station
		Vehicle	Standard Vans and Wheelchair Accessible Vehicles
		Service Span	Southeast Seattle Zones Mon-Sat 5 AM – 1 AM, Sun 6 AM – 12 AM Tukwila Zone Mon-Fri 6 AM – 9 AM, 3:30 PM – 6:30 PM

Project Evolution

Via to Transit was part of a broader collaboration among King County Metro, Sound Transit (both in the Puget Sound Region, WA), and LA Metro (Los Angeles County, CA), the latter of which applied for FTA funding for the group. The pilot aimed to explore transit-TNC partnerships and inform the feasibility of improving mobility options, especially for those previously excluded from TNC services due to cost and service availability issues (Gifford et al., 2021). The three agencies initially selected Lyft as the operator, but negotiations with the company on data sharing stalled the partnership. Recognizing that the pilot would be an important test for the novel ride-hail model, the agencies prioritized access to data and decided to find a new provider. They selected Via Transportation in February 2018, for the company's commitment to data transparency and its fleet of wheelchair-accessible vehicles that provided a standard of service matching that of paratransit (Gifford et al., 2021).

In the year leading up to service inauguration in April 2019, the Puget Sound Via to Transit pilot (hereinafter "Via to Transit") gained critical financial support from the City of

Seattle. The City budgeted to improve fixed-route bus service in southeast Seattle, but King County Metro could not implement the proposal due to limited in-house operating resources (King County Metro Planner #1, March 2023). Through negotiations, the City identified Via to Transit as an alternative to increasing bus service, as the pilot's goal to improve FM/LM connection aligned with the City's intended use for that fund. The City's commitment of $2.5 million complemented operating expenses contributed by the FTA ($350,000), Sound Transit ($100,000), and King County Metro ($100,000) and elevated the pilot from a weekday, peak-time service to one with comprehensive 7-day-a-week service in four of the five service areas (Gifford et al., 2021). Via to Transit operated between April 2019 and March 2023, with a four-month break in Spring 2020 due to the COVID-19 emergency. The pilot was subsequently integrated into the Metro Flex program, a long-term service category uniting all DRT services offered by King County Metro (King County Metro Planner #1, March 2023; Porterfield & King County Metro, 2023)

<u>Temporal Availability</u>

Zones within the City of Seattle received Via to Transit service throughout the week with a service span matched to that of the Sound Transit Link Light Rail (Gifford et al., 2021). From Monday to Saturday, the early start of service at 5 AM enabled riders to connect to the first northbound trains, meeting demands for trips toward downtown Seattle. Similarly, the end of service at 1 AM the next day facilitated connection from the last southbound trains from downtown Seattle. Sunday services, operating from 6 AM to midnight, maintained the same last-train connections. Via to Transit's long service spans totaled to 138 hours of weekly service, the highest among all microtransit programs examined in this study. Conversations with agency staff show that contracting out was important in enabling the long hours, because drivers were employed by Via and had flexible work schedules across the week rather than being employed full-time by King County Metro. This allowed Via to adjust the number of shifts available for different times of the day and pay more drivers during peak hours compared to other times, thus economizing labor costs. Via implemented these adaptive schedule changes every few weeks based on ride requests data and as the pilot evolved and attracted more riders.

This flexibility of driver and vehicle scheduling also allowed Via to maintain a reasonable average wait time of 8.5 minutes for standard vehicles, the third lowest among all pilots in this study (Gifford et al., 2021). The service also compared well to their fixed-route counterparts, suburban bus routes, which had a scheduled headway of 30 minutes. As Via to Transit ridership grew over the first year of the pilot, average wait time also increased to over 10 minutes just before the COVID emergency in March 2020 (See figure 10). Agency planners expected that wait time will continue to rise as they expand the service areas and eligibility, but identified the 15-min benchmark as a target for future services (King County Metro Planner #2, March 2023).

Besides the added flexibility, the RH model also created complexity in serving riders with disabilities, as standard vans used by Via were not wheelchair accessible. Via provided an additional fleet of WAVs that were deployed when requested by the rider and these trips accounted for a small fraction (0.3%) of all completed Via trips (Gifford et al., 2021). Thus, the potential for an economy of densities was much lower for WAV trips, resulting in a wait time that was three minutes longer on average as well as much higher rates of cancellations (9% vs. 2% of all trip requests) due to requests exceeding supply.

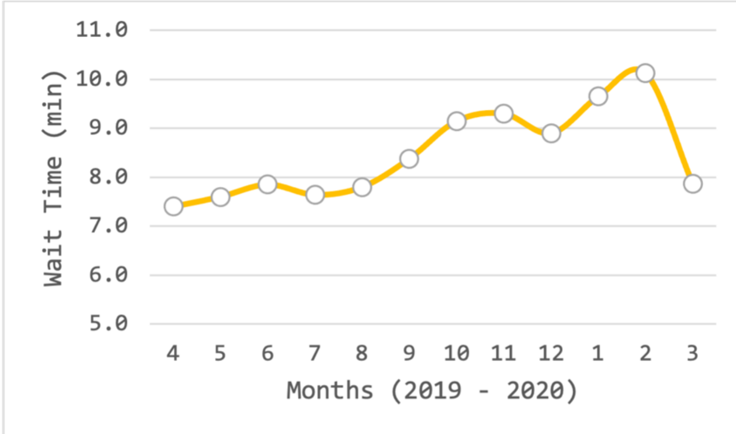


Figure 10. Via to Transit Wait Time Variation

<u>Operational Effectiveness</u>

Besides its good service availability, Via to Transit also performed highly in the number of trips served per vehicle revenue hour, even though the vehicles were among the smallest in the programs studied here. With an average of 3.9 rides per hour, the Via pilot ranks second among all programs, and first in RH programs (Gifford et al., 2021). While service hours stayed unchanged through the first year of the pilot, both daily ridership and effectiveness (rides per hour) increased steadily through October 2019 (see figure 11). This demonstrates that a rise in utilization may have reduced deadhead operation and increased economies of densities. Riders started using the new service gradually, as ridership took seven months to reach the peak in October 2019 before staying around an average of 885. While the Tconnect program implemented a service expansion that apparently contributed to a ridership increase, Via to Transit maintained stable levels of service while utilization rose. Area-specific ridership data show that a majority of sustained growth after June 2019 occurred in the two most heavily used service zones, Rainer Beach and Othello, and ridership for other areas remained stable. While the lack of more detailed trip-level data prevents pinpointing the driver behind these disparities, it is clear that Via to Transit service was valued highly in these zones – ridership increased either because existing riders used it more often or as more riders signed up for the pilot.

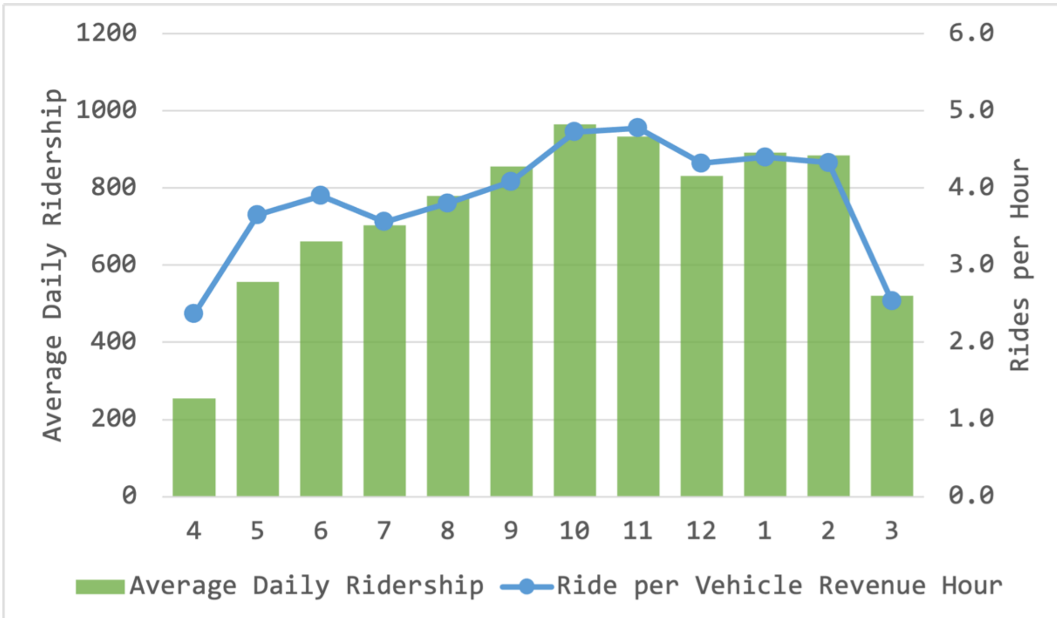


Figure 11. Via to Transit Ridership per Day and per Vehicle Revenue Hour

Via to Transit ranks second in operational effectiveness among microtransit service analyzed here, which makes it worthy to explore how it fares against regular bus services in the same areas. In King County Metro's last update of its service productivity benchmark, a service with low productivity refers to those ranking in the bottom 25% of all routes (King County Metro, 2021b). Via to Transit served 4.2 rides per hour after ridership stabilized in October 2019, placing it below the 8.1 threshold for shuttle bus routes (King County Metro, 2021b).. It is apparent that the curb-to-curb, flexible schedule model of microtransit limited the number of riders that could be served at the same time.

On the other hand, operational effectiveness of Via to Transit fares better than other road-based transit modes operated by King County Metro, according to NTD data. Access transportation, the ADA paratransit parallel to King County Metro's FRT, is a prominent DRT service operating under the traditional dial-a-ride model (FTA, n.d.). The service utilized transit shuttles and served 1.3 riders per hour in 2019. In comparison, Via to Transit achieved higher effectiveness while still making service available to riders needing mobility assistance. At the other end of the spectrum was the commuter vanpool program, which enabled riders with similar commutes to pre-arrange a shared trip on a van resembling those used by Via. The vanpool program provided direct, reliable transportation and is highly patronized – it served on average 6.2 riders per hour pre-pandemic compared to 4.2 achieved by Via in the same period (FTA, n.d.). Although the three programs discussed here used different service models, they shared the characteristics of a flexible-route, flexible-schedule transit service. Among these, Via appears to be a viable option to combine ADA-compliant services with general FM/LM trips while improving operational effectiveness.

Cost-Effectiveness

Via to Transit is the second-most cost-effective microtransit program among the 18 services reviewed in this study, achieving an average cost of $11.90 in the first year of operation (Gifford et al., 2021). The program was also the least expensive of the various microtransit experiment that King County Metro carried out since the publication of its 2015 Implementation Plan for alternative services. The pilot was significantly more effective than its predecessors such as Ride2, and most contemporaries like Community Ride and Community Shuttle programs (King County Metro, 2021a). Partly because of its success, the pilot continues to operate as part of the King County Metro’s new Flex program, and worked as a model for other flexible services that were also brought under this category (King County Metro Planner #2, March 2023).

Cost data and conversations with agency staff show that both supply- and demand-side factors contributed to the low average cost of Via to Transit (King County Metro Planner #1, March 2023; Gifford et al., 2021). First, the pilot operations were contracted out to a private provider that had access to a variety of vehicles and a large team of contracted labor. While agencies directly operating their microtransit programs are incentivized to use their existing vehicles, contractors like Via own smaller vans that are a better fit for microtransit. As shown by ride-per-hour analysis for all 18 programs reviewed, the number of boardings served by microtransit was often far below the vehicle capacity of transit shuttles and cutaway buses that transit agencies generally use.

Contracting out allowed Via to Transit to be more flexible in selecting vehicles, which very likely resulted in higher occupancy rates and improved cost-effectiveness. The pilot also benefited from the lower overall labor cost of contracting out – employment in the private sector is less subjected to union negotiations for higher wages and protective work rules such as straight-run mandates and mandatory breaks. It was likely that drivers were paid less than unionized transit workers and were able to achieve higher platform hours per hour they were paid.

Higher demand also contributed to better cost-effectiveness: agency staff observed that compared to other flexible services, Via to Transit operated in an urban environment served by a light rail line, contributing to higher economies of density as drivers spent more time serving trips rather than waiting for requests or running empty to pick up distant riders (King County Metro Planner #2, March 2023).

Environmental Sustainability

Via to Transit was focused on improving FM/LM access to transit, which was established since the earliest stages of planning (Gifford et al., 2021). Most microtransit programs operating under either ODT or RH models aimed to serve a broad rider group by allowing both "local" trips within the service area and those that connect to fixed-route transit. In contrast, the Via to Transit service was organized around five light rail stations to specifically facilitate transfers to rail and bus routes. The program's policy required either end of a trip to be the station within the service zone, and encouraged transfers by awarding free fares for the second leg of a linked trip involving a Via to Transit ride. The service area design and trip policies likely induced the high FRT transfer ratio of this pilot – 95% of trips in the first year involved a connection, implying that transit users highly valued Via to Transit as a station-access mode (Gifford et al., 2021). The remaining 5% of trips did not involve a transfer but nevertheless started or ended at the rail station, which suggests possible trip-making to points-of-interest around the station. These riders essentially paid the fare of a regular bus trip for a "local" ride on Via while forgoing the free transfer.

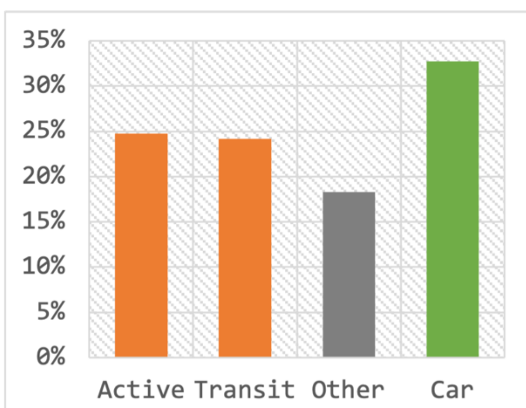


Figure 12. Previous Station Access Mode for Via to Transit Riders

The high fixed-route transfer ratio implies that Via could have encouraged people to use transit more frequently or made existing transit users' trips easier. Survey data show that both scenarios occurred during the pilot – around 88% of Via riders used other modes to access transit, whereas a minority of 12% did not previously use the light rail station at all (Gifford et al., 2021). This group of new riders indicates successful mode shift toward transit, although it is unclear what modes these riders used previously.

What the survey did cover was how mode choice changed for the remaining 88% of Via users who previously used transit, albeit through different access/egress methods. As shown in figure 12, around one-third of Via users utilized car-based modes to reach transit (green column), which included drive-alone, commercial ride-hailing, and being picked up/dropped off. By replacing these access trips with Via, the pilot relieved parking shortage, especially at the Tukwila station, where a park-a-ride lot was in use but could not satisfy demand (Gifford et al., 2021). It is unclear whether these trips represented savings in vehicle miles traveled which could contribute to reduced GHG emissions. According to a Union of Concerned Scientists report, a pooled ride-hailing service like Via to Transit has significantly lower emissions than non-pooled ride-hailing trips, but is on par with private vehicle trips (Anair et al., 2020). Agency staff reasoned that because Via places limit on trip service area and destination, it encouraged pooling more than conventional ride-hailing (King County Metro Planner #1, March 2023). This point of view is echoed by a TCRP survey of national microtransit operators, which observe that a structured, "one-to-many" service is more productive than conventional taxi or TNC trips that are "many-to-many" (Volinski et al., 2019). Therefore, it was possible that Via to Transit achieved better environmental sustainability by replacing the 33% of car-based trips.

In contrast, nearly half of access/egress trips replaced by Via were made on active or transit modes (orange columns in figure 12). Active modes like walking and biking have no GHG emissions and transit emissions are unlikely to change due to a small decrease in ridership, as service levels usually remain unchanged. Via to Transit likely increased emissions by replacing these trips, although the magnitude is uncertain.

Discussion and Conclusions

In this paper, I explored two main issues on microtransit experiments, i.e., the application of different service models across the U.S., and the impact of factors like service provision, institutional structure, and the local transit market on microtransit success. The main findings are as follows:

1. Microtransit pilots in the U.S. followed two major typologies: on-demand transit (ODT) and ride-hail (RH). In general, RH programs operated for longer hours and had shorter wait times. ODT programs represented an upgrade of the traditional dial-a-ride service: in most cases, they were operated either directly or contracted to paratransit providers; they followed fixed cycle time, used small transit buses, and were used in all types of urban, suburban, and rural environments. RH programs were a publicly-funded and regulated version of TNC services like Uber and Lyft, which outsourced most operations to private providers, used vans and standard-size passenger vehicles, had flexible service levels and schedules, and were only found in large urban areas among the programs reviewed in this paper. Outsourcing the program gave the transit agency more flexibility to adjust service levels at different times of the day according to demand, and operate the service for longer hours without escalating labor costs.

2. Operational effectiveness of microtransit showed large variations that were unconnected to local fixed-route transit effectiveness or population size of the primary urban center.

Among the agencies reviewed in this study, fixed routes had more boardings per hour if they were situated in an urban area with a larger population size. In contrast, microtransit ridership was generally limited regardless of the urban area size. Besides the apparent impacts of microtransit's relatively low temporal availability, limited patronage may also stem from local transit demand patterns and microtransit's low perceived reliability. With few exceptions, microtransit was implemented in low-density areas with spatially-dispersed travel demand, limited existing service, or underperforming fixed-routes. These travel markets were inherently more expensive to serve compared to higher density places with concentrated demand patterns. Additionally, the on-demand, flexible nature of microtransit may have further discouraged patronage: compared with conventional mass transit where vehicles arrive according to a predictable schedule, microtransit cannot guarantee trip availability at a certain time. This reliability issue was particularly prominent for services with long wait times, which likely made both regular trips and spontaneous travel difficult.

3. A minority of microtransit programs were cheaper to operate on a per-trip basis than fixed-route buses. Labor cost had the most important impact on cost-effectiveness.

Indeed, expenditure on operator salary constitutes a major share of operational costs for transit, especially for bus agencies. The economics literature characterize transit as one of "stagnating" industries where labor productivity experiences slow or no growth. These industries are said to suffer from the "Baumol's cost disease," where the wage level rises due to competition for labor from "innovating" industries and leads to rising unit costs (Sarriera et al., 2018).

Partly in reaction to this issue, a principal goal of recent microtransit pilots was to reduce costs, as demonstrated by two of the three common use cases (expand service to low-density neighborhoods and replacing low-performing fixed-routes). While vehicle size, technology, and route flexibility did have the potential to improve efficiency of transit, the two case studies in this paper demonstrated that contracting and labor costs played the most important role. To this end, microtransit was less a revolution in service model and more an attempt to mitigate the impact of rising labor costs, as agencies experimented with what transportation planner Steven Higashide dubbed as "publicly operated TNC (Higashide, 2019, p. 107)."

Microtransit cost-effectiveness may have less to do with flexible routing and scheduling – although they could facilitate more efficient use of operating resources. More importantly, transit agencies need to decide between continuing in-house operation or adopting varying levels of vehicle and labor contracting. Case studies in this paper suggested that microtransit tend to reach its best potential when a private provider owned vehicles, processed trip requests, and employed drivers. Still, contracting-out often raises important issues on in-house labor relations and datasharing. The expected cost-reduction is also variable over time – research shows that contracted services works best alongside directly-operated services, as a form of competition is created between in-house workers and private-sector employees (Sarriera et al., 2018). When considering contracting a new service, transit agencies need to carefully evaluate its real potential to reduce costs and improve service.

4. Microtransit is unlikely to generate significant environmental benefits. Both case studies showed that net GHG emission impacts from mode shift for the transit access/egress leg of the trip were likely to be positive or neutral at best. Evidence also showed limited potential for microtransit to attract new riders to the transit system. It is worth noting that while the wide variations in service provision and effectiveness across microtransit pilots limited the generalizability of this finding, the two case studies did respectively exemplify urban, high-ridership RH services and rural ODT services with limited patronage. The evidence hinted at limited potential for GHG emission reduction regardless of how a service is operated – while microtransit can meaningfully increase transit access by shortening trips for existing riders, their environmental benefits are dubious.

Future research on microtransit performance should focus on contrasting the impact of different labor contracting structures on service provision and cost-effectiveness. As data on microtransit is likely to remain limited due to the small number of pilot programs, in-depth case studies and conversations with agency staff are viable strategies to examine how contracting works in various transit markets and for different use cases, i.e. fixed-route replacement, new local service, and feeder to transit.

Another potential area for future research is comparing microtransit performance against more granular fixed-route data. This paper used system averages for such comparison and found consistently large gaps between microtransit and fixed-route effectiveness. However, this approach masked the potential variation among different fixed-routes in a transit system – a better comparison can be drawn between microtransit and suburban and local feeder buses, which are often used as substitutes for each other in practice. It is likely that some of the lower-cost programs examined here made better financial cases compared to low-performing fixed-route buses.

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