The State of Demand-Responsive Transit in Canada

FINAL REPORT
July, 2020

Dr. Willem Klumpenhouwer
Postdoctoral Fellow
Transit Analytics Lab
University of Toronto

Acknowledgements

This project was co-supervised by:

Dr. Amer Shalaby
Professor, Transportation Engineering
Director, Transit Analytics Lab
University of Toronto

Dr. Lee Weissling
Senior Research Officer
Ontario Society of Professional Engineers

Thank you to the following organizations for their contributions and support:

Mitacs is a national, not-for-profit organization that has designed and delivered research and training programs in Canada for 20 years. Working with 60 universities, 4,000 companies, and both federal and provincial governments, they build partnerships that support industrial and social innovation in Canada.

The **Ontario Society of Professional Engineers (OSPE)** is the voice of the engineering profession in Ontario. They represent the entire engineering community, including professional engineers, engineering graduates and students who work or will work in several of the most strategic sectors of Ontario's economy. OSPE elevates the profile of the profession by advocating with governments, offering valued member services and providing opportunities for ongoing learning, networking and community building.

Contents

Executive Summary

Transit planners far and wide are familiar with the ridership-coverage trade-off: With a set and finite budget, transit planners have to choose how much of their resources to dedicate towards providing everyone access to a transit stop, versus maximizing their ridership by consolidating service into a few fast and frequent lines. These two important transit goals are at geometric odds with each other: coverage-based service requires spread-out lines, routes, and stops to ensure access, while high-frequency (and high-ridership) lines rely on consolidating routes into corridors and limiting the amount of detours taken to serve neighbourhoods.

With recent technological advances in cloud computing and the growing prevalence of smartphones and mobile data connections, it is theoretically possible to manage this trade-off in real time. By adapting the routing of a vehicle and the stops it services, demand-responsive transit (DRT) has the potential to find dynamic routes between stops with real-time demand while still providing coverage where needed. By molding itself to the instantaneous needs of a community, demand-responsive transit may be able to provide vital access to the system while also consolidating riders into vehicles.

This study investigated the current state of practice of demand-responsive transit in Canada through a series of interviews with transit organizations and vendors. There is a growing number of communities that are being served by demand-responsive transit, including municipalities that had never had transit before. This report synthesizes and outlines some of the challenges, opportunities, and lessons learned from these transit projects.

From these conversations we learned that these technological advances have broadened the possibilities of where demand-responsive transit might be successful. By personalizing the transit trip and leaving route planning to sophisticated algorithms, the flexibility of these services has grown, meaning that demand-responsive transit may no longer be a low-productivity-only type of service.

Some municipalities introduced demand-responsive transit service as a way to build ridership as a first step towards a more robust fixed route system. This provides them with an important first step in the planning process: data collection. The granularity of data available to transit agencies operating application-based demand-responsive transit service is much more detailed than data that is collected for fixed-route service. Travel times, demand patterns, and in-vehicle crowding are all easily obtained through the information that is inherent in a booked-trip system. This data can provide transit agencies with extremely valuable information on trip pattern and needs which can be incorporated into future plans.

There is also a clear need for more research. There are no consistent planning standards and approaches for demand-responsive transit systems. Determining service area configurations, level of service parameters, and potential ridership is done on an ad-hoc basis, often by technology vendors as part of the procurement process. While these vendors are able to offer planning services, more research is needed to establish a methodology behind demand-responsive transit planning in a North American context.

Demand-responsive transit in Canada is growing. Municipalities are interested in new ways to serve customers in areas that would traditionally be excluded from transit service. While land-use, the prioritization of the automobile, and the lack of walkability in neighbourhoods plays a significant role in the ability of municipalities to provide transit service, demand-responsive transit may provide an increasingly feasible way to shift the conversation more shared, greener, and connected communities.

During the course of this study, the future of transit has been put in a state of flux. A worldwide pandemic of COVID-19 has reduced ridership on conventional transit systems, and has forced transit agencies to work against the very advantage that transit provides in an urban setting: The efficient sharing of trips in a small space. The lasting impacts of this pandemic and the future of transit systems is not clear. In Canada, the role of government in supporting individuals, business, and institutions continues to evolve. Whether the concept of "physical distancing" will become ingrained in our cultural fabric for years to come is unknown, but demand-responsive transit will continue to hold a place in that conversation.

CHAPTER 1

Introduction

The emergence of the smartphone brought with it a culture of convenience, flexibility, and rapid adaptation. Public transit has also had to embrace these technological and cultural shifts. While flexible and adaptive transit has been around for a long time in Canada[1] the arrival of transportation network companies (TNCs) such as Uber and Lyft with slick application interfaces and realtime GPS tracking of vehicles obviated the need for transit agencies to get on board with the possibilities offered by these technologies.

Since then, a tension has emerged between the buzzwords of micro, flex, and on-demand transit and the geometry and operational realities of transit agencies. Transit operates on the premise of shared rides for different purposes, each rider giving a small amount of their time and effort for greater efficiency and lower cost of moving people in cities. This compromise required by public transit is somewhat at odds with the convenience offered by at-your-fingertips applications.

This tension is in many cases fueled by a lack of clear understanding of the current reality of demand-responsive transit (DRT) service. While some research has been done on the current state of DRT projects in the United States,[2] Canada has some unique projects, funding characteristics, and technology companies that have emerged. This report is intended to provide a Canadian view into the current state of DRT service in Canada. Many of the organizations interviewed as part of this study expressed a need for clearer understanding of both the benefits and limitations of DRT service.

This report is intended to provide a synthesis of recent, current, and near-future DRT projects in Canada. The intention is to provide current and future planners and operators with a grounded discussion of what DRT service has provided municipalities, and what the current state of understanding of the capabilities of DRT service is at this point in time. Municipalities, regional planning organizations, technology vendors, and researchers are the intended audience for this report.

The document is divided into three chapters. The remainder of this introductory chapter provides context on what DRT looks like, sets the scope of the research, and provides an overview of the interview-based survey design and process. Chapter 2 provides a high-level overview of considerations related to DRT in Canada, outlining important considerations in service supply, demand, and quality, and provides some insight into where DRT is a feasible proposition. In Chapter 3, details on setting service standards, procurement processes, and operating considerations are discussed. The appendices include more detail on the survey materials.

In many cases, general information and conclusions that apply across DRT projects in a similar geographical context (the United States and elsewhere) have already been discussed in previous research reports. Where possible, reference to where this information can be found is provided to the reader, and any important conclusions and insights are repeated here.

1.1 Setting the Context

1.1.1 Defining Demand-Responsive Transit

There is a wealth of terminology surrounding public transit in general, and as a field that is evolving more rapidly in recent years, flexible transit service has many different flavours and branding. Terms such as demand-responsive transit, on-demand transit, and microtransit are sometimes used interchangeably, and agencies often refer to these service types as "alternative service delivery"[3] or "on-request" transit.[4] These terms are often used to impart different meanings by different transit agencies, consultants, and researchers. To avoid confusion throughout this report and to emphasize the importance of understanding the wide range of service types that fall under demand-responsive transit, it is worth pausing to carefully define specific terms used throughout the report.

It is best to start with a definition of public transit in general. The diversity in types of service offered by taxis, TNCs, transit agencies, and private shuttle companies can often lead to some confusion as to what type of service qualifies as transit, and what qualifies as ride hailing. Public transit consultant Jarrett Walker provides an excellent definition:[5]

> Public transit consists of regularly scheduled trips, open to all paying passengers, with the capacity to carry multiple passengers whose trips may

have different origins, destinations, and purposes.

With this definition in mind, Figure 1.1 provides a high-level conceptual diagram of where DRT fits in the spectrum of services available in many cities and towns in Canada. In general, DRT requires some level of sharing and some level of flexibility in routing. While they adapt to changes in demand patterns, they must provide regular service in some way, either by guaranteeing a minimum level of service (e.g. a bus is never more than 30 minutes away). The above definition does not require any specificity about vehicle routing, which is where DRT is the most able to adjust and adapt in real time. Within that definition are a number of possible service configurations, definitions, and parameters that make a service more or less personalized, aggregated, and productive.

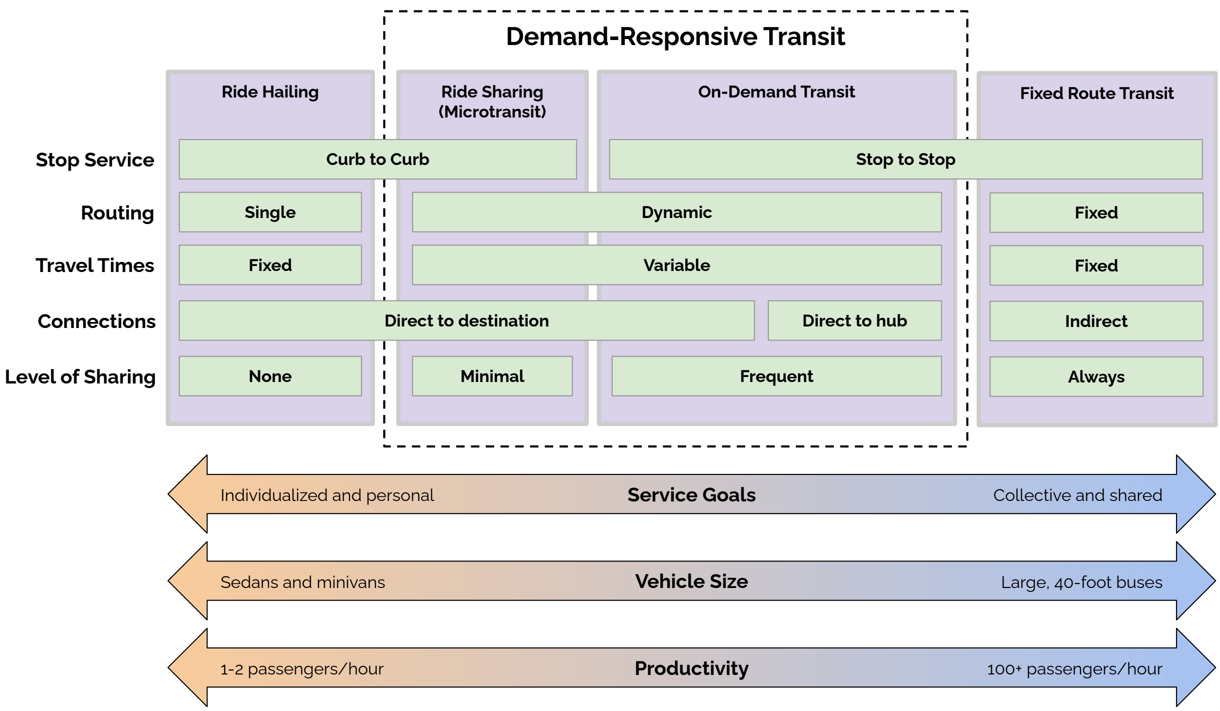

Figure 1.1: Conceptual diagram of transit and ride hailing services.

SAE International provides a partial taxonomy for the services discussed in this report.[6] They refer to the broader set of "demand-responsive transport" as "alternative transport services", but include in this definition bikesharing, scooter sharing, shuttles, taxis, carsharing, courier network services, pedicabs, personal vehicle sharing in addition to the concepts introduced above. In the transit context, they do not provide a definition of alternative transit that is outside of the general definition of microtransit, which they describe as " a privately or publicly operated, technology-enabled transit service that typically uses multi-passenger/pooled shuttles or vans to provide on-demand or fixed-schedule services with either dynamic or fixed routing". This definition does not capture the increasing number of services that use community or full-size transit vehicles. Figure 1.2 provides an example of two transit vehicles commonly used for DRT in Canada. Figure 1.2a is an example of a community size vehicle, while Figure 1.2b is an example of a van-type vehicle more closely associated with microtransit. The wide variety of vehicle types, branding, and approaches to service makes a clear distinction between services difficult.

(a) Cutaway bus (Bowen Island) **(b) Transit van (Calgary)**

Figure 1.2: Smaller vehicles typically used for DRT.

1.1.2 Research Scope

This study considers DRT systems that fall both within the "ride sharing" and "on-demand transit" definitions outlined in Figure 1.1. Ride hailing, which includes taxis and transportation network companies such as Uber and Lyft, are not built around shared rides, even when these services are offered as part of shared rides or advertised as transit, such as the subsidized Uber operations in Innisfil, Ontario.[7] Microtransit, which is generally the same as rider sharing, is often used interchangeably with DRT and on-demand transit service and generally refers to service consisting of smaller vehicles and which relies heavily on software applications with internet connectivity and GPS.

Additionally, the study focused on projects which have leveraged recent advances in technology platforms as part of their operations. While "dial-a-ride" service falls under the definition of DRT service, this service has existed and been studied for significant amount of time. Some municipalities interviewed currently or previously operated dial-a-ride service.

This report also does not include paratransit systems in its scope of research. While paratransit is a vital service and often required by legislation, it is typically not open to all paying passengers as service is limited to those with disabilities.

This wide variation of definitions and perceptions about what DRT looks like can complicate both discussion and opinion on the viability and scalability of DRT service. What is possible for DRT service is changing quite rapidly, and the context of the conversation has been preempted both by older forms of DRT such as dial-a-ride, and by venture-capital subsidized ride hailing technology companies such as Uber and Lyft.[8] Many of the organizations interviewed in this study emphasized the importance of keeping an open mind with what is possible with advances in routing and scheduling software.[9]

1.2 Interview-Based Survey Method

The nature of DRT means that individual projects can vary greatly in their design, operating model, and evaluation standards. For this reason, a traditional survey approach which requires a rigid question-and-answer structure is not flexible enough to capture the various project stages, political climates, geographic characteristics, and funding levels inherent in these flexible systems. Therefore, an interview-based survey method was used to facilitate a dialogue about challenges and opportunities faced during the four phases of DRT defined in this report.

The interview questions are detailed in Appendix A. They were designed to provide a starting point for dialogue about challenges and opportunities faced by a specific service provider. Conversations moved between subjects and topics organically. Agencies determined who participated in the study based on a provided set of topics; groups consisted of one to three participants.

Two survey instruments were used in this report. A detailed survey was conducted with transit agencies who have previous, currently operating, or planned DRT projects. A shorter survey was used for vendors who provide service to agencies for DRT projects to gain additional insight into the challenges and opportunities faced by vendors.

1.2.1 Respondents and Coverage

Table 1.1 lists the past, current, and planned DRT projects considered in this report. A total of 26 organizations were contacted: 17 municipalities, two regional planning agencies, six technology providers, and a third-party transportation operator. A significant portion of recent DRT projects were found in the prairie provinces and in Southwestern Ontario. No recent DRT projects were found east of Montréal. Table 1.2 list the vendors and regional organizations that were interviewed as part of the study.

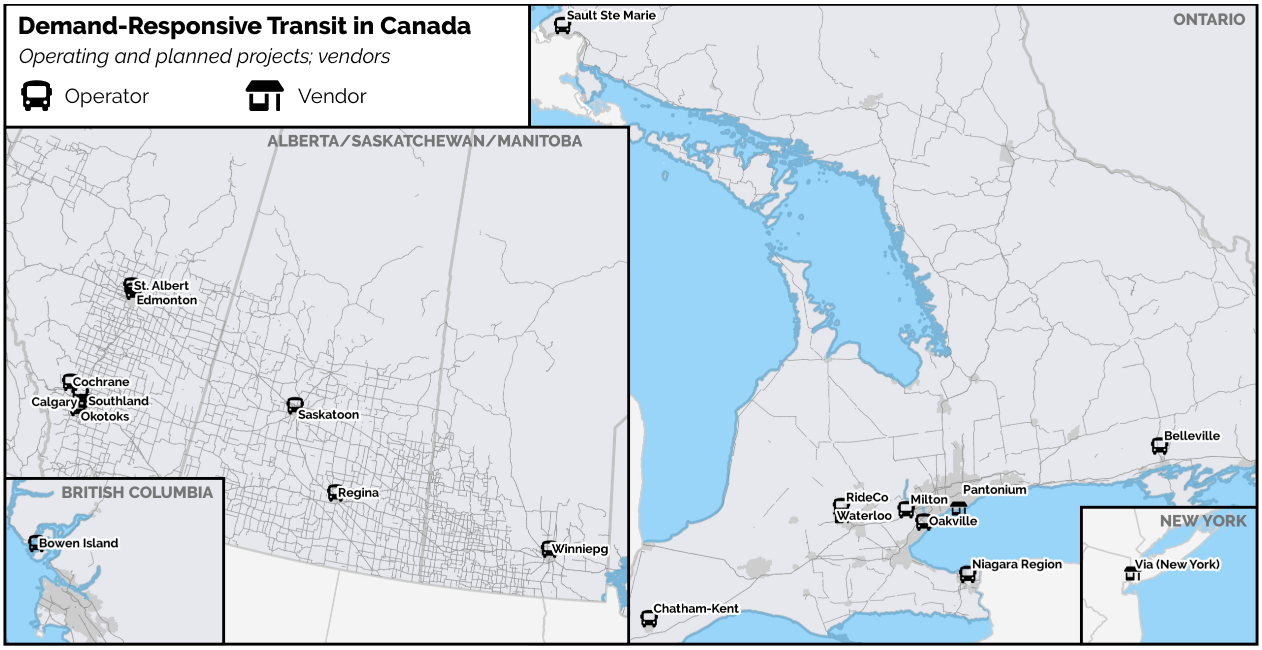

Figure 1.3: Organizations contacted for interview.

Table 1.1: Municipalities identified with recent, present, or upcoming DRT service.

Municipality	Province	Project Timeline	Interviewed
Belleville	Ontario	2018 to Present	Yes
Bowen Island	British Columbia	2019	Yes
Calgary	Alberta	2019 to Present	Yes
Cochrane	Alberta	2019 to Present	Yes
Edmonton	Alberta	Planned (2021)	Yes
Okotoks	Alberta	2019 to Present	Yes
St. Albert*	Alberta	Planned (2020)	Yes
Waterloo	Ontario	2018 to 2019	Yes
Winnipeg*	Manitoba	Planned (Unknown)	Yes
Chatham-Kent	Ontario	Planned (2020)[10]	No
Milton	Ontario	2015 to 2016[11]	No
Niagara Region	Ontario	Planned (2020)[12]	No
Oakville	Ontario	2015 to Present[13]	No
Regina	Saskatchewan	Planned (2020)[14]	No
Sault Ste. Marie	Ontario	2019 to Present	No
Saskatoon	Saskatchewan	Planned (2020)[15]	No

* Currently operating dial-a-ride service

Table 1.2: Regional transit authorities and vendors interviewed.

Organization	Type
ARTM (Greater Montréal)	Regional Transit Organization
Metrolinx (Greater Toronto Area)	Regional Transit Agency
Pantonium	Technology Vendor
RideCo	Technology Vendor
Southland Transportation	Service Operator
Via Transportation	Technology Vendor

1.2.2 Interview Process and Discussion

Given the wide variety in service types, planning and operation stages, and municipal involvement in planning and operations, interviews were conducted in a conversational style. This meant that interviews with different municipalities would focus on different aspects of service planning, design, and operation. For example, municipalities which had not yet launched DRT service focused their discussion on the planning process and outreach with communities, while those in operation were able to discuss implementation and operational challenges and successes.

Both municipalities and vendors who responded were enthusiastic participants and were strongly invested in the success of the projects they were involved in. Typically, discussions revolved around the configuration and state of the service and some of the unique challenges and decisions made by individual agencies (e.g. choice of fare structure and media, vehicle type, or community outreach process).

The financial viability and comparative quantitative performance of the systems was not discussed formally in the interviews and is not detailed in this report for a number of reasons: Almost all of projects discussed were currently operating, and operating in a pilot context, meaning that while some data collection was ongoing, official reports and conclusions about the success of the service from a quantitative standpoint was not available. The financial performance of the systems was kept out of the conversation in some cases for reasons of confidentiality, and in other due to the difficulty with comparing services with different goals and approaches based on limited performance metrics.

Notes

[1]Winnipeg, for example, operated an on-demand "dial-a-ride" service from 1974 to 1977 (D. Koffman, "TCRP Synthesis 53: Operational experiences with flexible transit services," *Transportation Research*

Board, 2004, p. 25).

[2] J. Volinski, "TCRP Synthesis 141: Microtransit or General Public Demand Response Transit Services: State of the Practice," *Transportation Research Board*, p. 222, 2019.

[3] SAE International, "Taxonomy and Definitions for Terms Related to Shared Mobility and Enabling Technologies," SAE International, Tech. Rep., 2018.

[4] The term "on-request" was thought to reflect better the action of the service, and avoided confusion with longer-term planning an adjustment of all transit service, which is also "demand responsive" or "on-demand" in some capacity

[5] J. Walker, *Human Transit*. Washington, D.C.: Island Press, 2012.

[6] SAE International, *Taxonomy and Definitions for Terms Related to Shared Mobility and Enabling Technologies*.

[7] L. Bliss, *'Uber Was Supposed To Be Our Public Transit'*, 2019.

[8] A. J. Hawkins, *Uber lost $8.5 billion in 2019, but it thinks it can get profitable by the end of 2020*, 2020.

[9] The role of technology in enabling modern DRT systems is further discussed in Section 2.3

[10] T. Terfloth, *Chatham-Kent to launch on-demand transit pilot project*, 2020.

[11] RideCo, "Solving the First Mile-Last Mile On Demand," Tech. Rep., 2018.

[12] Niagara Region, "Niagara Region On-Demand Transit - Public Works Committee Presentation November 5, 2019," Tech. Rep., 2019.

[13] City of Oakville, *Oakville Transit introduces Home to Hub service in North Oakville*, 2015.

[14] R. Bell, *Regina, Saskatoon looking to app to pilot on-demand transit service*, 2020.

[15] City of Saskatoon, *On-Demand Transit - effective June 29, 2020*, 2020.

CHAPTER 2

Getting Started

There is no magic formula for determining whether demand-responsive service is warranted, feasible, or even remotely appropriate in a given context. Each region and community's situation is relatively unique, and these differences can influence the success of DRT perhaps more strongly than that of conventional fixed-route service. Instead, transit agencies considering DRT would be best served to develop an understanding of the relationship between service supply, quality of service, and demand for service in conjunction with their goals for what the service should accomplish.

Using examples from Canadian municipalities, this chapter introduces some context of where and when DRT may be appropriate, and discusses how various characteristics in a given service area might influence a project's success. This includes a discussion of the role that technology plays in modern DRT systems.

2.1 Supply, Demand, and Quality

As with any transit system there is a relationship between supply, demand, and quality of DRT service, illustrated in Figure 2.1. These three components are strongly interconnected, and it is often difficult to determine which of the three aspects is influencing the other and in what way.

Supply is typically described quantitatively through vehicle hours, number of stops, and service area size, and qualitatively through the technology platform and vehicles used. Transit demand is discussed in terms of trips, destinations, and overall ridership. The quality of service is quantified through travel times, proximity to stops, and the average waiting time for a bus to arrive. With DRT, the quality of service includes measures that are focused on individual experiences of interactions with the service such as failed searches, route directness from origin to destination, and through trip ratings

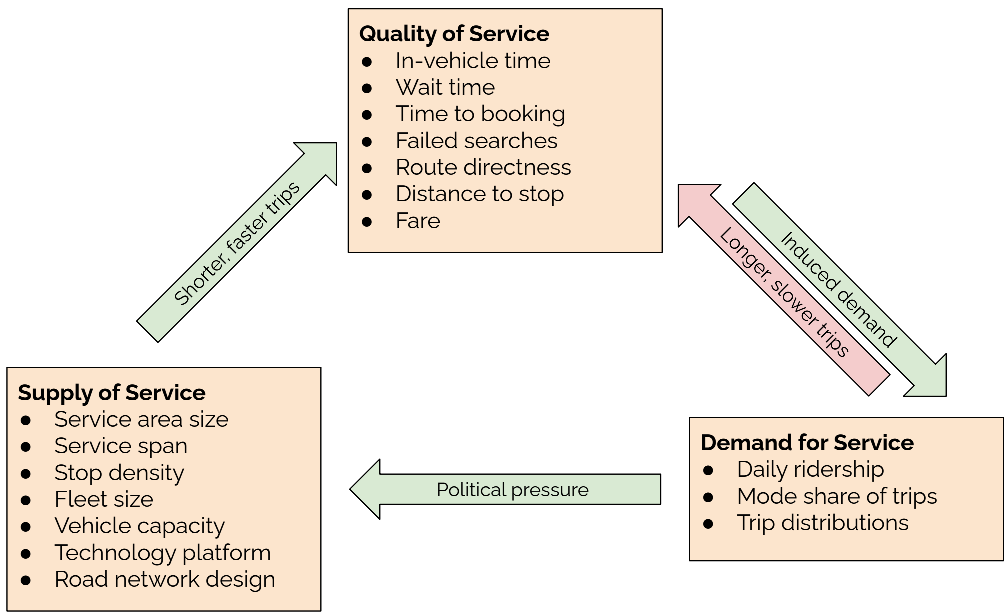

Figure 2.1: Supply, demand, and levels of service in DRT

provided by users through the application.

2.1.1 Road Network as Supply

The characteristics of the road network is also an important aspect of transit supply, as it has a direct effect on the amount of service that the agency is able to provide with a fixed level of resources. With DRT service, which is typically located in lower-demand suburban and exurban areas, the geometry of the road network can often be curvy and irregular, which influences the amount of flexibility in routing that is available to a DRT service.

Bowen Island, British Columbia serves as an illustrative example both for this and the following section. Bowen Island is a small community of approximately 4,000 residents[1] located on an island about 20 minutes by ferry from Vancouver (see Figure 1.3). TransLink, the Metro Vancouver regional transportation agency, operates fixed route service on the island to connect residents with each other and the ferry terminal. DRT service was introduced as a two-month pilot over the summer of 2019 in order to boost access to parts of the island not served by fixed route transit (see Figure 2.2) and to encourage visitors to the island to leave their cars at home. In this case, DRT service was limited to running along very specific roads as they were unable to access smaller side roads. On Bowen Island, there is no opportunity for short-cutting or for adjusting the shape of the route to minimize the distance travelled.

Figure 2.2: Bowen Island route map and representative roadway[2]

2.1.2 Demand Patterns

While transit demand is affected both by the supply and quality of service, transit demand is influenced mainly by the sociodemographics of the population, the land use and urban planning characteristics of the area, and the appeal and accessibility of other modes. These characteristics also strongly influence the patterns of demand, which can be categorized into two broad categories: many-to-many, and many-to-one. Figure 2.3 illustrates the differences between these two demand patterns.

With many-to-one service, trip patterns have origins or destinations concentrated at a single stop, typically referred to as a "hub". In areas where the destination hub is a connecting transit system, this service is typically described as first-mile/last-mile service. In many cases, a commuter-oriented service provides symmetric many-to-one service in the morning, and one-to-many service in the afternoon. If the connecting service at the hub has low frequency, coordinating the arrival of on-demand vehicles with that service may be extremely difficult or impossible, given the flexibility in travel and schedule times inherent in DRT systems.

An illustrative example can be seen again on Bowen Island, which is served from mainland Vancouver by an infrequent and often unpredictable ferry service. While it was possible to provide one-to-many service from the ferry to the rest of the island the reverse was not possible due to the fluctuations both in the ferry schedule and in the consistency of the DRT vehicle's travel time.

Outside of Bowen Island, many-to-one service was observed in larger cities operat-

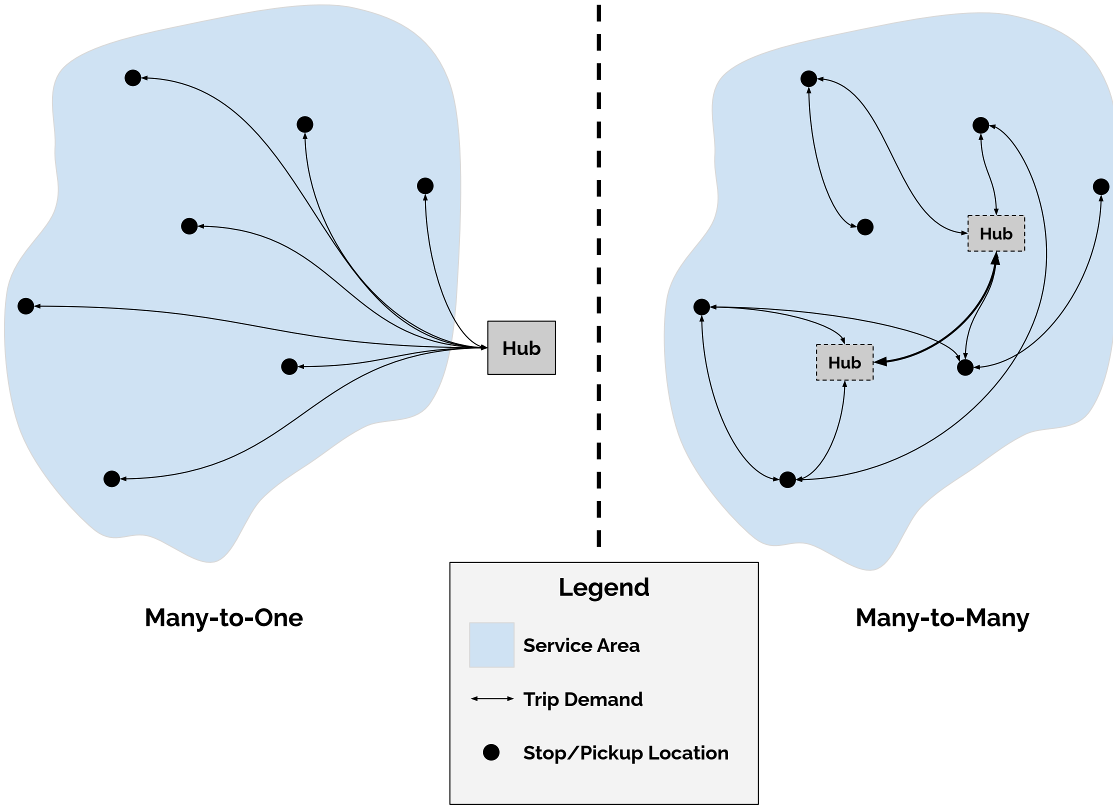

Figure 2.3: Many-to-one and many-to-many DRT Service

ing DRT in low-density suburban neighbourhoods. In Calgary, the on-demand service connected two communities still under development with a transit and shopping hub in the north of the city. The hub was located outside of the service zone. Oakville, Ontario's "home-to-hub" service is specifically branded as a many-to-one service connection to a transit hub. In St. Albert, Alberta, a small city adjacent to the provincial capital of Edmonton, trips on the evening on-demand service are concentrated at the connecting point with Edmonton's transit service.

Many-to-many service is more common in small and medium sized municipalities that introduced service spanning the entire city or town. In these cases, local hubs such as large shopping centres emerged as destinations for trips though a strong many-to-one pattern was not observed in the same way. Cochrane and Okotoks Alberta, as well as Belleville, Ontario operate a many-to-many type service.

Many-to-one service has the advantage of concentrated trip origins or destinations which can allow for a pattern of sequential pick up and shuttling to a hub. While this provides efficiency and increases sharing, it also consists of one-way trips, and vehicles will have to inevitably travel empty on a return trip. Flexibility in routing such as sharing

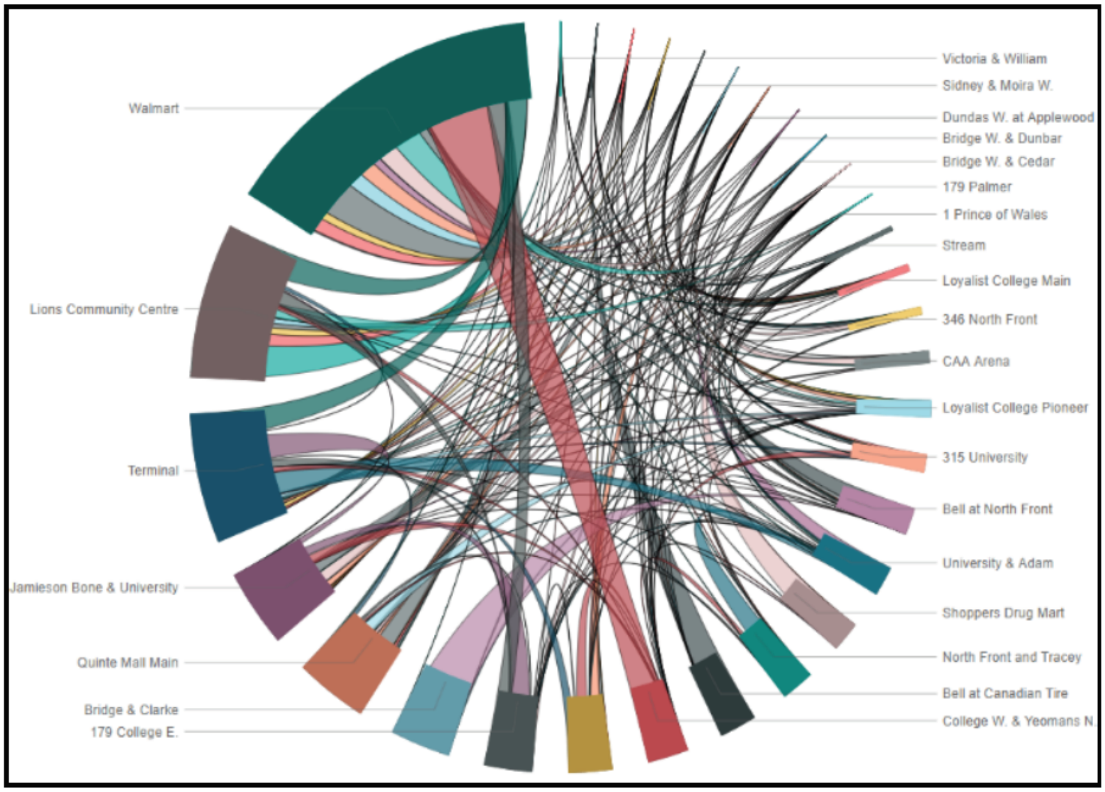

Figure 2.4: Origin-destination chord diagram in Belleville, produced by Sanaullah et al.[3]

vehicles between adjacent service zones can potentially mitigate this effect.

Many-to-many service can take advantage of trip patterns in two directions, with the trade-off that origins and destinations are more widely dispersed. Larger service areas can create situations where trip ends are far apart, providing fewer opportunities for shared trips. It is possible to take advantage of local hubs. For example, in Belleville, Ontario many trips begin and end at the Wal-Mart and Lions Community Centre (Figure 2.4). The ability to combine trips efficiently is a function of demand patterns, service area size, and routing technology, which is discussed further in Section 2.3.

2.1.3 Service Quality

There are two ways to approach service quality in planning. The first is to fix the supply offered by an agency, often as a result of fixed costs or operating budgets. This fixed supply will interact with the demand for service which results in a certain quality of service that the agency is able to provide. In situations where existing service was being replaced with new or updated DRT service, this approach was used to maintain existing cost levels.

Fixed-route service quality is relatively insensitive to how much demand for service there is. Small increases in demand over time are absorbed relatively easily into a fixed route system due to the high capacity of vehicles and fixed schedule. Only when ridership reaches very high levels does the quality of service degrade significantly due to overcrowding.

With DRT service, increases in demand can very quickly affect the quality of service that an agency is able to provide. Because of the dynamic nature of routing and scheduling with DRT service, and the widely dispersed trip origins and destinations, on-demand service is less easily able to absorb increases in demand, especially after a certain threshold is reached. To accommodate this with a fixed supply of service, on-board trip times must become longer and trips will become less direct. Many agencies reported having to add extra vehicles to avoid significant drops in service quality and trip refusals, where passengers are unable to book a trip when they would like. These refusals can occur due to vehicle capacity, or when the routing algorithms are unable to find a trip that includes the passenger but also does not exceed maximum on-board times for other passengers.

Another approach to the planning process is to fix service quality, and determine the supply of service that is required to match that. This approach allows agencies to determine what their service standards should be and what the goals of their service are (Section 2.2), before the supply of service is determined. This can provide agencies with better insights into the true costs of DRT service in their area, as the uniqueness of each service area can make comparing one service to another very difficult.

2.2 Determining Service Goals

Demand-responsive transit is proposed and implemented in areas where operating conventional transit is challenging where the topology of the network is irregular and where concentrated ridership is limited due to low population densities. In North America, rural communities and suburban areas with low population densities are most likely to fit this description. A 2010 estimation suggests that a population density of less than 770 people/km^2 is appropriate for a first look for DRT service,[4] though this value is likely to change with service area characteristics and technological advancements. As a comparison, Table 2.1 shows various populations densities for municipalities with current or planned DRT service. Many agencies are running DRT service in areas with much higher density than estimated in 2010, an indication that technology improvements have enabled cities to serve more people and higher population densities with DRT (see Secion 2.3). Service can also be introduced in developing areas to grow ridership; Calgary's pilot DRT service is focused on "providing on-demand transit services in newer communities where demand is presently insufficient to warrant traditional fixed route/fixed schedule operations."[5] The portion of Edmonton's planned DRT aiming to serve new communities followed similar motivations.

Table 2.1: Population densities of various municipalities in Canada[6]

Municipality	Province	Density (people/sq. km)
Belleville	Ontario	819
Bowen Island	British Columbia	73
Calgary*	Alberta	2,111
Cochrane	Alberta	1,081
Edmonton*	Alberta	1,856
Milton	Ontario	2,520
Okotoks	Alberta	1,698
Sault Ste. Marie	Ontario	1,250
St. Albert	Alberta	1,354
Winnipeg*	Manitoba	2,070

* Partial DRT service provided, densities are city-wide averages.

An important first step in the planning process is to determine what the larger goals of the service are, as these may differ greatly from agency to agency and service to service. Setting these goals also provides an understanding of what level of service quality is appropriate and therefore what resources are required to provide the appropriate supply.

As DRT services can vary significantly in their operating model, configuration, and levels of service, it is vital that the goals of the service be determined early in the planning process. Here are some potential goals that have motivated previous projects:

- **Building ridership**. Whether transit is brand new to a municipality or service is being expanded, a common goal of many DRT projects studied was to build transit ridership in an area. In Cochrane, Alberta, ridership growth may lead to the eventual introduction of fixed-route service. In Calgary, Alberta, DRT was introduced into a developing community that had not yet reached a population threshold dictated by policy for fixed-route service. Introducing DRT can act as a flexible catalyst for growing transit ridership.

- **Providing first-mile/last-mile connections.** In many cases, transit agencies recognized the potential for DRT to provide a large area with connections to existing transit networks, while decreasing walking distances to stops. This type of service is able to extend the reach of existing fixed-route transit networks at a lower cost and higher service availability than extending fixed-route service.

Regional transit agencies may also be interested in first-mile/last-mile service with the specific goal of managing trips to and from regional transit stations. This may include offering DRT service on top of existing municipal service, geared toward commuters. Regional transit agencies may be looking to reduce congestion on typical commuting roadways, or to limit the amount and cost of parking at station areas. These goals may complement or be at odds with municipal transit, and require careful planning.

- **Serving aging populations.** Some municipalities such as Cochrane, Alberta, cited supporting seniors' daily activities and aging in place considerations as part of their motivation for introducing DRT service. The flexibility of smaller vehicles, virtual stop placement, and on-the-fly routing can allow for direct connections between seniors complexes, shopping areas, and other major hubs. This general DRT service can also take pressure off of paratransit services by offering safe and direct connections to individuals who might otherwise not be comfortable accessing a fixed-route network.

- **Increased area coverage at fixed cost.** Often, it was operationally cheaper to offer DRT service in an area while still providing a comparable level of service frequency and reliability. Many agencies cited DRT's potential efficiencies in terms of vehicle hours for a given coverage area as a main factor in piloting or implementing permanent DRT service.

Success will look different for each of these goals. For example, if a transit agency's goal for a DRT service is to help support aging populations, a curb-to-curb service may be more appropriate despite its relative inefficiency compared with a stop-to-stop model. In this case, passengers may be willing to accept longer and more varied trip times in return for the reduced walking distance provided by curb-to-curb service. If a service is geared towards providing a first-mile/last-mile service oriented around a transit hub, the service may need to be designed around commuting patterns and connections to less frequent higher-order transit such as commuter rail. In this case, consistent arrival and departure times from the transit hub may be more important than the convenience offered by curbside pickup.

Trade-offs are a fundamental part of any transit service, and DRT is no exception. Both vendors and agencies stressed the importance for those planning service to have a clear understanding of what the goals of the service are so that these trade-offs can be weighed appropriately.

Another common theme among DRT service proposals is a need to connect non-commuting trip purposes with non-commuters. This includes seniors complexes, hospitals and other care facilities, pharmacies, and grocery stores. Many agencies identified this specific consideration as part of their motivation for moving forward with DRT service.[7]

In many cases, a move to DRT was driven by urban planning, urban form, and community integration considerations. Lack of sidewalks in suburban developments, curvy road geometries that make it difficult for fixed route service to succeed, and physical barriers such as expressways all reduced connectivity and walkability that is essential for successful fixed route service.[8]

2.3 The Role of Technology

Note that all of the high-level influencing factors in the previous section make no mention of technology. These motivations are functions of the geography of the area, both physically and sociodemographically. Agencies that have run various forms of dial-a-ride or low-tech DRT service in the past have cited similar rationales for service.

To best understand the impact that recent advances in routing and scheduling technology can have on the feasibility and success of DRT service, consider the dial-a-ride approach that has until recently been used in the city of St. Albert, Alberta. Passengers who were arriving from a connection with Edmonton Transit would call the driver of the bus directly and provide their information. “Drivers will only have their phones turned on for a 10-minute window”, states the St. Albert dial-a-bus website, adding that service “operates along existing bus routes and collector roadways.”[9] Drivers have to plan their routes based on their knowledge of the city and the destinations of passengers for each loop into the community. This limitation on routing and planning is partially why St. Albert is divided into two service zones.

Advances in cloud computing and routing algorithms can remove the need for driver route planning and greatly advance the efficiency and optimization process of dynamic routing. Technology providers can now compute thousands of itineraries almost instantaneously, adapting to changes in demand over large service areas. With constraints on maximum trip times, vehicle capacities, and the location of stops, these routing algorithms can search for the best route on an updating basis. In effect, the routing procedure being done once a cycle by a driver or dispatcher can now be done thousands of times, and at any point along the route. These algorithms take into account various optimization constraints such as total trip time (often in relation to direct trip time) and vehicle capacities. Service productivity can be quite sensitive to the adjustment of the constraints, as they directly impact the flexibility of the service overall and therefore the ability of the algorithm to find more efficient solutions. These cloud computing platforms offer the potential of scaling that was otherwise impossible for DRT service. Traditionally, DRT service is thought to have a very small maximum productivity, on the order of approximately three passengers per vehicle hour. Technology vendors suggested that with these computing approaches, productivity could be scaled by an order of magnitude if applied to a large service area zone with higher demand. This "scalability" makes the productivity overlap with coverage-based fixed-route service much larger.

When DRT service is introduced to community members, for example at public engagement events, their perception of the service is often relative to other application-driven transportation services such as Uber and Lyft. These TNC companies have spent huge amounts of resources developing applications that provide users with a seamless personalized experience. Real time vehicle and driver information, trip planning that includes connections beyond the DRT service provided, updated notification to customers, and even the understanding that the transit system is reacting to your needs when a booking is made all contribute to the sense that transit is working for the customer, instead of the customer needing to navigate the service.

Technology providers still have some ground to cover to provide an entirely seamless experience, both for the operator and for the transit user. Payment integration (both within the application and with existing fare media used by larger agencies), driver navigation, planning and modelling services, and a flexibility of the application to respond to unique edge cases in service design and geography were all mentioned as potential improvements that providers could make.

2.4 The Pilot Paradox

Transit agencies in Canada implement DRT service almost exclusively as pilot projects. Typically, these pilots are funded either through a specific grant, initiative, or dedicated innovation arm of a larger transit agency. In either case, transit agencies are experimenting with DRT on a pilot basis. There are advantages and disadvantages to this approach.

Two major risks with piloting service is the potential for unrealistic goal setting and expectations, and the inherent long-term decisions of individuals that are not captured with short-term pilots. With pilot projects, there is the potential for unrealistic expectations or over-selling of the service in order to get it funded and operating. This can create problems towards the end of the pilot where despite offering what would otherwise be adequate service, the pilot did not meet the high benchmark of expectation set at the outset and is therefore scrapped.

The second risk comes from the fact that many of the behavioural or land-use decisions made by individuals that strongly affect transportation patterns and efficiency are long-term decisions. Car ownership, choice of residence, and job location are all relatively long-term decisions that exceed the length of even the most long-term pilot projects. Individuals are not likely to relocate or sell a vehicle if they are not confident that the service will last past the length of the pilot. As a result, longer-term ridership growth, changes in trip patterns, and decreases in congestion and emissions may not be as high compared to a permanent service.

Pilot projects do also have significant advantages. In many cases, they are the only way to demonstrate the potential of a service, or to get funding to provide the service. They have the potential to encourage a feedback loop of evaluation and adaptation on a shorter-term basis, meaning that lessons learned from the service can lead to service improvements both in the system itself and in other DRT services. They carry with them the selling feature of being “an experiment” or “innovative”.

Ultimately, the long-term feasibility of DRT service in a given area will be measured by the continuation of the pilot, or by the introduction of fixed-route service in its place due to high ridership levels. These considerations are important for planners and engineers to understand as they discuss, measure, and evaluate the service.

2.5 Equity Considerations

By allowing agencies to provide coverage to areas that would not otherwise receive transit service, DRT service can provide disadvantaged groups with access to jobs and vital services such as groceries otherwise not feasible without owning a car.[10] This is especially true in towns where transit service did not exist at all prior to the introduction of DRT service. Some agencies reported a perception that “nobody will use transit in our town”, one that was proven incorrect very quickly after the service launched. This indicates that there there is a latent need for transit that may have been lacking a voice.

There is some concern about the "digital divide", which separates those who own smartphones, have data plans, and are adept at learning and using new technologies with those that don't and aren't. This digital divide is particularly correlated with lower income.[11] Almost all agencies provided a call-in option for users to book over the phone, however these were often only available during business hours, which did not coincide with the time when DRT service was offered. Generally, agencies reported minimal use of the call-in option, and one agency which did not offer the service at all reported almost no issues, though it is unclear whether this is due to barriers to reporting issues and needs or whether the need is actually minimal.

In addition to call-in options there are some strategies that agencies and vendors have used to mitigate some of these gaps. With a first-mile/last-mile many-to-one service, drivers can accept passengers at a hub regardless of having a prior booking, and passengers can use their internet connection or phone at home to book their trip. Providing free WiFi in key areas served by on-demand can allow individuals to book trips without needing a mobile data plan. One agency even considered providing tablets at hubs to allow for trip booking. To provide more universal access to their technology, vendors have continued to add features, such as booking by short message service (text), allowing users to book trips and receive updates through a cell phone that is not a smartphone.

As services continue to move digital, transit agencies will need to be continually mindful of the implications of these changes. For example, cashless systems can be a barrier to individuals who do not carry or own electronic forms of payment.[12] As transit is a vital service for lower-income individuals, it is important that these people are not left behind.

Notes

[1] Statistics Canada, *2016 Census*, 2017.

[2] Map courtesy of TransLink, photo from Google Maps.

[3] I. Sanaullah, S. Djavadian, B. Farooq, and L. Mellor, "Why Not Hail a Bus-ride? Evaluation of an On-Demand Transit (ODT) Service in Belleville, Canada," Ryerson University, Tech. Rep., 2019.

[4] J. F. Potts, M. A. Marshall, E. Crockett, and J. Washington, "TCRP Report 140: A Guide for Planning and Operating Flexible Public Transportation Services," *Transportation Research Board*, 2010, p. 30.

[5] J. Gondek and S. Keating, *On-Demand Transit Service Pilot - Application to the City of Calgary Council Innovation Fund (PFC2018-1291 Attachment 1)*, City of Calgary, 2018.

[6] Statistics Canada, *2016 Census*, Densities are for population centres, as defined by Statistics Canada.

[7] Potts, Marshall, Crockett, and Washington, "TCRP Report 140: A Guide for Planning and Operating Flexible Public Transportation Services"; J. Steiner, "Cochrane's Transit Alternatives Analysis Draft Final

Report," Urban Systems, Tech. Rep., 2013, Both of these reports utilize a decision matrix to emphasize this point.

[8]E. Pisani and B. Allen, "TES-TRS-18-13: Grand River Transit Alternative Service Delivery Pilot," Region of Waterloo, Tech. Rep., 2018.

[9]City of St. Albert, *St. Albert Dial-a-Bus*, 2020.

[10]Y. Zhang, S. Farber, and M. Young, "The Benefits of On-Demand Transit in Belleville: Findings from a User Survey," Tech. Rep. May, 2020.

[11]Statistics Canada, "Canadian Internet Use Survey, 2012," *The Daily*, 2013.

[12]R. D'Amore, *Via Rail goes cashless, leaving some consumers in the lurch*, 2019.

CHAPTER 3

From Idea to Execution

Once it has been determined that DRT is appropriate for a given area and the larger goals of the service have been established, specific decisions on service parameters, vehicles, procurement models, and evaluation must be made. This chapter discusses some of the decisions made by agencies and the rationales behind them. This chapter also includes a discussion of some operational considerations and lessons learned, including some of the operational changes made by DRT services during the COVID-19 pandemic.

3.1 Collecting Data

The amount and granularity of data collected by municipalities as part of the planning process for DRT service was relatively minimal among the organizations interviewed. In many cases, a baseline value for ridership or productivity (e.g. 150 trips/day) and a fixed cost was provided to potential vendors, and much of the additional analysis was left to vendors as part of the bidding and implementation process. Much of the ridership estimation was done by looking at other jurisdictions with similar populations and area characteristics and estimating from them.

This approach can both propagate errors and assumptions made by the jurisdictions used for comparison and introduce new issues by not accounting for the many ways in which service areas with similar populations may differ in important details such as sociodemographics and climate. Where data on community needs and demand was collected, it was typically through engagement sessions, where potential transit users were able to consider different aspects of the service planning process and provide input into their priorities. Engaging communities early and often is cited as a major reason for success in many transportation projects, and DRT is no exception.[1]

Ideally, more comprehensive and qualitative information on the demand patterns of communities would be collected to provide vendors and agencies with a better sense of where DRT service may be feasible. The demand characteristics in Figure 2.1 can allow for a clearer understanding of the relationship between service quality and supply. This can help set more realistic expectations for community members, politicians, operators, and planners.

3.2 Estimating Service Parameters

There is little in the way of standards, formulas, or academic research for developing service parameters such as zone size and fleet allocations for DRT. One recent study focusing on a Canadian context (Regina, Saskatchewan) provides an analytical method of comparing semi-flexible transit systems with fixed-route bus service for a fixed demand,[2] and is a good place for an interested reader to start. While analytical models on dial-a-ride service have been around for quite some time,[3] the potential advantages of optimization algorithms provided by cloud computing technologies have not been explicitly included.

While there is no limit to the potential level of sophistication possible in estimating service parameters, most transit agencies reported using fairly simple approaches.[4] Service areas were estimated primarily based on the geographical boundaries of communities and municipalities. This can provide familiarity and clarity to customers about where the service is available. Service areas were almost always contiguous shapes[5] whose boundaries followed those of communities, usually rivers or arterial roads. In smaller towns such as Cochrane and Okotoks, Alberta these areas encompassed the entire town.

3.2.1 Service Area

There is some debate as to the appropriate size of a given service zone. Reports from the United States indicated that zone size can be extremely flexible, ranging from 3 to 75 square kilometers (1.15 to 30 square miles).[6] While existing zones were limited by the routing capabilities and local knowledge of drivers, this is no longer a concern as routing technology becomes the default trip planner.

Generally, larger zones enable more direct trips and connections to a wider variety of places. For a many-to-many demand situation, where trip origins and destinations are spread out, a larger service zone may be more appropriate. In a first-mile/last-mile service configuration smaller zones in peak periods may be required to manage demand.

There are a number of other parameters that can be set by the technology provider that can affect the productivity, fleet size, and level of service of the system. Maximum trip length as a function of direct travel time limits the amount of time a passenger will spend on the bus to a reasonable expectation. This restriction can avoid the potential for long, circuitous trips that encourage shared rides but are unappealing to those that board first. It can also reduce some of the inherent randomness in trip lengths that are characteristic of DRT service. Response windows and cycle times of buses provide measures of service standards, and allow for some comparison with fixed route service frequency.

For example, consider a DRT service similar to Calgary's on-demand pilot that serves a zone using a single transit vehicle. The service operates as a first-mile/last-mile operation from a transit hub and serves a single zone in an exurban community. Each trip out to the community and back to a staging point takes H minutes, a random variable representing the cycle time of the vehicle. Assuming random and independent bookings of trips, and unlimited capacity, the expected wait time $\mathsf{E}[W]$ can be expressed as:[7]

$$\mathsf{E}[W] = \frac{\mathsf{E}[H]}{2}\left(1 + C^2(H)\right) \tag{3.1}$$

Where C is the coefficient of variation of the cycle time H, representing the level of randomness as a fraction of the average cycle time. If the coefficient of variation of the trip times remains constant, introducing a second bus improves wait time by half. While it is reasonable to expect that introducing a second bus will improve reliability somewhat, it will likely not reduce it by half as well, meaning that the expected waiting time will fall somewhere above half the single-bus scenario.

3.2.2 Fleet and Fleet Size

The majority of transit agencies operating DRT used smaller vehicles for their service, compared with the standard "40 foot" (12.19 m) buses used for normal fixed-route operations. Figure 1.2 shows two common vehicle types; a 20-30 foot cutaway bus and a large capacity van.

Typical rationales for the use of smaller vehicles included lower operating costs, ease of access to communities and smaller roads, quieter operations, and more personalized service. In some cases, estimated productivity and sharing was low enough that transit vans were appropriate. Belleville, Ontario and St. Albert, Alberta use their regular full-size buses for their evening DRT service, taking advantage of their existing fleet without needing to purchase new vehicles.

While specific procedures for fleet size estimations were not discussed in the interviews, they were typically understood to be an output of the estimated service area demand (rides/unit time), the estimated cycle times (unit time), and in some cases the desired productivity and cost (rides/vehicle/unit time). These three values were estimated based either on existing demand or on population density and sociodemographic characteristics, and were usually done in coordination with the technology company.

3.2.3 Fares and Fare Collection

All transit agencies that were interviewed charged or are planning to charge a flat fare or no fare for their DRT service.[8] While some agencies have distance-based fares for higher-order transit such as rail and express bus,[9] Canadian cities and towns in general prefer a flat fare model across their service area. While electronic fare media is becoming more common in larger cities in Canada, electronic fare payment is still not used in the majority of study areas, and many of the pilot projects studied struggled with fare integration.

Collecting fares for DRT requires some additional considerations. Many of the technology vendors included or allow for some form of integrated payment, however many agencies still allowed for bookings on monthly passes or through "pay as you board" systems. When rides are booked and payment is not collected in advance, there is the potential for high rates of trip cancellations as there is little consequence to a passenger for missing a boarding. This can be mitigated by requiring an e-mail address to create an account, and educating riders on the consequences of booking trips that are not needed. In some cases a small penalty such as a one-week suspension of the account was implemented, however this approach was extremely rare. Potential misuse of service is discussed further in Section 3.4.3.

With virtual account-based systems that do not require a physical pass or card, it is possible to share login information and monthly passes over a geographical distance that would otherwise be impossible. One agency described an example where a user with a monthly pass would request trips in different areas of the city nearly simultaneously, indicating that multiple individuals were using the account to travel. One approach used to mitigate this problem was to offer bulk discounts on individual trip purchases. This more directly reflects the cost of a single trip on DRT while still providing discounts to individuals who use the service more frequently.

3.3 Procurement

There are a number of different procurement strategies that are possible with DRT. Vehicles, operators, and technology platforms all have the possibility of being procured through a contractor or developed in-house. In Canada, a number of different permutations of these configurations exist.

With the exception of Waterloo's in-house development of some supplementary scheduling software for one of their on-demand projects, none of the projects interviewed used technology that was developed by the municipality. Agencies felt that vendors were better able to provide the technical expertise needed to run these cloud-based platforms and to develop efficient routing algorithms.

Vehicle and operator procurement models fell under two categories. Table 3.1 lists some of the configurations used by Canadian municipalities and their technology providers. These configurations reflect different approaches and goals for the service: In Belleville, city buses and operators are used for their evening on-demand service. On the other hand, Edmonton is planning to procure a turnkey solution from a vendor which includes vehicles, operators, and software.

Table 3.1: Procurements for various DRT projects in Canada

Municipality	Vehicles & Operators	Technology Vendor	Headquarters
Belleville	In-House	Pantonium	Toronto, Ontario
Bowen Island†	In-House/Contracted	DoubleMap[10]	Indianapolis, Indiana
Calgary	Contracted	RideCo	Waterloo, Ontario
Cochrane	Contracted	RideCo	Waterloo, Ontario
Edmonton*	Contracted		
Okotoks	Contracted	RideCo	Waterloo, Ontario
Sault Ste. Marie	TBD	Via	New York, New York
St. Albert*	Contracted	Pantonium	Toronto, Ontario
Waterloo‡	Contracted	RideCo	Waterloo, Ontario
Winnipeg	In-House	(Dial-a-ride)	

* Planned, 2020/2021.
† TransLink (In-House) vehicles, 3rd party operator.
‡ One of multiple service configurations.

In most cases, a technology provider will partner with a transportation company that offers vehicles and operators. This partnership will bid on the request for services together. Because the operation of the vehicles and the routing and scheduling technology is very separable, this partnership model is easy to facilitate.

While this can create the potential for confusion as to who is the main contact and liaison with the municipality, typically the issues and questions that arise fall clearly under the expertise of one of the providers or another. Issues with drivers, service, and vehicles belong to the transportation provider, while data, service parameters, and technology issues belong to the technology provider. Some agencies reflected that establishing relationships and lines of communications with both providers is a key aspect of making sure issues are dealt with in a timely manner.

Planning of service parameters and estimation of needs was typically left to the vendors. While technology providers offer planning services as part of their design and implementation process, they emphasized that it is important for transit agencies to have clearly defined goals for their system at the outset of the project. This avoids any miscommunication or misunderstanding of the type and quality of service being provided, and the costs of providing this service.

Combining the planning and implementation process into a single procurement carries some risks. It can make it difficult for agencies to know if the bids they are receiving are reasonable and if their budget fits the goals and needs of the service.

Given the wide range in vehicle types, levels of service parameters, and geographical considerations in planning DRT, it may be advantageous for a municipality to consider a two-stage procurement process. In stage one, planning services are contracted to determine service area characteristics, operational performance, and cost and ridership estimations. In stage two, procurement of the service can happen using the valuable information gleaned in the planning process. This allows for the separation of the planning and implementation process that is generally missing in contracted DRT service in Canada.

3.4 Operations

3.4.1 Training and Adjustment

Training drivers to use the new technology is relatively straightforward. A tablet is typically provided to the driver who is able to view their trip itinerary and passenger requests, along with turn-by-turn navigation information. Agencies reported minimal issues with training drivers on the new technology.

The main adjustment with operators was getting them to trust the system, especially in areas with existing service. Drivers were concerned that regular passengers would be missed, or that the routing provided by the software was inefficient, leading them to develop their own routes instead of following the software's lead. This can be mitigated with education and training; the applications will often allow a comparison of an operator's potential trip with the suggested one, and in some cases it is possible to demonstrate how much more efficient the software is. A message of focusing on customer service and safe driving may encourage drivers to embrace the benefits of the software.

3.4.2 Operating During a Pandemic

As this research was conducted, Canada was in the middle of an economic shutdown as part of a response to public health concerns around the Covid-19 pandemic. A the time of writing, transit agencies have experienced upwards of 80% ridership drop, and many agencies have offered their service for free during the pandemic while continuing to provide a similar level of service to that before the pandemic, despite facing massive shortfalls.

Nevertheless, it is clear from the remaining levels of ridership that transit is a vital and important service for many people. With this in mind, agencies were asked about their response to the pandemic, in particular understanding how DRT service has been affected. This section provides some insight on this topic from those interviews.

The advantage of modern DRT systems is that they are both flexible to demand, and are able to dynamically adjust the capacity of vehicles. This has allowed agencies to adapt more cost-effectively to the decrease in demand, and remove a lot of the uncertainty surrounding crowding and capacity enforcement from the day-to-day operations. By adjusting the vehicle capacities, passengers have certainty that they will have physically distanced room on the bus when it arrives, and drivers will not have to enforce physical distancing by refusing pickups.

A few agencies used the pandemic as an opportunity to test the flexibility of the service, both in scalability and adaptability. Belleville, which operated evening DRT service before the pandemic, made the decision to transition to exclusively offer DRT service for several months during the pandemic. As they were using existing full-size buses as part of their service, transitioning involved minimal infrastructure costs and driver training. Okotoks reported utilizing the extra vehicle hours made available by lower demand to provide a grocery delivery service, minimizing the increase in operating costs. Agencies with smaller vehicles may have a harder time providing the appropriate level of physical distancing, even after limiting capacity through the booking process.

3.4.3 Cancellations and Misuse of Service

There are some novel ways in which the introduction of digital technology provision can lead to some abuse of the service. These revolve around trip cancellations and sharing of account-based fares such as monthly passes.

Trip cancellations are a regular aspect of the service, and should be expected. Part of the appeal of modern DRT service is the ability to allow for the spontaneity of trip making, and with that spontaneity comes the ability to cancel trips with short notice as well. This flexibility can become an issue when individuals use the flexibility of the service to book multiple trips with no intention of using them. Not only is extra vehicle capacity is being reserved by individuals that will not use it, other trips may be denied to legitimate users to avoid extending in-vehicle time beyond a maximum threshold. In other words, unused trips can cause the system to plan for "ghost users", denying trips to legitimate ones. This behaviour has been observed by multiple transit agencies. Usually, an individual books multiple time slots throughout a period of departure (e.g. every 15 minutes for 2 hours), and then cancels all but one once they have made their decision.

In most cases, users must register with an e-mail to access the service, and this gives the agency a method by which to educate users on the etiquette of booking trips, and in worse cases suspend users' access to the service for a time period. Most agencies have not resorted to this extreme measure, reporting that in the vast majority of cases education has sufficed to rectify misbehaviour.

Another way in which the service can be misused is through "trip piggybacking". In this case, the system has denied a user a trip for a given time window (an undesirable result for the agency but still a reality in some cases). That user may know of a friend or family member that was able to book a trip, and they meet the bus with their friend at a given stop, requesting a trip as they board instead of booking in advance. If the trips are not to the same destination, this can add extra in-vehicle travel time for other passengers, resulting in a lower quality of service. If there are capacity restrictions on the vehicle (such as physical distancing guidelines during a pandemic) this can create a conflict between the driver and passengers.

Finally, there is a possibility for users to share passes that allow unlimited rides outside of a single household. By sharing account and login information, it is possible for two individuals on opposite sides of the service area to use the service almost simultaneously, unless checks are put in place by the technology provider. This potential for account sharing can cause some decrease in fare revenues. However, agencies did not report this issue as a major problem, only a consideration. In Okotoks, Alberta, this influenced the municipality's decision to offer single-fare rides at a bulk discount in lieu of monthly passes.

3.5 Evaluating Performance

Performance evaluation included the collection of a number of different measures by agencies, though the quality and detail of these measures varied depending on the municipality's level of interest in evaluating different aspects of the service. These measures fall into one of three categories: inputs, outputs, and outcomes.[11] Inputs, while typically easy to measure, are generally poor ways to quantify the quality or success of a service. Outputs are a better but imperfect substitute for what agencies should ultimately be evaluating: outcomes. Figure 3.1 summarizes common measures for DRT service in each of these three categories.

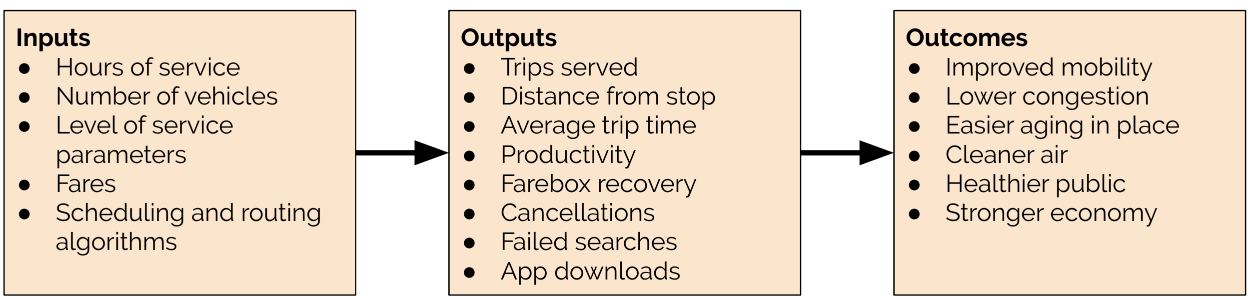

Figure 3.1: Inputs, Outputs, and Outcomes in DRT service.

Many of the technology platforms used by recent DRT pilots include a number of service parameters that can be set by the operator. Along with service area boundaries and stop locations, operators can set maximum in-vehicle trip times, trip scheduling windows, and vehicle capacities, all of which affect the level of service that can be offered. Setting these inputs is typically done with the help and advice of the technology provider.

These technology platforms also allow operators to collect, download, and analyze detailed information on the operations of the service. This includes various performance statistics such as average wait and trip time, productivity (passengers/vehicle revenue hour), or cost recovery ratios. These outputs can be analyzed on an extremely granular geospatial and temporal level, allowing planners to incorporate these outputs into future service adjustments.

Agencies can circle back to their original goals (see Section 2.2) to determine the outcomes that they would like to measure. These outcomes are often more difficult to ascertain and may require multiple data collection approaches (and the combination of outputs) to properly quantify. Nevertheless, outcomes speak to the motivations in the first place and are and essential part of evaluation.

Agencies are typically very familiar with inputs. Many agencies interviewed spoke first about their service in terms of vehicle hours, available budget, and service parameters. Often, the quantity of service is set by agencies as a result of their available budgets, while the available demand is determined by the characteristics and size of the pilot area. These two constraints lead to a fixed level of service that is possible under these configurations, which can ultimately determine whether the service meets its goals.

Ideally, the setting of service goals should include some measurable outcomes, and some moderate goals for the service. These goals must take into account the inherent aspects of pilot service (see Section 2.4) and serve more as a way for the municipality to understand and adjust their service than as a benchmark for success. Long-term transit project evaluation can be extremely difficult for these reasons.

3.6 Final Thoughts

While the premise of demand-responsive transit has existed for many years, the potential for the service has been greatly improved by the possibilities of automation and connected devices. These new approaches to routing, scheduling, and personalization of service have broadened the circumstances under which DRT service may be feasible.

These improvements have enabled transit service where it was otherwise not feasible or cost-prohibitive, including in smaller towns and cities. The growing interest in DRT in these areas in Canada over the past few years has demonstrated that the potential for DRT to bridge an important gap in transit ridership is growing.

It is important for municipalities to understand the fundamentals of this change, and consider DRT service carefully before deciding whether it is an appropriate solution for a given areas. It is both important to understand that DRT is not a one-size-fits-all solution, and that technology will not solve the basic fundamental aspects of geometry in cities and towns. Instead, DRT is becoming increasingly adept at providing adequate service coverage and managing demand in a more fluid way.

More research is needed on details of this change. We need to better understand the limitations of the technology in an operational context, and develop guidelines and standards for determining service areas, fleet size, and other service parameters.

As the plethora of pilot projects reach the end of their initial phases, it is crucial to carefully evaluate the service based on their initial goals, and to develop methods to evaluate the service in a fair and consistent manner. Just as one DRT service is unique from another, so too must the evaluation of different services vary.

Even during the short study period encompassed by this report, and even during a pandemic which has greatly affected transit ridership, DRT services are continuing to be announced and renewed. DRT will remain an integral part of the toolbox of services available to transit agencies. It is important that we continue to understand the service better and share knowledge across municipalities as part of a continual process of improvement.

Notes

[1]Town of Cochrane, "Transit Task Force Local Transit Service Recommendation to Town Council," Cochrane, AB, Tech. Rep., 2018; Volinski, "TCRP Synthesis 141: Microtransit or General Public Demand Response Transit Services: State of the Practice."

[2]B. Mehran, Y. Yang, and S. Mishra, "Analytical models for comparing operational costs of regular bus and semi-flexible transit services," *Public Transport*, vol. 12, no. 1, pp. 147–169, 2020.

[3]C. F. Daganzo, "An approximate analytic model of many-to-many demand responsive transportation systems," *Transportation Research*, vol. 12, no. 5, pp. 325–333, 1978.

[4]One transit agency in the United States even went so far as to suggest that agencies were "making it up as they go", a statement that applies also to a Canadian context (Volinski, "TCRP Synthesis 141: Microtransit or General Public Demand Response Transit Services: State of the Practice," p. 20).

[5]One exception to this contiguous shape rule was on Bowen Island, where vehicles were only able to access very minimal portion of the road network, and due to technology limitations areas had to be very tightly drawn around the roadways to avoid bookings in unreachable areas.

[6]Ibid.

[7]E. E. Osuna and G. F. Newell, "Control strategies for an idealized public transportation system," *Transportation Science*, vol. 6, no. 1, pp. 52–72, 1972.

[8]Many agencies offered free service temporarily as part of their roll-out process. Edmonton Transit indicated that they will not be charging a fare for their DRT service, assuming that the majority of trips will transfer to their fixed route network and be charged a fare there. This was done in part to avoid potential issues with third-party fare collection as part of their fully contracted procurement model.

[9]TransLink and Metrolinx both charge distance-based fares on their rail system, and Edmonton is considering distance-based fare policies as part of their SmartFare implementation.

[10]Bowen Island Municipality, "Transportation Advisory Committee Meeting Revised Agenda July 24 2018," Bowen Island, Canada, Tech. Rep., 2018.

[11]P. Schryvers, *Bad Data: Why We Measure the Wrong Things and Often Miss the Metrics That Matter*.

Prometheus Books, 2020, Schryvers provides a comprehensive discussion on the trials and tribulations of using inappropriate metrics to measure performance.

Glossary and Acronyms

DRT **Demand-responsive transit**. A general term for generally accessible transit that operates in response to calls or requests from riders. The level of sharing, automation, and directness of service can vary from service to service. Vehicles do not operate on a fixed route or fixed schedule and typically pick up several passengers at different locations before taking them to their respective destinations. 3–22, 24–34

first-mile/last-mile Transit service designed with the aim of providing connecting service to passengers between a larger demand transit node (such as a rail station) and their ultimate origin or destination. 13, 17, 18, 22, 26

microtransit Modern, small-scale demand-responsive transit which emphasizes personalized and direct service, with less sharing. Often referred to as "ride sharing". Typically uses smaller vehicles and capitalizes on widespread mobile GPS and internet connectivity. 6

on-demand transit Demand-responsive transit that focuses more on sharing and productivity than microtransit or ride-sharing services. 6, *see*

ride hailing A transportation service such as taxis or traditional Uber, Lyft, and other transportation network companies. This service is characterized by having single origin-destination trips and door-to-door service. It is not counted as a transit service in this report, even in cases where it is subsidized by government. 4–6

TNC **Transportation network company.** An organization that pairs passengers via websites and mobile apps with drivers who provide on-demand services. Transportation network companies are examples of the sharing economy and shared mobility. 3, 4, 20

APPENDIX A

Survey

A.1 Initial Email to Primary Contact

Dear `primary_contact`,

I am a Postdoctoral Fellow at the University of Toronto Transportation Research Institute (UTTRI), working on a research project sponsored jointly by the Ontario Society of Professional Engineers (OSPE) and MITACS. The project aims to synthesize the state of practice of flexible or demand-responsive transit (DRT) systems in Canada and help future DRT projects learn from previous experience in this emerging and exciting field.

I would like to invite you and your organization to participate in an interview-based survey about your experience with your DRT project.

The interview would involve yourself, a colleague, or a small group of individuals from your organization you feel would best be able to provide information on the planning, implementation, operation, and evaluation of DRT service.

The interview will take at most one hour to complete. Before the interview, some assembly of documents and data may be required to provide the best flow of information.

If your organization is willing to take part, please provide me with a list of individuals and email addresses whom you feel would be best suited to participate in the interview process (include yourself if applicable). I will reach out to these participants with an email outlining the process in more detail and obtain informed consent for their participation.

If you have any questions or concerns about the process, I would be more than happy to discuss these with you. Thank you for your time, and I look forward to hearing from you.

Willem Klumpenhouwer, PhD
Postdoctoral Fellow
University of Toronto Transportation Research Institute
Department of Civil and Mineral Engineering | University of Toronto

A.2 Informed Consent Email to Participants

Note: After establishing initial contact with the organization through the primary contact as detailed above, this email will be sent to each person participating in the survey process at a given organization to ensure informed consent is obtained individually.

Dear `particpant`,

I am a Postdoctoral Fellow at the University of Toronto Transportation Research Institute (UTTRI), working on a research project sponsored jointly by the Ontario Society of Professional Engineers (OSPE) and MITACS. The project aims to synthesize the state of practice of flexible or demand-responsive transit (DRT) systems in Canada.

You are invited to participate in an interview-based survey about your experience and work with DRT systems in Canada. Your responses will help to form a synthesis of the current state of practice of DRT in Canada and ultimately develop best-practice guidelines for future DRT systems.

The interview will be conducted via teleconference and will include either yourself or multiple people from your organization as part of a group interview process. The interview is designed to be completed within on hour.

Participation is voluntary, and you may refuse to participate or withdraw at any time before, during, or up to one week after the interview is conducted. You may decline to answer specific questions or participate in any part of the procedure without negative consequences and without affecting responses to other parts of the survey. You are able to withdraw any or all of your responses or your participation up to a week after the interview is conducted.

The interview will be recorded to ensure that responses are captured accurately. Individual responses and the recorded interview will be kept confidential and destroyed upon completion of the project. The final report, which will be made publicly available, will contain a summary of synthesized information and best practices and will not contain information that identifies a specific individual or position. You or your organization will be provided with a copy of the final report upon completion of the project.

If you agree to participate, you will be provided with a summary of the information that will be discussed in the interview in advance. Based on this summary, I ask that you assemble any data or documentation (technical reports, council presentations, business cases) you can provide and bring them with you to the interview. This research has been reviewed and approved by the Human Ethics Protocol at the University of Toronto. If you would like to know more about my research, please contact me at willem.klumpenhouwer@utoronto.ca. If you have any concerns, you are also free to contact the University of Toronto Ethics Review office at 416-946-3273 or ethics.review@utoronto.ca.

Willem Klumpenhouwer, PhD
Postdoctoral Fellow
University of Toronto Transportation Research Institute
Department of Civil and Mineral Engineering | University of Toronto

A.3 Agency Interview Questions

Note: The survey is written as if the interview is conducted with one participant. Language and responses may be adapted for multiple individuals. Some prompts are suggested to aid in the information gathering process.

A.3.1 Introductions and Preamble

Hello, and thank you for agreeing to meet and participate in this study. My name is Willem Klumpenhouwer, I am a Postdoctoral Fellow at the University of Toronto's Transportation Research Institute and am working in partnership with Mitacs and the Ontario Society of Professional Engineers to learn about flexible or demand-responsive transit in Canada.

This is an interview-style survey. I am interested in having a conversation with you about `service_name` that `agency` has participated in. As we move through the questions, feel free to add information that you feel is relevant to the research project and the information that the question is discussing.

The interview is divided into five parts: Some basic information on the project, and a discussion of four phases that encompass transit projects of this nature: Planning, Implementation, Operations, and Evaluation. If `service_name` has not yet moved through all four of these phases, we may not need to discuss these questions; any information you can provide is valuable.

I will remind you that this survey is entirely voluntary – if at any point you wish to withdraw or decline to answer a question, you may do so without affecting the rest of the survey or without any negative consequences.

As discussed, the interview will be recorded. This is to ensure that I capture your responses accurately. The recordings and any personal information your provide will be kept confidential. Are we okay to proceed?

[Pause to answer any general questions about the survey. If approval is received to proceed, continue below. If not, thank them for their time, record the reason for withdrawal if possible.]

A.3.2 General Information

1. Please provide your name and organizational affiliation.
2. Please give a brief overview of the service.
3. Please provide the following information about the service (planned operating) or , where applicable:
   - 3.1. Operating dates
   - 3.2. Ridership estimates
   - 3.3. Approximate size and population of the service area
   - 3.4. Fleet size
   - 3.5. Service span

A.3.3 Planning

1. Why did your organization decide to implement a demand-responsive service?
2. What were the primary goals for introducing such a service?
3. What market analysis, if any, was undertaken as part of the planning and proposal process?

4. What technical analysis, if any, was undertaken as part of the planning, service design, and cost-benefit analysis process?
5. Did you draw on any case studies, reports, or studies on demand-responsive transit as part of your design process?
6. What public engagement, if any, was conducted as part of the planning process?
7. How did you decide what operational model to use?
8. Were any operational targets or standards set for the system as part of the planning phase?
9. Is there anything you would have done differently during the planning phase of the project?

A.3.4 Implementation

1. What was the process undertaken to secure funding for the service?
2. What portions of the project were done in-house and what used a vendor?
3. What advice would you have for future agencies regarding the structure of your relationship with the vendor?
4. Did you encounter any regulatory challenges or complications as the program was implemented, either internally or externally?
5. Flexible transit operations are quite different than conventional transit operations, and new for most agencies. What kind of training and preparation was needed for staff to operate or monitor the service to ensure success?
6. What were some challenges and successes when rolling out the program from planning to operation? What challenges did you encounter?
7. Is there anything you would have done differently during the implementation phase of the project?

A.3.5 Operations

1. How has the adoption of new technology been received?

2. What accommodations have been made for persons with disabilities or those who do not have access to specific technology (smartphone)?
3. Have you had to handle any incidents outside of normal operational issues?

A.3.6 Evaluation

1. What metrics were established to measure and evaluate service performance? How were they measured?
2. What challenges and opportunities were faced with developing, measuring, and collecting data for these metrics?
3. What, if anything, would you like to collect and measure that you are currently unable to?
4. What is the nature of the feedback you have received from the public regarding demand-responsive transit services?
5. Do you have any final thoughts or important items we have not covered?

A.4 Vendor Questions

1. What is your name, title, and organizational affiliation?
2. What is the nature of your organization's involvement in the project?
3. How many different demand-responsive transit projects has your organization been involved in?
4. Are there any specific challenges you have faced with planning, developing, rolling out and operating demand-responsive transit service?
5. How do you evaluate service performance?
6. What type of data do you prefer to collect for evaluation purposes, and why?
7. Are there any regulatory improvements you would like to see to make demand-responsive transit project and contracts more successful in Canada?
8. Are there any lessons learned from your experience you would like to share with future demand-responsive transit services?

9. Is there anything else you would like to add?