Mobility-as-a-Service: A Technology and Data-Driven Solution to Reducing High Private Vehicle Dependency in Canadian Cities

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Summary

For over fifty years, cities around the world, especially in Canada, have been shaped by the private automobile. In recent years, we've begun to change our design practices, recognizing that designing for the car first, and people second can have negative impacts on human health, safety, the environment. Initially proposed in Finland, the concept of mobility-as-a-service, or MaaS, has offered cities a potential method of reducing private car ownership, therefore reducing traffic, and improving the climate impacts of our transportation system, among several more benefits. This report includes an in-depth literature review into pre-existing research on MaaS, with the knowledge gained being applied in a data-driven analysis to determine whether MaaS should be explored in Canadian cities.

Conceptually, MaaS refers a new model of organizing transportation for people, by prioritizing complete trips from A to B, utilizing technology to continuously optimize the network. Under MaaS, mobility options are packaged together in such a way that mobility needs can be met in a more complete, door-to-door way than currently available. This is achieved by prioritizing multimodal trips with more seamless connections and using a simple payment structure, all in an intuitive app. For example, if a user needed to travel to the inner city for work, a MaaS provider could be used to connect a rideshare vehicle with a subway ride, and finally to a bike from a shared bike service, getting the user to their destination. Additionally, the payment for the entire journey could be made in one transaction through the phone application that was used to plan the journey, or even with a monthly subscription.

Population density data, modal breakdowns, transit proximity, and access to alternative mobility options for Canada's largest cities were analyzed and compared to European cities that have already experimented with MaaS. Upon completing the analysis and comparisons, Canada seems to be a viable market for MaaS adoption, though the service would likely be centered more on transit and ride-sharing compared to their European counterparts.

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1 Introduction

1.1 Background

In the years following World War II, we've witnessed the rapid development of new cities and transformations of existing cities to accommodate the private automobile, which had only recently become available to the masses. With the original aim of providing residents with the freedom to move as they please, the influx of private vehicles in cities has led to heavy traffic congestion, thus reducing the ability for residents to travel freely, not to mention a significant environmental footprint. The rise of private vehicle ownership has shaped the ways in which we've designed our cities and managed our infrastructure. Figures such as Robert Moses, the American urban planner and politician known for his 'urban renewal' program, influenced North American cities to engage in urban sprawl and to prioritize automobiles when designing neighbourhoods, commercial districts, and transportation infrastructure. In recent years, many cities in Canada and elsewhere have strived to cater to people rather than cars by changing zoning practices and making significant investments in pedestrian friendly transportation infrastructure such as public transit, bike lanes, and new mobility options. These efforts are also being accelerated because of the targets many cities and countries have set to achieve carbon neutrality in the coming decades. The transportation sector has historically been responsible for a large portion of Canada's emissions, accounting for 24% of Canada's total emissions in 2020, making it the second largest contributor to our national carbon emissions (Environment and Climate Change Canada, 2022). Thus, reducing private vehicle ownership and encouraging Canadians to consider other means of transportation is crucial, and MaaS could be a viable way to do so.

Since it's inception at the ITS European Conference in Helsinki in 2014 (MaaS Alliance, 2017), mobility-as-a-service, has offered a novel, technology-based solution to make transportation of people more accessible, dependable, and multimodal. Conceptually, mobility-as-a-service, or MaaS, is a shift to thinking of transportation as a monthly expense, hence one's mobility will no longer be linked to the

assets they own such as their car. With MaaS, users will be able to use advanced algorithms through phone applications to plan and pay for multimodal door-to-door trips, effectively offering the same convenience as owning a vehicle, without the negative impacts that go along with high vehicle ownership rates. Given its multimodal nature, MaaS will meet users' mobility needs by combining modes in a seamless and simplified way with respect to payment, timing, etc.

1.2 Scope

The report will begin with an in-depth literature review to provide more context into the exact definition of MaaS along with several factors that must be considered when implementing the service. The knowledge gained will then be applied to a Canadian context, using a data-driven approach to determine if MaaS could be a viable option for Canadian Cities. Various datasets, such as population density, mode splits, etc., will be used to perform a comparative analysis between European cities that already have existing MaaS with Canada's three largest cities.

2 Literature Review

2.1 Focus of Review

This literature review will focus on reports, papers, and peer reviewed articles that attempt to properly define MaaS, establish the reasons why MaaS implementation should be more widespread, and assess its utility in improving mobility relative to the current transportation landscape in cities around the world. While the concept of mobility-as-a-service is less than 10 years old, its popularity has grown rapidly, and its reach has gone beyond simply transportation and urbanist circles. In recent years, the idea of building products and subscription-based services has become very popular, transforming the entertainment, software, and Transportation industries, among many others. With growing popularity, MaaS has also become a well researched field, with researchers and academics from around the world trying to better understand how the service could change existing transportation systems and people's mobility

behaviour. More specifically, researchers want to understand how people will adjust their travel behaviours in terms of mode choice, frequency of travel, distance of travel, as well as which demographics will stand to benefit. In more recent years, another growing focus has been on how the societal changes from the Covid-19 pandemic will play out with respect to MaaS deployments, and whether the shift to more remote and hybrid work environments would increase or reduce the likelihood of MaaS providing value to commuters.

2.2 Defining Mobility-as-a-Service

To begin to break down the questions described above, a proper definition of mobility-as-a-service must first be established and understood. The MaaS Alliance, a public-private partnership established to encourage creativity and cooperation to complete the groundwork for mobility-as-a-service, produced a white paper in 2017 (MaaS Alliance, 2017) that attempted to answer these initial questions. As described in the white paper, MaaS could be described as the natural evolution of the movement of people through cities. What was once dominated by privately owned cars has become much more multimodal and dynamic, largely catalyzed by the transition to more mobility services, such as ride-share, ride-hail, and car-share. However, mobility-as-a-service reaches further by integrating all these services together, utilizing the mobile phone as the "command center" for personal mobility. As described, MaaS operators will fill a gap between transportation operators and users, making door-to-door mobility simpler, and entirely integrated into one service, including payments. The figure below, from the white paper, describes the end-to-end role of the MaaS operator.

Figure 1: *Processes in a MaaS Offering (MaaS Alliance, 2017)*

A report produced by the United Nations Economic Commission for Europe (United Nations Economic Commission for Europe, 2020) provides a deeper dive into the specifics of MaaS with a primarily European context. The authors define 5 different levels of MaaS deployments, with respect to how the payment process works. In its most basic form, being level 1, MaaS can mean an application is used to

provide information to users about combining modes to complete trips, and no payment option is available. This level of MaaS already exist to a certain extent, with applications such as Google Maps, Citymapper, Moovit, etc., being offered in many cities around the world. On the highest payment level, implying full MaaS integration, users can pay monthly or annual subscriptions to MaaS providers to have unlimited access to the service, thus never having to pay for individual trips that can combine several modes. Compared to level 1, a level 5 deployment would undoubtedly place more risk on the MaaS provider as they would need to ensure their user revenue can recoup the cost of working with each mobility provider. There is ongoing debate as to whether the MaaS broker should be a private company driven by a business model, or a public agency who would act more as an operator. Figure 2 below displays the 5 payment levels of MaaS, as well as some benefits and risk levels for the broker—the party that users will interact with to plan and pay for their trips, and the mobility operator—the party that offers the mobility services offered to the public through the broker. It should be noted that the figure below is applicable to both the private and public MaaS models.

		BROKER		MOBILITY OPERATOR/PROVIDER	
		BENEFITS	RISKS	BENEFITS	RISKS
LEVEL 5 Subscription-based billing & Payment	• Mobility Packages • Subscriptions	• User Profile • Portfolio of risks	High	• Pre-sale of availability	Low
LEVEL 4 Account-based Billing & Payment	• Monthly invoicing	• User Profile • Crowdsourcing of mobility data	Medium	• Reduction in sales costs	Low
LEVEL 3 Pay-as-you-go	• Invoicing	• User Profile • Crowdsourcing of mobility data	Medium	• New sales outlet	None
LEVEL 2 Direct payment	• Booking • Direct Payment	• User Profile • Crowdsourcing of mobility data	Low	• New sales outlet	None
LEVEL 1 Information	• Schedules • Routing		Low		None

Figure 2: *Benefits and Risk Levels for the Broker and the Mobility Provider under payment option levels (United Nations Economic Commission for Europe, 2020)*

2.3 Establishing the Purpose Behind Mobility-as-a-Service

Understanding the general meaning of MaaS and its various levels of implementation, a study conducted by transportation, psychology, and business researchers from around the world (Tomaino, et al., 2020) evaluates the psychology that impact people's transportation choices and investigates how MaaS would play into that psychology. The authors describe the primary difference between MaaS, and traditional transportation options is what is referred to as "perceived control", or the ability for one to feel that they are in control of their transportation experience. One of the primary motivations behind driving and private vehicle ownership comes down to having a high level of perceived control when one can somewhat determine their own speed and route. Many argue that MaaS would reduce one's perceived control as they would need to relinquish control of their travel choices to an algorithm, and would have little say in the modes and routes they take. In doing so, passengers may also engage in "algorithm aversion"—modifying their route and mode choice due to a lack in confidence in the algorithm from prior delays, or simply a preference of certain modes or routes. On the other hand, traffic and public transit can both be unpredictable, minimizing the sense of perceived control for travelers, so having access to real-time updates, such as bus or subway locations, and more reliable connections between mobility options could boost the sense of perceived control for riders.

2.4 Factors that May Impact the Success of Implementation

MaaS is highly reliant on public transit agencies offering high quality transit that connects the places people like to go to. While other modes such as shared vehicles and bikes can certainly fill the gaps and complete the last mile of trips, MaaS would simply not be competitive to private vehicle ownership in terms of time and cost, without reliable transit. In a report published in 2020 by researchers from the University of Saskatchewan, the University of Toronto, and Eindhoven University in the Netherlands (Diab, Kasraian, Miller, & Shalaby, 2020), titled "The Rise and Fall of Transit Ridership Across Canada: Understanding the Determinants", an empirical, data-driven analysis was performed to understand the factors that have impacted transit ridership in recent years. Among many findings from the study, it was

observed that increased gasoline prices lead to an increase in transit ridership, which likely accounts for drivers who switch to transit. Another finding was that transit ridership is highly linked to the household types and business/recreation opportunities in the area. Therefore, municipalities that have zoning practices that encourage the construction or townhouses, rowhouses, etc., will see increased transit ridership. Another finding of interest is that rideshare services such as Uber and Lyft will increase transit ridership in large cities, though they will decrease transit ridership in smaller cities and communities. This finding suggests that rideshare services already serve as an extension of transit services, thus potentially validating the concept of MaaS providing value to residents of big cities.

To understand the current sentiment around public transit, it is also important to consider some long-term changes to transportation that have come from the Covid-19 pandemic. In a report by American researcher (Brough, Freedman, & Phillips, 1010), the transit ridership was analyzed throughout the Covid-19 pandemic and compared to pre-pandemic levels in King County, Washington (encompasses Seattle). Similarly to many other cities around the world, King County saw dramatically reduced transit ridership during the pandemic, though it was found that the decrease in ridership was less prevalent in less-educated and lower-income groups. For a deeper dive into the impacts of Covid-19 on MaaS specifically, an article written by an Australian researcher (Hensher, 2020) attempts to understand what steps must be taken to ensure the continued viability of MaaS in a post-Covid era. Most importantly, the author notes that public transit agencies and private mobility operators must put more emphasis on making those services cleaner and more hygienic. Additionally, the author suggests that in an age of remote work, since potential MaaS users may not be commuting as much, we should think of MaaS as a more multi-service package. For example, establishing partnerships between MaaS providers and retail services or delivery services, and potentially introducing points or rewards programs to MaaS to incentivise people to use the service.

With one of the main goals of MaaS being to reduce transportation related emissions, electric mobility options must play a significant role in future implementations. A highly technical Paper was produced by

researchers from the Norwegian University of Science and Technology that aimed to propose an architecture for the systems required for the collection, analytics, and sharing of mobility data in an electric mobility-as-a-service environment (Anthony Jr., Petersen, Ahlers, & Krogstie, 2020). For the purpose of this literature review, the technical specifics of the application programming interface, etc., are not relevant. However, the paper did show that an electric based MaaS ecosystem would require cities to massively increase the electrical vehicle charging infrastructure available. It should be noted that this study was conducted in Norway, where EV adoption and investment has been far greater than what has been done in Canada.

2.5 Assessing the Current State of Mobility-as-a-System

Researchers from Arup and MaRS discovery district collaborated to produce a white paper (Arup; MaRS Discovery District, 2018) to assess the state of mobility-as-a-service and to understand how it has evolved, with a specific emphasis on the Greater Toronto-Hamilton Area (GTHA). The study consists of an in-depth literary review, as well as interviews with several senior industry professionals from private sector companies and public sector organizations and transit agencies. The study identified several benefits to introducing MaaS including better door-to-door mobility without needing private vehicles, better service than owning a private car, and a better ecosystem for intelligent transportation system advances. The study also revealed several impacts of specific modes within a MaaS ecosystem. It was noted that car-sharing services are best at reducing car ownership and private car use, while ride-hailing produces more urban congestion and vehicle kilometers travelled than other modes. The research team also analyzed several MaaS deployments in the GTHA and observed some interesting results. With respect to suburban commuters, particularly in the City of Vaughan, it was found that they almost exclusively drive to Go stations as they are unaware of other options, and they even describe the drive to the go station as the worst part of their day due to the limited free parking availability at stations. Suburban commuters also reported to have difficulty seeing all their mode options in one centralized

place, and they were unable to problem-solve to find alternative routes to get to work when they experience issues with their chosen mode.

A study from Brazil was performed, that assessed the different MaaS availabilities in Sao Paolo, Brazil (Santos Rodrigues, et al., 2021). It should be noted that the MaaS applications available in Brazil have no integrating payment structure, thus they would be considered level 1 applications by the United Nations' definition. Focusing exclusively on those who use MaaS applications, which turned out to be 75% of the people surveyed, the study found that Google Maps was far more popular than other MaaS apps such as Moovit and Citymapper, though all three had many users in Sao Paulo. It was also found that the there was nearly a perfect split between genders for use of MaaS apps, and 60% of those users are aged 18-35, and these users were primarily workers trying to get to their offices using public transit with walking being the most common first and last mile mode. Another study conducted by a research team from across Europe and Israel (Islam Sarker, et al., 2019) found that users of MaaS style transit apps are not opposed to sharing information to improve the accuracy of the service for others, which has become an increasingly important aspect of MaaS apps. Of those surveyed, 30-40% are willing to share information on their travel times and experience to help others, while 50-60% believe that sharing user data would improve transit planning applications.

Perhaps the most significant implementation of MaaS technology yet can be seen from the Finnish company 'MaaS Global', as they have deployed their 'Whim' application in Helsinki in November 2017, before expanding to areas including, Antwerp (Belgium), Tokyo (Japan), Switzerland, Vienna (Austria), etc. (whim, 2022). The company effectively groups several mobility services into various packages at different price points, to suit the specific needs of users, and allows users to utilize their services either through a monthly subscription fee or a pay-as-you-go method. It should be noted that there was limited peer-reviewed research and articles available that have analyzed the Whim app, thus, this information was found on a presentation from the MaaS alliance website (MaaS Alliance, 2019). To facilitate this first MaaS deployment, ground-breaking policy changes were made in Finland, requiring mobility providers to

share their data with the public, making it more accessible to MaaS operators. Given the rapid expansion of the service to new cities and it's high rating in the Apple App Store, it is assumed that the deployment has been successful though, as mentioned, limited peer-reviewed studies can be found to validate that claim.

3 Application

3.1 Problem Statement

With a thorough understanding of the concept of mobility-as-a-service and the reasoning behind its existence, the application portion of this report will utilize a data-driven approach to evaluate the feasibility of MaaS implementation in Canadian Cities. As proposed through the various white papers analyzed in the literature review, MaaS can be implemented both for urban and suburban areas as well as for more rural areas. However, for simplicity's sake, this analysis will focus on the three largest cities in Canada by population density, being Toronto, Montreal, and Vancouver (Statistics Canada, 2020). By considering the existing mobility offerings in these cities and analyzing transit ridership and proximity data, relative to cities with existing MaaS deployments, the viability of a MaaS deployment in these three Canadian cities will be evaluated.

3.2 Analysis

3.2.1 Population Densities

When considering the cities that have already worked towards implementing MaaS, such as Helsinki, Antwerp, Tokyo, Vienna, Sao Paulo, etc., several shared characteristics can be identified. For instance, they are all large cities with high population densities, and they tend to have high-quality public transit systems. And perhaps most importantly, they all experience significant traffic congestion, hence why they

have pushed the MaaS model as a solution to reducing car traffic and private vehicle ownership. Figure 3 below displays the population densities of Canada's three largest and densest metropolitan areas (in blue) relative to some of the cities with current MaaS operations (in orange). It should be noted that Helsinki was included in the comparison as it was the first city to implement true MaaS, and the other cities considered were chosen at random from the list of Cities that "Whim" has expanded to. The data for the Canadian cities was retrieved from the Statistics Canada transit proximity dataset from 2020 (Statistics Canada, 2020), while the other cities' data was retrieved from the 'World Population Review' website (World Population Review, 2022).

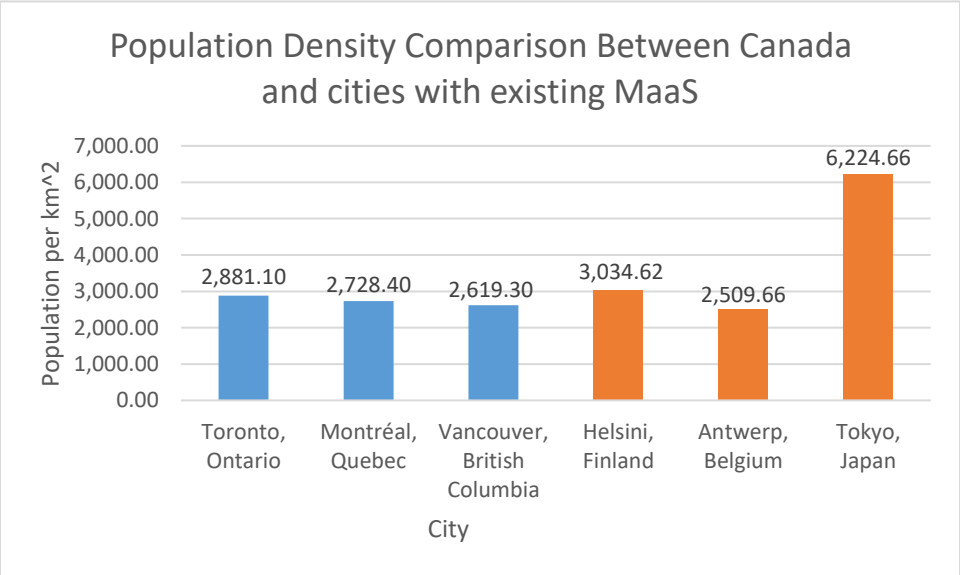

Figure 3: *Population densities of Canadian Cities relative to cities with existing MaaS operations*

Though Tokyo has a significantly higher population density compared to the other cities, the population densities of Toronto, Montreal, and Vancouver are all comparable to that seen in Helsinki and Antwerp. Thus, moving forward, this analysis will only compare the three Canadian cities to Helsinki and Antwerp. It should also be noted that all three Canadian Cities have metropolitan populations in the range of 2.5 million to 6 million (Statistics Canada, 2016), the European cities both have metropolitan populations closer to 1.5 million, and Tokyo is the World's most populous city with over 37 million inhabitants (World Population Review, 2022).

3.2.2 Modal Split

Another key factor that must be considered when implementing MaaS is the current modal split in the city. Though there isn't necessarily an exact modal split that will yield the most successful MaaS deployment, cities that have high transit ridership for example, should ensure that their transit infrastructure is used by MaaS riders, when possible, while cities with high active transportation use could orient the service to favour walking and cycling. Figure 3 below offers a comparison between the three Canadian Cities to Helsinki and Antwerp in terms of modal split for work commutes. It should be noted that the data for the Canadian cities, derived from Statistics Canada's 2016 census (Statistics Canada, 2016), only refers to the cities rather than their metropolitan areas. It is likely that the data would skew heavily towards driving in all three cities if the entire metropolitan areas were included. The data for Helsinki was retrieved from a City of Helsinki study from 2021 (City of Helsinki, 2021), and the data for Antwerp was retrieved from a City of Antwerp document from 2018 (City of Antwerp, 2018).

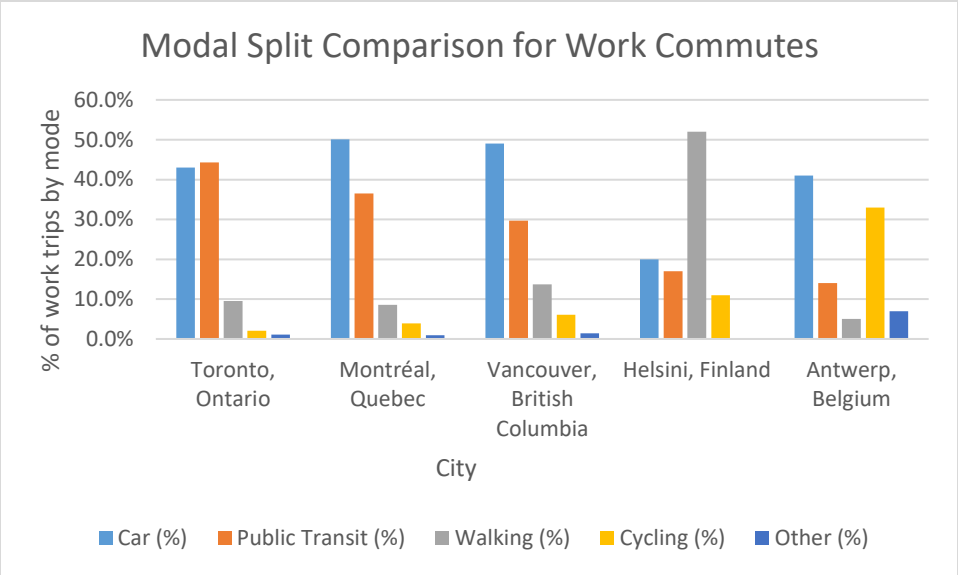

Figure 4: *Modal splits of Canadian cities relative to European cities with existing MaaS operations*

As seen in the data shown above, Canadian cities tend to favour car trips compared to their European counterparts, which seems consistent with the car-dominant culture seen in North America. However, Antwerp has a similar share of drivers to Toronto, the Canadian city with the lowest share of drivers. It

can also be seen that Canadians are more reliant on public transit than both Helsinki and Antwerp, which could potentially be beneficial when implementing MaaS. Perhaps the starkest comparison that can be seen is how popular active transportation modes such as walking, and biking are in the European cities, relative to Canadian cities. Perhaps it can be traced to cultural differences or simply better walkability being offered in European cities, but regardless, this inconsistency would make a Canadian MaaS deployment look very different from one found in Helsinki or Antwerp. With cycling being incredibly popular in Antwerp for example, perhaps it is more of a priority to integrate bike sharing service into the MaaS package, while Canadian MaaS providers should prioritize having strong partnerships with transit authorities and rideshare companies. As shown in figure 5 below, the three Canadian cities being analyzed all have transit connectivity within 500m of over 90% of residents. The data used to populate the figure was taken from the Statistics Canada transit proximity dataset (Statistics Canada, 2020).While many Canadians already rely on transit, this suggests that a far greater proportion of trips could be completed with public transit. It should be noted however that far fewer residents are within 500m of rapid transit. Specific data for proximity to rapid transit is not available.

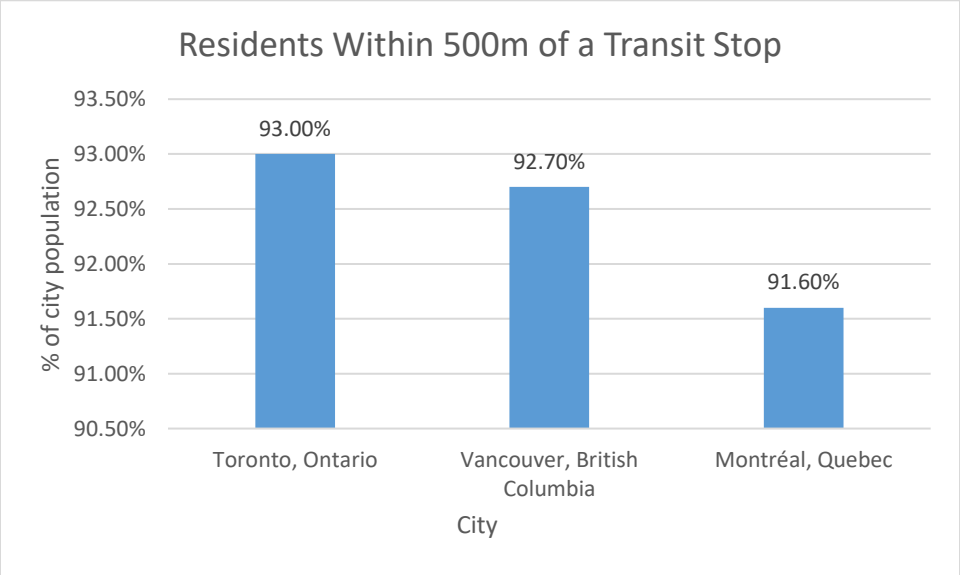

Figure 5: *Percentage of residents within 500m of a transit stop*

3.2.3 New Mobility

Additionally, alternative mobility options must be considered to ensure that the Canadian cities being analyzed could accommodate the first and last miles between transit rides to provide utility for MaaS. Canada has welcomed ride-hailing services such as Uber for nearly 10 years, with the service being available in all three cities. There are additional ride-hailing providers that are available in some Canadian Cities though not all, such as Lyft in Toronto and Montreal, 'TappCar' in Edmonton, etc. Canada has also slowly been exploring the ride-sharing and microtransit, space, with start-ups such as 'RideCo' in Waterloo and Spare Labs in Vancouver, not to mention the ride-hailing companies such as Uber's plans to enter the rideshare market in Canada (Mobility Innovators, 2022). Currently, most of these services are limited to smaller cities as they can provide better mobility service than traditional transit when the demand is low. However, it is likely that they will expand to larger cities in the coming years, given that American microtransit company 'Via' has experienced success in many large cities. In terms of micromobility, all three cities currently offer bikeshare services—Toronto Bike Share in Toronto, BIXI in Montreal, and Mobi in Vancouver—and all three offer both standard and electric bikes, though electric bike availability is low across the board. Additionally, shared electric scooters have grown in popularity across Canada with many cities, including Waterloo, conducting pilots. Toronto and Montreal, however, have both banned shared electric scooters due to safety concerns. However, the continued interest in shared scooters in smaller cities across Canada could theoretically boost public perception of the technology, prompting the large cities to reconsider bans that have been made. Considering all the alternative modes of transportation available in these cities, it is likely that a MaaS provider would be able to package various ride-share, ride-hail, and micromobility services together with public transit to offer a valuable service to users. And as companies around the world continue to develop autonomous vehicle technologies, it is likely that the cost of ride-share and ride-hail services could decrease, making trips combining them with other modes more financially attractive options for mobility than private vehicle ownership and use.

4 Conclusions

From the analysis conducted as part of the application portion of this report, certain conclusions can be drawn. Given the relatively comparable population densities between Canadas three largest cities, Toronto, Montreal, and Vancouver, with Helsinki and Antwerp, it is unlikely that a MaaS deployment in one of the Canadian cities would struggle to find enough users. Additionally, given the high share of drivers and Transit riders in Canada relative to their European counterparts, a Canadian MaaS deployment would likely prioritize combining public transit with ride-sharing services to make use of the modes that already experience high use. And considering the findings from the Arup and MaRS white paper that most transit commuters drive to transit stations in the GTA, there would likely be a large market of people looking for better ways to complete the first and last miles of their transit trips. While walking and bike-share/micromobility should still be included in MaaS offerings in Canada, the service may simply prioritize offering users the modes that they are more used to, at least at the beginning. And lastly, given Canada's relatively large adoption of new mobility options such as ride-share, micromobility, and the continued interest in the growing area, Canada is on track to have the mobility offerings needed to provide excellent door-to-door mobility without needing a private car, for most trips.

5 Recommendations

To deploy MaaS technology in Canada, several actions must first be taken. Mobility-as-a-service will dramatically change the mobility landscape, and the existing public policy models for public transit, ride-sharing, micromobility, etc., will likely need to be changed to require more data to be shared between companies and the public. Further research into the policy changes made in Finland should be conducted given that a MaaS deployment has already been successful there.

Canada must also decide for itself whether mobility-as-a-service should be operated by a public organization, i.e. an extension of the public transit agency, or if it should be left to the private market.

Both options have various benefits and drawbacks, and the overall service would likely be very different depending on which option is chosen. If the private market option is chosen, perhaps there would be multiple MaaS players offering different products that will suit different target markets, while a public option could be more affordable, and cities would be able to use the service as a means to achieve emissions reduction goals by prioritizing transit and EV trips for example.

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