Opportunities and Challenges of Mobility-as-a-Service (MaaS) for Rural-Metro Communities: Case Study of the Rio Grande Valley, TX

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16. Abstract: Mobility-as-a-Service (MaaS) emerges as a potential solution to several contemporary transportation challenges. This technology aims to offer mobility options on a single application for which users can purchase the service rather than the means of transportation, integrating several mobility options, payment, and real-time information into a single application that is easily accessible. The Rio Grande Valley is a small urban and rural area challenged by automobile dependent urban form, traffic congestion from an exploding population, and limited mobility options for low-income and vulnerable people.. Few studies have explored the impact MaaS could have in a U.S. context, and even fewer have studied in small urban and rural contexts in the United States. This report demonstrates that while respondents are supportive of transit, their distances are conducive to multimodal use, and that they have easy access to smartphones and internet, that the car is almost exclusively used for travel trips. Finally, a MaaS offering in the Rio Grande Valley would face several, likely, insurmountable challenges, but that efforts should be undertaken to improve transportation options and experiences in the Rio Grande Valley.		
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Abstract

Mobility-as-a-Service (MaaS) emerges as a potential solution to several contemporary transportation challenges, including declining public transportation budgets, demand for more sustainable mobility options, and community needs for expanded mobility access. This novel technology aims to offer several mobility options on a single application for which users can purchase the service rather than the means of transportation. MaaS does this by integrating several mobility options, payment, and real-time information into a single application that is easily accessible. The Rio Grande Valley is a small urban and rural area challenged by automobile dependent urban form, traffic congestion from an exploding population, and limited mobility options for low-income and vulnerable people. MaaS might help relieve these issues. Current studies have focused on the MaaS system broadly and the challenges a potential system could face. These studies have overwhelmingly focused on a European context. Few studies have explored the impact MaaS could have in a U.S. context, and even fewer have studied in small urban and rural contexts in the United States. This professional report demonstrates that while respondents are supportive of transit, their distances are conducive to multimodal use, and that they have easy access to smartphones and internet, that the car is almost exclusively used for travel trips. Respondents clarified that they are largely unaware of transit or how to use it in the Rio Grande Valley. This report shows respondents' concerns with weather and perceived loss of control as barriers to using other modes of transportation. Finally, a MaaS offering in the Rio Grande Valley would face several, likely, insurmountable challenges, but that efforts should be undertaken to improve transportation options and experiences in the Rio Grande Valley.

Chapter 1. Chapter 1: Introduction

In recent years, the Mobility-as-a-Service (MaaS) concept has gained traction as a potential solution to the complex mobility challenges communities worldwide face. This emerging technology envisions a single application integrating various transportation modes and payment systems, allowing users a seamless and efficient mobility experience. With an overdependence on cars for mobility, dwindling public transportation budgets, and a growing demand for sustainable mobility, Mobility-as-a-Service emerges as a potential solution. MaaS can offer users savings by not having to purchase a vehicle but, instead, the ability to use one as they need it. Potential purchasing options would likely be a pay-as-you-go system that eventually moves into a subscription-based service. This service could also assist in expanding public transit ridership as more people have easy access to the system. Since the service will not require users to own a vehicle, it has the potential to reduce carbon emissions from the manufacturing of cars and cut unnecessary car trips as people can use other, more sustainable modes of transportation.

Currently, the Rio Grande Valley in Texas faces several mobility challenges, including but not limited to an overdependence on car ownership, traffic congestion from an exploding population, and limited mobility options for low-income and vulnerable people. Mobility-as-a-Service could potentially alleviate these issues. Current studies have focused on the MaaS system broadly and the challenges a potential system could face. These studies have overwhelmingly been in a European context, so few studies have shown the impact MaaS could have in a U.S. context, and even fewer in a small urban and rural context here in the United States.

This professional report seeks to determine if MaaS could be a solution to the mobility issues that residents in the Rio Grande Valley face. This report accomplishes this by first reviewing the current literature regarding MaaS. Second, this report discusses the pilot programs that have been attempted in the past. Next, this report discusses the literature regarding mobility issues. Fourth, this report lays out the context of the Rio Grande Valley. Then, the background and methodology of the interviews are explained. An explanation of snowball sampling is discussed, specifically detailing the limitations, but overall usefulness of the interview data. An analysis of the responses is discussed, and finally, a discussion of how MaaS can or cannot play a role in solving the mobility issues reported. This report seeks to inform all interested in mobility challenges and the concept of Mobility-as-a-Service about the role MaaS may or may not play in the near future.

Chapter 2. Review of MaaS

2.1. Introduction

With declining public transportation budgets, a demand for more sustainable mobility options, and communities seeking to expand mobility access, Mobility-as-aService (MaaS) emerges as a potential solution. While the idea of a travel broker is not new, the concept of MaaS is fairly new. Research regarding MaaS has exploded in recent years with new focuses emerging. This literature review aims to summarize the key findings from over 100 studies and expand the current state of knowledge regarding this concept. This research aims to provide a comprehensive and current understanding of MaaS and how it can transform the transportation industry.

2.1.1. Defining MaaS

Mobility-as-a-Service (MaaS) is a "relatively new concept" aiming to change transportation access dramatically (Barreto et al., 2018). Called by some the "Netflix of transportation," MaaS seeks to offer a combination of different mobility services onto a single platform (Smith et al., 2018). Currently, there is no agreed-upon formal definition for MaaS (Lopez-Carreiro et al., 2020). One of the first attempts to define MaaS came from Mr. Sampo Hietanen, who is considered the "Father of MaaS" after starting the first MaaS system called Whim in Finland (Audouin and Finger, 2018). He defines MaaS as a "mobility distribution model in which a customer's major transportation needs are met over one interface and are offered by a service provider" (Ison and Sagaris, 2016). However, Kamargianni offers the most widely accepted definition, "The concept of Mobility as a Service (MaaS) aims to break the determining role of car ownership. Instead, travelers are presented with various travel options tailored to their needs, either as a subscription package or in a pay-per-use approach" (Becker et al., 2020; Kamargianni et al., 2016; Jittrapirom et al., 2017; Mulley, 2017). The critical part is "to see transport or mobility not as a physical asset to purchase (e.g., a car) but as a single service available on demand and incorporating all transport services from cars to buses to rail and on-demand services"(Mulley et al., 2018). Another critical part is to have a single service from which the customer purchases and gets charged (Mulley et al., 2018; Maas, 2020). While some may see this as revolutionizing the transportation industry, others see MaaS as an "evolutionary continuation in terms of transport integration." (Lyons et al., 2019). Lyons writes, "Emerging from an era of unimodal travel information systems becoming

multimodal and then integrated multimodal information services, MaaS is now about adding seamless booking, payment, and ticketing to the integration offer." (Lyons et al., 2019). Considering these definitions, this paper will show why MaaS is an essential and still under-researched topic in the transportation industry.

2.1.2. The Importance of MaaS

Mobility-as-a-service has emerged as a potential solution to helping move people towards more sustainable mobility. Coupled with congestion and pollution problems, policymakers are open to new ideas (Matyas, 2020). Storme states that MaaS can significantly help in three ways: reducing traffic volumes, emissions, and congestion in urban areas and increasing efficiency in rural areas (Storme et al., 2020). Given the car's several negative externalities, there is also growing consumer demand for alternative mobility solutions. "People, particularly in the more densely populated city regions, are becoming more willing to abandon car ownership." (Wilson and Mason, 2020). Also, in densely populated areas, 'there has been a reduction in license uptake amongst young people," suggesting attitudes towards car ownership are changing (Wilson and Mason, 2020). While MaaS may not replace car ownership, there are high expectations from city leadership that MaaS "may lead people to refrain from buying a (second) car." (Caiati et al., 2020). In fact, "Research consultancy firms state that MaaS will replace billions of private car journeys per year." (Maynard, 2018; Storme et al., 2020). This potentially huge impact has led companies such as Mitsubishi, BP, and Toyota to "make significant investments in MaaS in the expectation that it will be widely adopted." By some estimates, the market could be worth hundreds of billions of dollars in the coming decade (Tomaino et al., 2020; Wagner, 2019).

Given the high potential of MaaS to help solve these issues, researchers have begun to take an interest in MaaS. Academic interest in MaaS has been rapidly increasing (Maas, 2022). Figure 2-1 shows the number of publications about MaaS in recent years. This heightened research interest is supplemented by the increasing number of pilot programs conducted in Europe, Australia, Taiwan, and other countries worldwide (Polydoropoulou et al., 2020; Arias-Molinares and García-Palomares, 2020; Chang et al., 2019; Hensher et al., 2021).

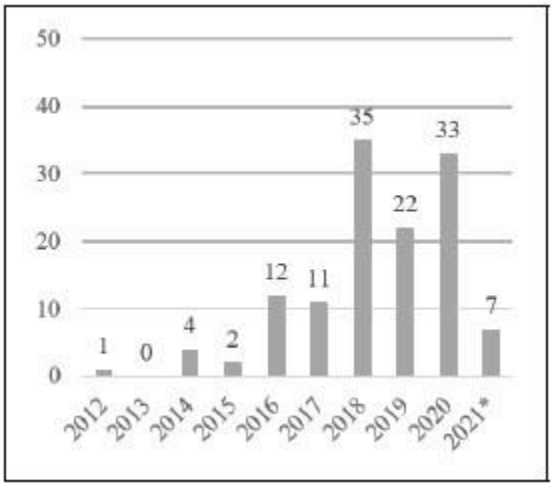

Figure 2-1: MaaS Publications in Recent Years (Maas, 2022)

2.1.3. Objectives

This literature review explores and synthesizes the current knowledge on MaaS and its importance as a potential solution to move people towards more sustainable modes of transportation. This review provides a comprehensive definition, typology, and service characteristics of MaaS. In addition, this paper highlights the technological, institutional, and financial requirements, challenges, and opportunities of a MaaS system.

Furthermore, this review explores how MaaS fits in urban and rural environments. This paper also identifies the demographics of users most receptive to a MaaS system, how previous travel behavior influences adoption, what user preferences are in a MaaS system, and challenges towards user adoption. This research aims to provide a comprehensive and current understanding of MaaS and how it can transform the transportation industry.

2.2. Service Characteristics

The literature discusses many vital characteristics of a MaaS service. An oftencited list of crucial service characteristics is by Jittrapirom et al.:

- Integration of transport modes

- Tariff option
- One platform
- Multiple actors
- Use of technologies
- Demand orientation
- Registration requirement
- Personalization
- Customization (Jittrapirom et al., 2017)

This review examines at four essential service characteristics more in-depth: User-centricity, Multiple Actors, Multimodality, and a single platform.

2.2.1 User-Centricity

Over the years, business models have concentrated on users. Many industries have moved in this direction, inspired by firms like Uber, Lyft, AirBnB, and other businesses that focus on "platformization and servitization" (Caiati et al., 2020). It is not unimaginable that transportation at large would move in this direction as well. MaaS has long been described as a "user-centric" concept (Smith et al., 2022; Jittrapirom et al., 2017). The system seeks to "fulfill users' needs for mobility with a wide range of transport services for both travelers and goods, offering tailor-made transport on demand." (Mulley et al., 2018). MaaS' strength is that the wide range of transportation options can meet users' diverse needs (Mulley et al., 2018). Jittrapirom writes that MaaS inherently allows users personalization and customization (Jittrapirom et al., 2017).

Personalization is that the user can receive "specific recommendations and tailor-made solutions on the basis of her/his profile, expressed preferences, and past behaviors (e.g., travel history)." and customization in that users can "freely compose a specified chained trip or build their mobility package with a different volume of usage of certain transport modes to better achieve their preferred travel experiences." (Jittrapirom et al., 2017). This user-centric approach is what makes MaaS truly a service.

2.2.2 Multimodal

For MaaS to offer users flexibility in modes of transportation, it must offer users a multimodal experience. MaaS moves beyond a single mode of transportation and integrates "various forms of

transport services into one single mobility service accessible on demand." (Arias-Molinares and García-Palomares, 2020). While every MaaS system can offer different things depending on its transportation environment, they typically offer transport modes like car-sharing, car rental, underground, rail, bus, bike-sharing, scooters, ride-hailing, and taxis (Kamargianni et al., 2016).

2.2.3. Multiple Actors

Not to be confused with the last section, a MaaS system inherently involves multiple actors. The two main actors are typically public transit agencies and the private sector. Even amongst these two groups, it breaks into many different actors. This review discusses these partnerships further. Looking at Figure 2-2 below, Beutel describes the many actors involved in a MaaS system. MaaS only works when these actors create a single platform of "various mobility service providers with diverse modalities." (Beutel et al., 2014).

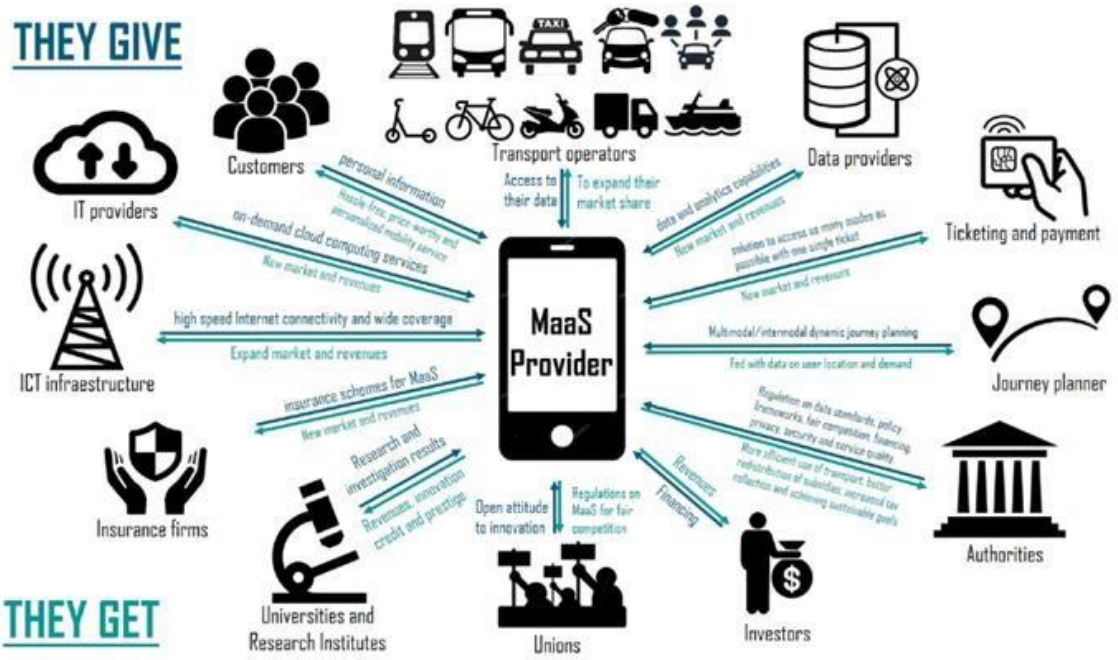

Figure 2-2: MaaS Ecosystem: What Actors Give and Get (Arias-Molinares and García-Palomares, 2020; Kamargianni & Matyas, 2017)

2.2.4. One Platform

A single platform is critical to the success of a MaaS system. For users to experience the convenience of MaaS, there needs to be a single platform that integrates the different modes of

transportation, data, and real-time information for trip planning, ticket, and payment. Li and Voege describe this as a key success factor, "A user of MaaS does not need to have different cards, different accounts or individual payments." (Li and Voege, 2017). The literature mentions that this integration is important because it helps "contribute to enhancing the overall quality of their (customers) travel experiences" at "all stages of their journeys." (Caiati et al., 2020). The literature extensively discusses the importance of ticket and payment integration. Li and Voege write that MaaS must "offer a combined ticket for intermodal travel." (Li and Voege, 2017). This has historically been done through a smart card system, but more recent writings on ticket integration in MaaS have said a smartphone is an "essential condition." (Smart Card Alliance, 2003; Kamargianni et al., 2016; Li and Voege, 2017) Overall, this integration onto a single platform is critical because, as Smith writes, a single platform reduces "the complexity of MaaS by minimizing the volume of new digital systems and apps, practical procedures, and pricing models the adopters have to learn and manage." (Smith et al., 2022).

2.3. Typology of Maas

The literature discusses several different types of MaaS, but Jana Sochor's typology is the one that is often cited. Sochor categorizes MaaS into four levels depending on how well and how much they integrate into their system. Figure 3 shows the different levels: Level-1: Integration of information, Level-2: Integration of booking and payment, Level-3: Integration of the service offer, and Level-4: Integration of societal goals.

2.3.1. Level-1: Integration of Information

Level-1 involves sharing information from multiple mobility services. These systems are a multimodal travel planner and a place to find information on payment and timetables (Sochor et al., 2018). They are typically funded by ad revenue and, if large enough, selling traffic information to cities (Sochor et al., 2018). An example of a MaaS system at this level would be Google Maps. A user can open the Google Maps application on their mobile device and see the time it takes to make a trip by driving, walking, cycling, public transport, or through a ride-hailing service like Uber and Lyft (and sometimes with price estimates for using that service).

2.3.2. Level-2: Integration of Booking and Payment

Level-2 goes beyond just trip planning and allows users to purchase the mobility services they need once they plan their multimodal journey. This level of service makes it easier for the user to make multimodal trips because of the convenience of purchasing the tickets. Still, Sochor says, “the offer is probably not holistic enough to convince households to actually sell their first or second car.” (Sochor et al., 2018). From a business perspective, a level-2 service is not profitable. Users will most likely be unwilling to pay extra for the added convenience, and the start-up costs of integration are still prohibitively high (Sochor et al., 2018).

2.3.3. Level-3: Integration of the Service Offer

Level-3 is the most integrated MaaS system accomplished to date. Sochor describes it as a “comprehensive alternative to car ownership” that “focuses on the total needs of a household.” (Sochor et al., 2018). Level-3 services are typically subscriptionbased and multimodal. The business requires a commitment from consumers beyond a single trip, and the business typically operates locally (Sochor et al., 2018). A local lens is needed for the MaaS operator to deal with mobilities that best fit the local context or region (Sochor et al., 2018). For example, a MaaS operator may be more car-sharingfocused in a rural environment than in a public transit-focused urban environment. An example of this level in the real world is with UbiGo of Sweden and Whim of Finland. Both of those operators offered a bundled subscription service to MaaS.

2.3.4. Level-4: Integration of Societal Goals

The final level of MaaS in Jana Sochor's typology of MaaS is the integration of societal goals. To date, this has not yet been fully realized. This level goes further than the simple business of a multimodal subscription bundle and incentivizes people to choose more sustainable modes of transport. At this level, a MaaS operator works with the government and other stakeholders to align MaaS policy to achieve more sustainable travel from consumers. A MaaS system that works to achieve societal goals does run the risk of losing focus on profitability. This balance has to be met by "developing contractual models for private-public cooperation, as well as understanding how changes in a policy framework will affect users' behavior with transport service providers and MaaS operators as intermediaries." (Sochor et al., 2018).

Figure 2.3 : A proposed typology of MaaS (Sochor et al., 2018)

2.3.5. Cognitive Impact of MaaS Levels

It is important to note that with each increasing level of MaaS, there is not only a convenience factor to the user, but this convenience is cognitively less straining on the user to plan, pay, and ultimately engage in multimodal travel. The literature interestingly discusses this, with Lyons writing more in-depth about the topic. Lyons proposes her typology, which looks at the cognitive strain of each level of MaaS. See Figure 2-4 below.

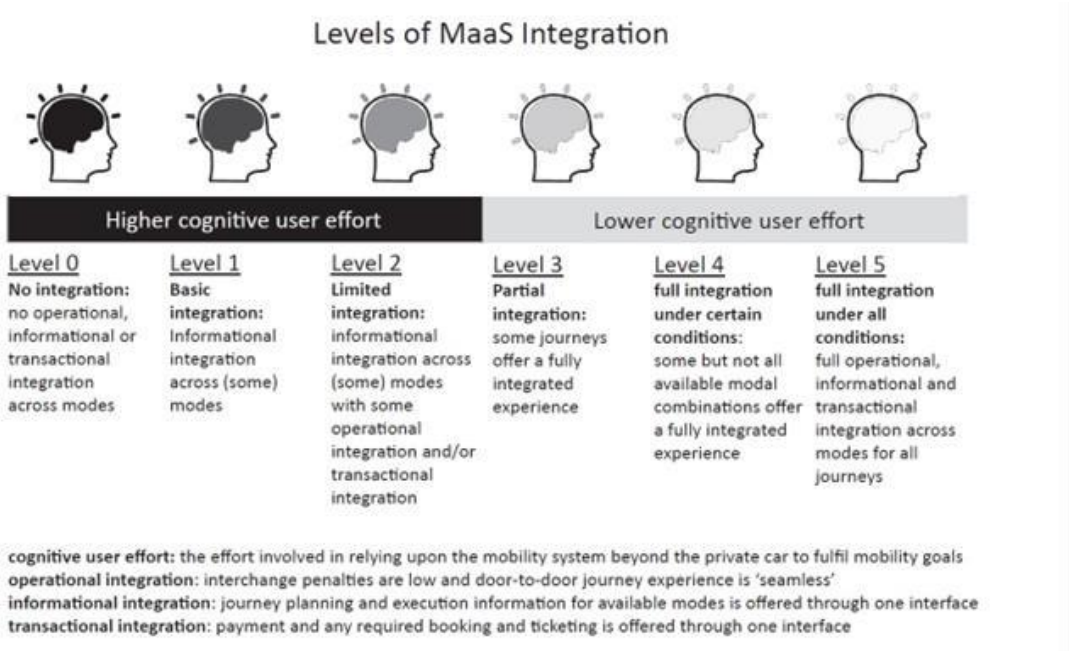

Figure 2-4: Conceptualization of MaaS Levels from a Cognitive Perspective (Lyons et al., 2019)

2.4. Technology

Technology is often at the forefront of discussions about MaaS. At its core, it is a disruptive technology attempting to move people away from car ownership and into service mobility. While the concept of a "travel broker" is not new, the technology at our disposal today makes MaaS much more possible. Wong writes, "Big data analytics, the internet of things, and autonomous vehicles are all closely intertwined with a future in which Optimising proponents argue will offer more efficient vehicle use, transport networks, better-utilizing infrastructure and delivering a more seamless customer experience." (Wong et al., 2020). This review looks at the technology that has made MaaS possible: Smartphones, Automated Vehicles, Cloud-based Platforms, and Big Data Analytics.

2.4.1. Smartphones

The literature describes the widespread adoption of smartphones as "the single greatest innovation for transportation in the last decade." (Wong et al., 2020). Smartphones that can connect to the internet have allowed people to access several different platforms to accomplish tasks at the touch of a screen. Pflügler describes it as "A big variety of services is offered in the market, and the popularity of smartphones is intensifying it." (Pflügler et al., 2016). Another writes, "The digital mobility services are well received by the public, forming the fourth most important application category used in smartphones, just after weather, social networking and communication." (Pflügler et al., 2016; Forrester, 2013). This widespread adoption has made smartphones the "main enabler of this transformation of the transport sector towards what is known as Intelligent Mobility." (Holmberg et al., 2016; Felländer et al., 2015). Initially, these intelligent mobility options were carsharing, carpooling, bike sharing, and e-hailing services (Audouin and Finger, 2018; Shaheen, Cohen, & Chung, 2009). Since then, the opportunity for "cross-modal journey planning and guidance" has become a reality (Aditjandra, 2019). With single platforms that allow servicing of mobility (servicification of transport) (Chase, 2015). "Access to a smartphone or tablet is therefore likely to be necessary to use MaaS." (Zijlstra et al., 2020).

2.4.2. Automated Vehicles (AVs)

Automated vehicles are considered one of the "Three Revolutions," moving technology closer to MaaS (Calderón and Miller, 2020). Automated vehicles promise to transform the transportation industry by reducing labor costs and allowing for better fleet rebalancing operations (Calderón and Miller, 2020). Calderón and Miller write, "The relationship of AVs with MaaS is evident when considering that one of the main impacts of AVs is to challenge conventional modes of automobile ownership" (Calderón and Miller, 2020). Often, electric vehicles go hand in hand with autonomous vehicles.

Electric vehicles offer an environmentally sustainable alternative to internal combustion engines (ICEs) (Cooper et al., 2019). This can help reduce air pollution caused by vehicle fleets and public transportation (Cooper et al., 2019; Parliamentary Office of Science and Technology, 2010). Autonomous and Electric vehicles have safety challenges, range limitations, charging vehicles, and high expense (Calderón and Miller, 2020; Cooper et al., 2019). However, their advancements can offer "immense opportunities and benefits" (Wong et al., 2020; Cooper et al., 2019).

2.4.3. Cloud-based Platforms

Cloud-based platforms play a crucial role in MaaS by providing users with journey planning, ride-share matching, maps, navigation, and all the information to run a single mobility platform (Pflügler et al., 2016). A platform is necessary for MaaS, "Indeed, in every presentation, definition, study, and media article on the topic, Mobilityas-a-Service is presented as a service accessed through a digital platform." (Zijlstra et al., 2020). Others write that Information and Communications Technology (ICTs) are the main component of MaaS (Jittrapirom et al., 2017; Aditjandra, 2019; Audouin and Finger, 2018). ICT is an enabler of the necessary integration of these services (Aditjandra, 2019; Audouin and Finger, 2018; Zijlstra et al., 2020). The literature writes about how different the technology environment is for MaaS today compared to just a few decades ago. "Two decades ago, information systems were rudimentary by today's standards and unimodal in nature." (Lyons et al., 2019). Cloud-based platforms allow users to see different information concerning different mode choice options. They also offer an embrace of the "disruptive societal trends" like "the rise of the modern sharing economy." (Smith et al., 2022; Sochor and Sarasini, 2017). This increasing diffusion of ICT offers potential for providing "better multimodal transport information potentially available for query at any place or time." (Aditjandra, 2019).

2.4.4. Limited Access to High-Speed Internet

While the Internet has drastically impacted society, access to high-speed Internet is certainly not guaranteed (Eckhardt et al., 2020). MaaS systems, especially in rural areas, must address this issue. Users must have access to a smartphone or computer to sign up for the service, trip plan, or use the service fully. This lack of access can also play out in economically distressed areas where smartphone access is not ensured. Digital literacy will play a major role in the ability of users to access and use MaaS (Eckhardt et al., 2020; Hensher et al., 2021). Another concern is that "ICT have the opportunity to raise the expectations of passengers for higher and better services which may not be matched by the network of services provided." To have a truly successful MaaS system, this issue of expectations "must not be overlooked." (Aditjandra, 2019).

2.4.5. Big Data Analytics

Any MaaS system that will integrate mobility services into a single application must be able to work extensively with data. “The amount of data that is generated by mobility services is enormous.” (Maas, 2022). Below in Figure 2-5, it is apparent that the amount of data for a MaaS system is indeed enormous. A MaaS system must be able to contain data from every mobility provider in the system. This includes data on bus and train timetables, distance to stops and scooters, vehicle fleet information, and much more (Audouin and Finger, 2018; König et al., 2016; Cottrill, 2020).

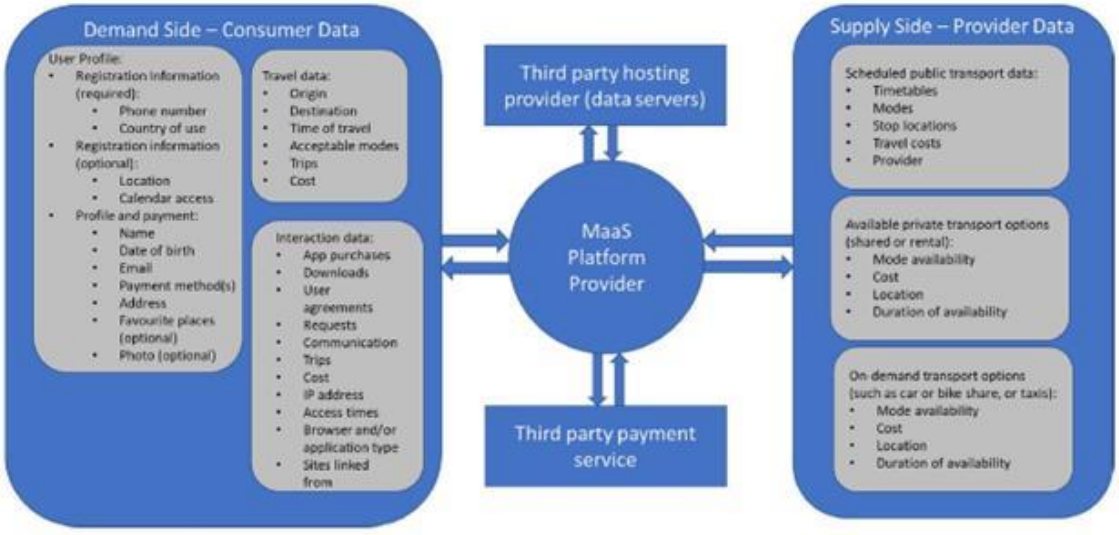

Figure 2-5: High-level conceptualization of a MaaS-style data ecosystem (König et al., 2016; Cottrill,2020)

2.4.6. Difficulty Integrating Data and Technology

One of the strengths of MaaS is its ability to combine several different mobility options into a single application, which poses problems when integrating different technologies and data. From the user’s perspective, MaaS needs an “integrated user interface, through which all services can be accessed and booked.” (Becker et al., 2020).

From the MaaS operator’s perspective, an “integrated strategic and operational planning across all mobility services (i.e., network/service areas, fleet sizes, fare integration)” is necessary (Becker et al., 2020). Put simply, “data as the key enabler of (or barrier to) “the integration of the operations and business models.” (Lyons et al., 2019). Problems arise when integrating data from multiple actors, let alone getting them to share it. Polydoropoulou offers a solution: "Policymakers should

establish standards for the data collection, management and sharing to support the interoperability of data and APIs feeds and increase the effectiveness of the collaboration between MaaS actors." (Polydoropoulou et al., 2020). Policymakers can incentivize investment in this domain given the high costs required and "public transport authorities could leverage their existing travel information systems, ticketing, and transaction platforms to become a full MaaS provider themselves." (Polydoropoulou et al., 2020; Geurs et al., 2018). "Availability and standardization of open data" are crucial for a successful MaaS system (Meurs et al., 2020). Currently, schema-matching algorithms can categorize integrated data through similar attribute names; "however, vocabulary of attribute names is designer specific, and same attributes are not necessarily built of same words or synonyms" (Hirashima et al., 2019). Polydoropoulou highlights this problem by writing, "the regulatory framework of the cities, the lack of standardization and openness of the application programming interfaces and the need for transport-related investments constitute risks for the successful implementation of MaaS in the study areas." (Polydoropoulou et al., 2020).

2.4.7. Privacy Concerns

Data is critical in any MaaS system, but privacy concerns arise when working with data as sensitive as people's movements. Research suggests that people are generally open to sharing location data and basic information necessary to register for a mobility subscription (Caiati et al., 2020; Transportation Systems Catapult, 2016). "On the contrary, the app access to GPS increases the utility of MaaS subscription, implying that people consider it as an advantage." (Caiati et al., 2020). Of course, a MaaS operator will still need to take steps to protect data on individuals (Callegati et al., 2018). Yuan writes that the "cyber-physical nature of MaaS systems makes them vulnerable to physical attacks from malicious drivers, cyber attacks on the hailing apps, and economic attacks by controlling the two-sided markets." (Yuan et al., 2016). Cities and MaaS operators must work to guarantee the "protection, confidentiality, and privacy of any personal information without conditioning the operational efficiency of the system." (Barreto et al., 2018). Finding that balance will be challenging (He et al., 2017).

2.5. Institutional and Financial Setting

The literature extensively discusses the importance and challenges of institutional and financial settings to MaaS. This review looks into four parts of that setting in-depth: governmental policies

and regulations, public-private partnerships, funding and financing mechanisms, and business models.

2.5.1. Governmental Policies and Regulations

The policies and regulations that are in place greatly influence the success of a MaaS system. The current transportation system is not favorable to MaaS. Therefore, new and redesigned policies and regulations are needed to support MaaS. The literature repeatedly reports that "Legislation has been argued to hinder innovation and renewal in the transport sector." and "act as a barrier for innovation and change in the transport sector." furthermore, "Perceived external barriers primarily regarded legislation." (Mukhtar-Landgren and Smith, 2019; Trafikanalys, 2016; Karlsson et al., 2020). Drawing on lessons from the Swedish MaaS system of UbiGo, the literature shows that from the private sector perspective on challenges to MaaS, "the private service providers primarily mentioned taxation as a barrier, arguing that taxation laws have not (yet) accommodated the ideas of a sharing economy." The service providers cited "varying value-added tax levels in relation to types of mobility services" as the main concern because they were "considered to create unfair conditions for different actors." (Karlsson et al., 2020). Another example of regulatory barriers that MaaS systems have faced pertains to current competition law (Karlsson et al., 2020). Currently, "a public transport authority cannot cooperate with a specific private firm without procurement, as public actors are not allowed to restrict or distort market competition." and worries of "monopolistic and predatory behavior from larger brokers/suppliers" (Karlsson et al., 2020; Wong et al., 2020).

The literature proposes several solutions to regulatory and policy barriers to MaaS. Becker writes that "more effective measures of taxation (or road pricing) will have to be developed to manage demand towards a more system-optimal state." (Becker et al., 2020). Cities can more generally promote MaaS by making owning and using private cars more costly (Smith et al., 2022). These policies can include minimum parking requirements and good accessibility to public transport (Karlsson et al., 2020).

On a broader level, the government can "relax the modal regulatory regime to accommodate mixed-mode opportunities" and consider the impact of antitrust/competition regulations "on the ability of monopoly-like service providers (like heavy rail operators) to cooperate with other participants in the market, and the impact that the public benefit may have on the approval (or not) of such cooperation by regulators." (Hensher, 2017; Mulley et al., 2018; Merkert et al., 2020).

Overall, “The findings indicate that law-making authorities can facilitate MaaS developments by adjusting relevant regulations and policies such as transport-related subsidies, taxation policies, and the definition of public transport. Regional and local authorities could contribute to creating conducive conditions for MaaS by, for example, planning urban designs and transport infrastructures to support service-based traveling.” (Karlsson et al., 2020).

2.5.2. Public-Private Partnerships

Public-private partnerships have a prominent role in any MaaS system. The literature defines a public-private partnership as one with “co-operation of some durability between public and private actors in which they jointly develop products and services and share risks, costs, and resources which are connected with these products or services” (Eckhardt et al., 2020; Van Ham & Koppenjan, 2010). Although there has been a significant increase in the number of collaborations in transport, partnerships face several challenges (Mukhtar-Landgren and Smith, 2019). Meurs outlines that “land transport providers are reluctant to cooperate with each other, with regard to sharing the available data (on, e.g., their travelers’ behavior) and making payment systems interoperable.” (Meurs et al., 2020). He continues that public transport providers view a risk of losing market share (and related loss of revenue) if they partner with private providers (Meurs et al., 2020). In addition, transport providers are reluctant to cede ‘ownership’ of their customers (Lyons et al., 2019). Furthermore, the costs “required to achieve interoperability” may be too high to consider a partnership (Meurs et al., 2020).

In any partnership, there will always be questions of roles and responsibilities. Public-private partnerships are no different. Given the level of uncertainty in this novel mobility option, the lack of clarity is deafening. Several papers highlight the challenges these uncertainties pose (Meurs et al., 2020; Karlsson et al., 2020; Smith, Sochor, and Karlsson 2017). In one of these studies, interviewees mentioned that it was “unclear which type of actor would be the face of MaaS for the end users (customers) and own the end-user relationship, who would take responsibility for end-user support, and who should refund the end users when the system falters.” (Smith et al., 2019). All of these uncertainties relate directly to the “overall lack of experience” these transport providers have in MaaS (Smith et al., 2019; Smith et al., 2017).

These challenges are considerable barriers to a successful MaaS system and are seemingly insurmountable, yet many offer solutions. Public-private partnerships in MaaS do best when the stakeholders share a common set of values and goals and when a “MaaS Champion” (typically the

government) leads the effort to adopt MaaS (Hensher et al., 2021). Karlsson suggests that public-private partnerships in MaaS need "a common vision and roadmap are needed, where public and private actors share the risk inherent in investing in a new and unproven concept." (Karlsson et al., 2020). Meurs advances this by writing, "Shared goals, limited risks for the partners involved, trust, and stimulating public actions are crucial for a successful alliance." (Meurs et al., 2020). Finally, Smith writes, "A shared conceptual space is key for collaborative problem-solving." (Smith et al., 2019; Roschelle and Teasley, 1995). To establish a common vision and values in a public-private partnership, there must be a "MaaS Champion." (Hensher et al., 2021). Hensher writes, "Fostering a healthy MaaS ecosystem environment requires the identification of a "MaaS Champion" whose role, amongst others, is to influence the development of MaaS to align with broader societal goals." (Hensher et al., 2021). Being a "MaaS Champion" is a "considerable task," however, the literature points to the government being the best to handle it (Hensher et al., 2021; Polydoropoulou et al., 2020; Mulley and Kronsell, 2018; Smith and Hensher, 2020; Vij and Dühr, 2022; Karlsson et al., 2020).

Starting these partnerships with pilot programs can be helpful. One researcher noted, "We request public actors to invest in joint knowledge-building through collaborative experimentation and piloting." (Smith et al., 2019). Further evidence shows that with pilot programs, "learning appears to be the main motive for the firms to get involved." (Meurs et al., 2020). There is not the same mistrust that may take place in an outright partnership. It is important to note the difficulty in turning successful pilot projects into full programs. Still, those early partnerships can help establish a certain level of trust between public and private actors. An example of the government taking a more active role is in the Netherlands, where the "national government is actively collaborating with private partners on the formulation of standards in open access to information, reservation, and payment systems." (Meurs et al., 2020). MaaS requires a "difficult transition that will require continuous adaption," but with a "strong political will connected to a strong vision and ambition to facilitate change," it can be done (Docherty et al., 2018; Karlsson et al., 2020).

2.5.3. Funding and Financing Mechanisms

"MaaS implementation requires funding." (Karlsson et al., 2020). It is certainly not cheap. The literature discusses the funding and financing mechanisms for MaaS and, more specifically, their challenges. Karlsson defines "financing" as "a policy instrument that features the use of "monetary techniques and tools, either to levy resources intended to be redistributed (taxes, fees) or to direct

the behaviors of actors (through subsidies or allowing deduction of expenses." (Mukhtar-Landgren and Smith, 2019; Lascoumes & Le Gales, 2007). MaaS financing faces several challenges from both a public and private sector perspective.

From a public sector perspective, there is limited public funding, especially for a novel concept. Policymakers "fear getting trapped in an expensive program with results that are less than satisfactory." (Eckhardt et al., 2020). Even successful pilots face funding issues when trying to convert into full programs. UbiGo in Sweden had positive results and still said that a "lack of financial support" was a barrier to continuation (Meurs et al., 2020). Overall, "budgets for public transport are decreasing and will decrease further in the coming years." (Geurs et al., 2018).

From a private sector perspective, there is a "lack of 'proof of concept.'" (Karlsson et al., 2020). The potential benefits of a MaaS system are large, "profitable markets for new transport services; renewed opportunities for the traditional transport and infrastructure business sectors as part of innovative service concepts and cooperation; and smarter transport connections for all sectors." (Mulley et al., 2018). Despite this, the lack of appropriate business models concerns all organizations (Karlsson et al., 2020). An impediment that interviewees cited in the UbiGo MaaS program cited the procurement process as a major difficulty in moving the program from a pilot program into a fully operational one (Smith et al., 2019).

2.5.4. Business Models of MaaS

Business models in MaaS have been a large subject of discussion among researchers and industry practitioners. Creating a viable business model is paramount to the success of a MaaS system. The mobile phone market has greatly inspired the business models for MaaS (Lyons et al., 2019). The two main tariff options for a MaaS program are pay-as-you-go and subscription (Caiati et al., 2020). Pay-as-you-go is already a common tariff option used in transportation. Both car rentals and car-sharing services employ this with a mix of fixed and variable (per-minute or per-mile) costs (Caiati et al., 2020). This tariff option is similar to the early days of the phone industry, charging by the minute or the number of characters in a text. The much-preferred tariff option would be a subscription-based model. "It is a business concept whose adoption has rapidly grown in digital products and services settings, like music, e-book, electronic magazines, ecommerce, cloud computing, and pay TV services, and is recently beginning to take shape in the transportation sector." (Caiati et al., 2020). Many bike-sharing services have adopted this subscription model.

Public transportation has also started introducing monthly subscriptions to their services (Caiati et al., 2020).

Subscription plans have their downsides. The literature provides four reasons for this. First, "Subscriptions induce welfare losses for two reasons. First, pass holders overconsume the alternative modes, as the marginal fare they face drops to zero. Second, non-pass holders tend to shift to car use due to the crowding induced by pass holders, causing additional distortions." (Hörcher and Graham, 2020). Third, "most individuals are not accustomed to thinking about the marginal costs of their transport use." (Vij and Dühr, 2022; ITS Australia, 2018). This was evidenced in the Whim trial, where they offered subscription plans comparable to the cost of car ownership, and consumers thought the subscription price was too high (Vij and Dühr, 2022). The fourth and final reason is that "profit margins in transport are much lower than other sectors of the economy." (Vij and Dühr, 2022). While it is unclear which business model to use for MaaS, it should ideally "bring value to users," society, mobility service providers, and MaaS operators and MaaS integrators (Smith and Hensher, 2020).

2.5.4.1. Three Types of Business Models

Smith is often cited for the three business models he proposes that could be used for MaaS: Market-driven development, Public-controlled development, and PublicPrivate Partnerships (Smith et al., 2018). Each of these development models has advantages and disadvantages.

Market-driven Development

Market-driven development "implies that the MaaS integrator and MaaS operator roles are either absorbed by incumbent private actors, such as transport service providers or technology providers." (Smith et al., 2018). Smith argues that the role of public transport (PT) would be relatively unchanged, given that the mission is still to provide quality traditional PT (Smith et al., 2018). Generally, the public sector would act as an

"enabler rather than a driving force." (Smith et al., 2018). Smith contends that this rests on a couple of assumptions. First, MaaS is a feasible business opportunity (Smith et al.,

2018). Secondly, private sector actors have "higher incentives and better capabilities to develop innovative services that meet customers' needs, compared to the public sector." (Smith et al., 2018). Smith points out that regardless of those assumptions, a public transport authority "would

still have to invest in internal technological, organizational and business development to make PT tickets available for resale." (Smith et al., 2018).

Public-Controlled Development

Public-controlled development would enlarge the public sector's role in maintaining the current public transport they offer and working as a MaaS integrator. Smith writes three arguments for this type of development. First, the main goal of MaaS is trying to achieve the societal goals of more sustainable travel. Second, public transportation is the "backbone of MaaS." Third, "public and private actors might have conflicting goals." Private actors might try to sell as many and as expensive trips as possible. Furthermore, because there is no proof that a business opportunity exists, Smith argues that public transportation might be the better bet.

Public-Private Development

Public-Private development is considered the "middle way" between market and public developments (Smith et al., 2018). Smith states that this both enlarges the public transport role and opens the role of MaaS operator to a private sector actor (Smith et al.,
2018). Proponents of this type of development argue that it "will result in a lower initial investment cost for MaaS operators as it could facilitate the integration process technically and contract-wise." (Smith et al., 2018). This development type could also help create a "neutral buffer" that prevents a MaaS operator from being "too dominant." (Smith et al., 2018). Smith cites an interviewee who stated that this would help avoid the fate that car rental companies and hotel owners faced when they became "too dependent on brokers" who would use "their positions to negotiate unjust business deals." (Smith et al., 2018). The literature broadly cites this type of development with the "highest chances of success." (Maas, 2022).

2.6. Transportation Environment

2.6.1. Urban Environment

Cities offer an ideal environment for a MaaS system due to the higher transportation demand and, typically, the presence of a public transportation system.

Despite the numerous trial programs for MaaS, there is a gap in the literature about the specific issues of MaaS in an urban environment. Even fewer studies regarding MaaS exist in a suburban or small metropolitan area context. There was one brief piece on how a MaaS system in a suburban context would need to focus on carpooling due to other mobility options being much more limited (Wright et al., 2020).

2.6.2. Rural Environment

Rural areas face several unique challenges, and where MaaS could have a substantial impact. The literature generally defines rural areas as places that "are significantly characterized by agriculture and forestry-based industries, dispersed settlement structures, primarily small to medium-sized, non-central towns." (GrossFengels and Fromhold-Eisebith, 2018). With much of the world urbanizing, rural areas face a declining and aging population (Gross-Fengels and Fromhold-Eisebith, 2018; Porru et al., 2020; Geurs et al., 2018; Poltimäe et al., 2022; Liu et al., 2020). Rural areas are also categorized with more considerable travel distances due to the lower population density, making commuting long (Gross-Fengels and Fromhold-Eisebith, 2018; Barreto et al., 2018; Hult et al., 2021). Given these longer distances, public transportation is typically not feasible financially and infrastructurally (Dytckov et al., 2022). Given the lack of transportation options in rural areas, vulnerable populations such as children, the elderly, and the disabled face even less accessibility to jobs, amenities, healthcare, etc. (Gross-Fengels and Fromhold-Eisebith, 2018; Hult et al., 2021; Barreto et al., 2018). "Poor access to transport is known to increase the risk of social exclusion, which means 'the lack or denial of resources, rights, goods and services, and the inability to participate in the normal relationships and activities, available to the majority of people in a society." (Bauchinger et al., 2021).

A MaaS system would face user acceptance challenges due to privacy concerns and lower digital literacy (Liu et al., 2020; Hult et al., 2021; Barreto et al., 2018). In addition, changing people's travel behaviors is already tricky, so introducing a multimodal service in a predominantly car-centric area would prove to be more difficult (Eckhardt et al., 2020). A MaaS system also requires substantial funding and technology infrastructure, which would be especially a concern in more rural transport offices, where funds are more limited, digital infrastructure is not as common, and small staff sizes would not have the time to implement a new program (Liu et al., 2020).

Despite the challenges, the literature writes extensively about the benefits of a MaaS system in a rural area (Barreto et al., 2018; Eckhardt et al., 2020; Gross-Fengels and Fromhold-Eisebith, 2018).

Rural areas have profited immensely from adopting ICT innovations in agriculture, so a MaaS system would not be entirely foreign (Gross-Fengels and Fromhold-Eisebith, 2018). Eckhardt writes that, “Rural Mobility as a Service (MaaS) could improve the accessibility of remote areas and offer new and efficient transport services by integrating different types of transportation and exploiting digitalization.” (Eckhardt et al., 2020). Gross-Fengels and Fromhold-Eisebith furthers this by saying that, “rural areas could reap substantial benefits from adopting and adapting digitally supported services, tools and platforms, in fact offer widely unexplored territory for ICT-based initiatives.” (Gross-Fengels and Fromhold-Eisebith, 2018).

Barreto offers that a rural MaaS service should “focus on servicing rural areas by creating supporting strategies to the public transport administrator that operates in rural MaaS, and in the future use of autonomous vehicles to reduce public subsidy cost of operating door to door services also in the rural area” (Barreto et al., 2018). Geurs takes this further by advocating that a rural MaaS system should “involve community-based public transport, in which local citizens collaborate with public transport operators in providing mini-bus transport services on fixed routes and timetables.” (Geurs et al., 2018). Technology barriers can “be overcome by creating inclusive solutions to deal with the technological illiteracy of the users.” (Barreto et al., 2018). Eckhardt attempts to solve the profitability problem by arguing that a “MaaS operator could, in addition to the mobility of people, include last-mile deliveries (parcel, post, shopping, pharmacy products, and meal deliveries) and statutory social and health service transportation integrated.” (Eckhardt et al., 2018). Moreover, “Recent literature suggests deploying demand responsive transport to serve “thin flows” from low population density areas.” (Calderón and Miller, 2020). Liu offers a valuable graph in Figure 1-6 below to illustrate the critical issues and key strategies for MaaS in rural areas (Liu et al., 2020). Overall, the literature generally says that a MaaS system could be a sustainable solution that improves transportation accessibility and reduces social exclusion.

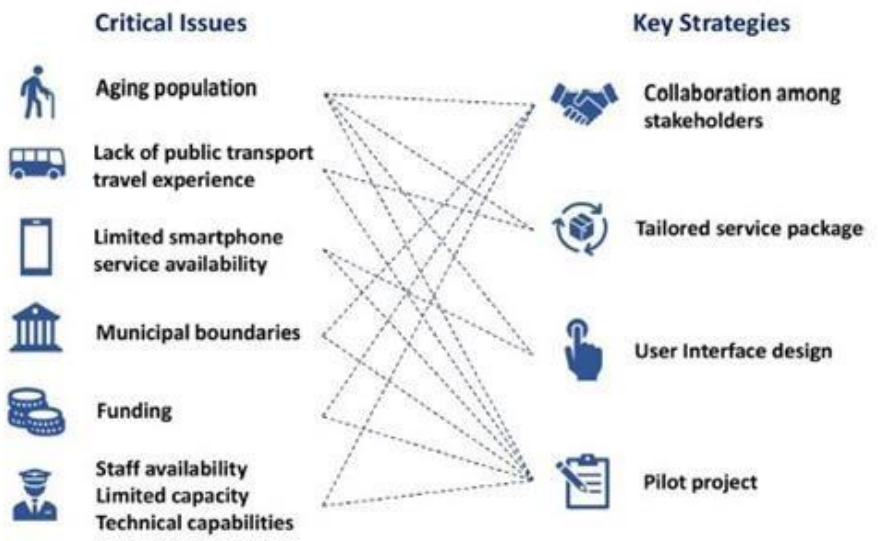

Figure 2-6: Critical issues and key strategies for MaaS in small urban and rural communities. (Liu et al., 2020)

2.7. Users

The success of MaaS relies on its ability to attract and retain users. This is why it is essential to understand the factors that influence user adoption and retention. Numerous studies have studied the demographics, travel patterns, perceptions, and preferences of potential MaaS users, and user adoption challenges. This section reviews the findings from those studies and the strategies the literature offers for user adoption and retention in a MaaS system.

2.7.1. Demographics

The literature offers several insights into the demographics of the people who use or would potentially use MaaS. Regarding age, studies have shown universally that younger people are more likely to use MaaS. In 2021, Matyas and Kamargianni found that "age is inversely related with the likelihood to use MaaS package." (Zhang and Kamargianni, 2022; Matyas and Kamargianni, 2021). Another study from the Netherlands "shows that younger people between 18 and 34 years old tend to be more willing to adopt MaaS schemes." (Zhang and Kamargianni, 2022; Alonso-González et al., 2020). "Similar conclusions were also drawn from a study in Australia, which indicates that young full-time employed individuals are the potential MaaS users, while older retired individuals lack interest in MaaS." (Zhang and Kamargianni, 2022; Vij et al., 2020). A

possible explanation comes from Lyons: "Young people are both learning to drive later and making fewer trips by car." (Lyons et al., 2019). Mulley furthers this by saying that "younger people are less inclined to purchase a car than previous generations and that they are more open to the idea of sharing a car and purchasing subscription services through a mobile device" (Mulley et al., 2018). In addition, younger generations wish to adopt a more sustainable lifestyle (Li and Voege, 2017). Older people are much less willing to use MaaS (Tsouros et al., 2021). This is especially true when a household has two or more children (Hoerler et al., 2020).

When it comes to gender, the results are much more mixed. "Caiati et al. found that females are more likely to subscribe to MaaS than males, while Matyas and Kamargianni found that males have a higher inclination to MaaS adoption than females." (Zhang and Kamargianni, 2022; Caiati et al., 2020; Matyas and Kamargianni, 2021).

Furthermore, "some studies also suggested the insignificance of gender influencing MaaS subscription choice." (Zhang and Kamargianni, 2022).

For the areas of income and education level, the literature is much clearer on who potential users are. Users tend to have higher incomes and education levels. Zijlstra specifically shows this with early adopters tending to be "highly mobile, have a high socioeconomic status, high levels of education and high personal incomes." (Smith et al., 2022; Zijlstra et al., 2020). Sochor continues these findings with her results showing that "factors frequently identified to positively influence the propensity to adopt MaaS include living in densely populated areas, being young, being wealthy, and having a high level of digital competence." (Smith et al., 2022; Sochor, 2021). Tsouros more specifically identifies that "individuals who work as full-time employees are more likely to purchase MaaS plans containing at least three different modes." (Tsouros et al., 2021). Overall, the users of MaaS tend to share similar characteristics of an "age below 55, travel frequently, have high income/socio-economic status and are of higher education are more likely to use MaaS." (Tsouros et al., 2021).

2.7.2. Travel Behavior

An important factor relating to potential MaaS users is their travel habits. Travel habits are difficult to change, so studies have looked extensively into the travel habits of users most likely to adopt MaaS (Eckhardt et al., 2020). Studies have shown that people who already engage in unimodal travel, whether by car, bus, walking, or cycling, are the least likely to adopt a multimodal MaaS system (Tsouros et al., 2021; Alonso-González et al., 2020). Unimodal car users are even less

likely compared to pedestrians and cyclists to adopt MaaS and are less likely to share rides with others (Feneri et al., 2022; Geurs et al., 2018). One study of MaaS users contradicted this by finding that "frequency of current car usage significantly influenced the potential uptake level, with the frequent car user (three or four days per week) being most open towards MaaS." (Hoerler et al., 2020). Another study found that infrequent car users were the most likely to adopt MaaS (Smith et al., 2022; Tsouros et al., 2021).

According to the literature, those most likely to use a multimodal MaaS system frequently use public transportation or multimodal travel (Alonso-González et al., 2020; Cisterna et al., 2021; Zijlstra et al., 2020; Tsouros et al., 2021; Hoerler et al., 2020). At the very least, early adopters will be frequent public transport users (Tsouros et al., 2021).

This is especially true of people who are more multimodal-minded. Zijlstra found that "we can expect that people who have a multimodal mindset are more inclined to use MaaS." (Zijlstra et al., 2020). Another study divided people based on travel patterns and found that the two groups of the five total groups most open to MaaS were both of the most multimodal groups. (Alonso-González et al., 2020). That same study found that unimodal transport users may be less favorable to MaaS due to a perception that ondemand modes of transportation are "premium and potentially expensive." (AlonsoGonzález et al., 2020). Hoerler showed that users with previous car-sharing experiences were significantly more open to using MaaS (Hoerler et al., 2020).

The purpose of travel can also play a role in adopting MaaS. The multimodal nature of MaaS could help with first/last mile connectivity. Studies have shown that "Transfers and multiple payments may deter potential passengers." (Lucken et al., 2019).

A MaaS system with one platform to pay for and plan trips could help address this issue (Lucken et al., 2019). Calderón and Miller state that "A strong argument supporting MaaS is that it can help tackle the "first mile/last mile" problem, considering that the flexible nature of several mobility services could be exploited if they operate as feeders for fixed transit lines and rail transportation." (Calderón and Miller, 2020; Djavadian & Chow, 2017). Others state that a MaaS system could accommodate freight or delivery services, which could potentially help with the adoption of MaaS (Calderón and Miller, 2020; Le Pira et al., 2021).

MaaS could also prove to help with infrequent trips. An example of this is tourism. Tourist trips often involve multiple stops at different attractions, and they have to choose multiple modes of transportation to get to them (Kim et al., 2021). Tourists consider travel time more important

because “they must consider the lengthy accumulated travel time while on a tour.” (Kim et al., 2021). Kim argues that “MaaS can be more effectively designed in tourism.” (Kim et al., 2021). Utriainen and Pöllänen argue that “MaaS could enhance tourists’ mobility options.” (Utriainen and Pöllänen, 2018). A study of tourists showed that “53.9% of participants declared being open to using a combined mobility service for weekend leisure trips.” (Hoerler et al., 2020). Concerning infrequent trips, the literature is not as extensive. One study showed that people generally prefer ride-hailing and ridesharing for non-commuter trips; however, a Belgian pilot program showed that users had “difficulties in bypassing their personal car, especially for (non-repetitive) leisure trips.” (Wilson and Mason, 2020; Storme et al., 2020). Others, like Geurs, have said the opposite, stating that a MaaS platform would work best if it targeted “students and travelers who perform infrequent trips.” (Geurs et al., 2018).

2.7.3. User Preferences

Willingness To Pay

The willingness to pay for MaaS is far lower than the estimated costs of a person’s current travel costs (Liljamo et al., 2020). Generally, the willingness to pay is defined as the “maximum price a consumer is ready to pay for a certain product or service” (Liljamo et al., 2020; Le Gall-Ely, 2009). Average transport costs in the United States for 2018 were $813 a month, yet users would only be willing to pay for MaaS if the monthly subscription was far less (United States Department of Labor, 2018; Liljamo et al., 2020). In several European studies, the willingness to pay was mostly around 150 euros (Solita, 2017; Liljamo et al., 2020). One study, with an average willingness to pay 140 euros, was just 64% of their current mobility costs (Liljamo et al., 2020). In another study, only 10% of participants were willing to consider 400 euros a month (Liljamo et al., 2020). Another study showed that the willingness to pay was 137 euros (Tsouros et al., 2021). Respondents reported in one study that they would “prefer long-term subscription plans (6–12 months), instead of shorter-term plans (1–3 months).” (Caiati et al., 2020). Overall, people are not typically aware of their mobility costs and estimate them poorly (Liljamo et al., 2020). This shows that any MaaS offering must demonstrate that they lower the mobility costs to be financially attractive (Liljamo et al., 2020).

Convenience

The literature offers mixed results in people's perceptions of MaaS's convenience. On the one hand, MaaS takes away the difficulty of determining feasible itineraries for multimodal travel (Aditjandra, 2019). On the other hand, people value the flexibility a private car provides for infrequent trips (Storme et al., 2020). The ability to travel spontaneously is often desired more than travel speed (Daniels and Mulley, 2010; Geurs et al., 2018). This conclusion leads Storme to state that "MaaS should be regarded as a complement – rather than a substitution of – private car use in the near future." (Storme et al., 2020).

Environmental Impact

The literature also offers mixed results regarding whether MaaS achieves more sustainable outcomes. Users who are open to MaaS certainly are people who wish to adopt a more sustainable lifestyle and have more pro-environmental attitudes (Li and Voege, 2017; Hoerler et al., 2020; Tsouros et al., 2021). MaaS also can help introduce people to modes of transportation that they typically do not use, which could mean more public and active transportation use when they typically use a private vehicle (Storme et al., 2020). However, the actual impact is mixed. One study found that MaaS bundles did impact private car use, yet another study showed that it was mixed (Storme et al., 2020; Jang et al., 2021; Hensher et al., 2021). The study showed that while car owners used active and public transportation more, those who used public and active modes of transportation also now had more access to and used car rental and sharing options (Jang et al., 2021). The study concluded that the ultimate impact on sustainability would depend on the magnitude of the two different transitions (Jang et al., 2021). Another study found that reducing private car use was difficult in real life (Storme et al., 2020).

2.7.4. User Perceptions

People are curious about MaaS and view the concept favorably. People held these positive views even though few had used IMM platforms before (Keller et al., 2018). One study showed that people held a "positive attitude towards the role MaaS could play in helping behavior change and the decrease in private vehicle dependence." (Matyas, 2020). In another study, "43% of the respondents would be willing to adopt a mobility package, assuming it could cover all mobility needs of the respondent." (Liljamo et al., 2020).

Psychology plays an important role in the adoption of MaaS. Tomaino showed that four factors play into this: Perceived control, Consumer identity, Perceived Costs, and Social Factors (Tomaino

et al., 2020). With MaaS, travel is mostly automated, which helps take the cognitive pressure off of consumers; however, this could be perceived as "relinquishing control" and "can undermine their sense of psychological power, responsibility, and trust in the platform." (Tomaino et al., 2020). This is especially true with MaaS' route optimization. On the one hand, this feature is convenient to users, especially in areas they may need to become more familiar (Lopez-Carreiro et al., 2020).

On the other hand, this will "inevitably make decisions that will conflict with passengers' preferences, engendering a sense of frustration and a perceived loss of Algorithm control." (Tomaino et al., 2020; Mick and Fournier, 1998). This is especially true if the algorithm makes a mistake (Dietvorst et al., 2015; Tomaino et al., 2020). Tomaino offers that "conversely, MaaS platforms may boost the consumer's perceived control by offering a variety of transportation modes to choose from, as well as relief from erratic traffic conditions by improving the reliability of the system." (Tomaino et al., 2020).

Consumers also want to signal their "identities—to themselves and others— through their consumption choices." (Tomaino et al., 2020; Spence, 1973). Tomaino states that "while vehicle ownership is often associated with a sense of accomplishment and high status, the adoption of MaaS could signal positive attributes such as concern about the environment (Tomaino et al., 2020; Schwartz, 2012; Moody et al., 2019; Zhao and Zhao, 2018). However, the environmental impact of MaaS is not typically salient to consumers and hence makes for a weak signal." (Tomaino et al., 2020; White et al., 2019).

Consumers may also find switching from their current travel habits too costly (Tomaino et al., 2020). This change disrupts the status quo. One study already demonstrated this challenge when respondents "felt it would have required too much effort to learn how to use a new service." (Karlsson et al., 2020). The literature offers some recommendations to remedy this challenge. Smith offers that MaaS can make this transition more manageable "by making the MaaS services flexible enough to enable adopters to customize the services to fit with their current travel needs and habits." (Smith et al., 2022). MaaS should "reduce the complexity of MaaS by minimizing the volume of new digital systems and apps, practical procedures, and pricing models the adopters have to learn and manage."(Smith et al., 2022). Social factors also heavily influence consumers (Caiati et al., 2020). Caiati writes, "People tend to be more willing to subscribe to MaaS when they

have positive reviews of the service and when more relatives, friends, and colleagues already have a subscription." (Caiati et al., 2020).

Overall, several factors make someone more open and willing to try a MaaS system. Lyons offers a helpful chart (see Figure 2-7) for MaaS regarding the individual choice-making for someone's adoption of MaaS.

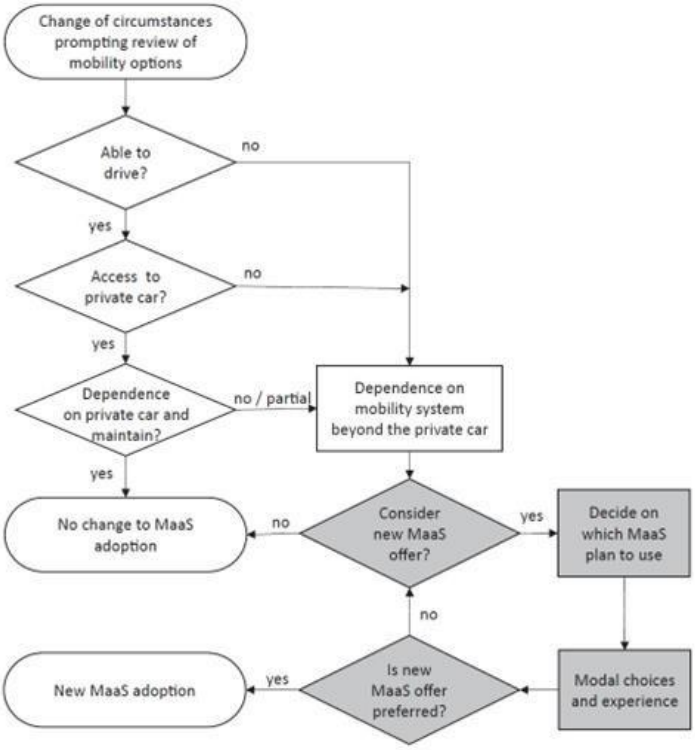

Fig. 3. Individual choice making and the adoption of MaaS.

Figure 2-7: *Individual choice-making and the adoption of MaaS (Lyons et al., 2019)*

2.7. Conclusion

This literature review aimed to analyze and summarize over 100 articles of research relating to MaaS. This review showed several findings. MaaS is a single platform that works to move people away from car ownership to instead pay for a mobility service either as a subscription or a pay-as-you-go service. MaaS is an emerging topic of interest among researchers and policymakers.

The service characteristics of MaaS were outlined with a greater focus on MaaS' user centricity, multiple actors, multimodal, and single platform. Two typologies were discussed, with one being Jana Sochor's four-level typology and the other being Lyon's cognitive typology.

Advances in automatic and electric vehicles, smartphones, cloud-based computing, and big data analytics have made MaaS possible. Despite these advancements, difficulties with access to high-speed internet, data sharing, and privacy concerns persist.

Institutional and financial factors play arguably the most prominent role in MaaS's success. Several barriers to MaaS exist, along with several policies to help reduce these barriers. Ultimately, a "MaaS Champion," likely the government, is beneficial. There is also difficulty in making a MaaS system profitable. There is an interest amongst the private sector for MaaS, but there is hesitancy about it, given the lack of "proof of concept." Ultimately, out of all the business models, a public-private partnership is considered the model with the highest chance of success. This review examined both urban and rural environments and the current state of literature on them.

The users of MaaS are a largely studied area of focus for MaaS. Users who are younger, male, high-income, and educated are more likely to try MaaS. A user's travel behavior also influences their likelihood of using MaaS. MaaS could be helpful in tourism travel, commuting, and freight, but may have a more challenging time reaching those who make infrequent trips and want the spontaneity of travel owning a car can provide. Regarding a willingness to pay, users have a far lower willingness to pay compared to how much they spend on transportation, making a MaaS system challenging to achieve. While MaaS may provide more convenience to users, the results for MaaS being environmentally friendly are mixed. Overall, people are interested in trying MaaS but know little about it. Retention of users is critical.

Current studies have focused on the MaaS system broadly and the challenges a potential system could face. These studies have overwhelmingly been in a European context, so few studies have shown the impact MaaS could have in a U.S. context, and even fewer in a small urban and rural context here in the United States. Furthermore, research on how to better connect people to their actual transportation costs so MaaS looks like a more attractive option is needed if MaaS wants to be successful. Finally, more practical guidance for policymakers is necessary for MaaS to become a reality beyond a pilot program.

Chapter 3. MaaS Pilot Programs

3.1. Whim: Finland

History

Finland has long been the pioneer of mobility-as-a-service. The country has been considering employing a more future-oriented ITS solution to mobility challenges since 2009 with its first ITS national strategy (Smith et al., 2018). In the strategy, a recognition that "an increased use of ITS could realize a versatile transport system that guides citizens towards using environmentally sustainable, economical and safe modes of transport, but that this development required a modern, customer-oriented transport policy." (Smith et al., 2019). The Finnish government made a push "towards deregulation and increased market orientation." (Smith et al., 2018). When the government entered office in 2015, they "identified three means to achieve this vision: digitalization, experimentation and deregulation." (Smith et al., 2018). This kind of vision and single voice makes Finland stand out amongst other countries for being a "vocal driving force" and MaaS Champion and has been identified in surveys of those involved in the project as critical (Smith et al., 2018).

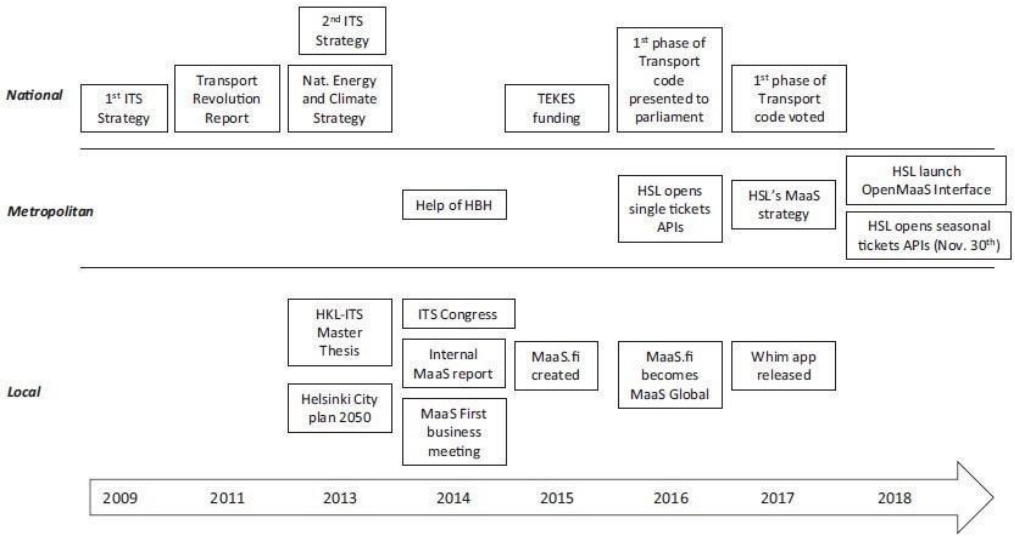

Fig. 1. Timeline of development of Whim in Helsinki in function of the governance level (Authors' elaboration).

Figure 3-1: Timeline of the development of Whim in Helsinki (Audouin & Finger, 2018)

With the support of the Finnish government, the capital city, Helsinki, partnered with a recently formed MaaS company called MaaS Global to create and launch the
Whim App (Smith et al., 2018). “In early June 2017, after about a year of testing, MaaS Global, a private start-up based in Helsinki and headed by Mr. Sampo Hietanen (who is often presented as the father of the MaaS concept), finally released its Mobility-as-aService packages for the HMA, by making its Whim app available for download on app stores.” (Audouin & Finger, 2018). The initial 2016 launch of Whim drew some of the first international attention to the concept (Smith et al., 2018).

MaaS in Finland received additional support from the Finnish government, which rewrote the Transport Code in 2017 to be enforced by 2018, which supported MaaS through deregulation (Smith et al., 2018). This deregulation came in two parts. First, the
Finnish Parliament lowered taxi permitting requirements, including “limits on the number of taxi licenses as well as price regulations” (Smith et al., 2018). Second, the newly written code required all participants in the transportation market “to provide their operational data as well as their single tickets for third-party resale and use.” (Smith et al., 2018). This transport code rewrite helped push Whim to be considered as the only true MaaS offering ever provided.

Program Description

Whim launched to the public in 2017, allowing users access to a wide range of mobility options, including public transportation, car rentals, and taxis. “Although carsharing and bike sharing services existed in Helsinki at that time, those were not integrated in the Whim Offerings." (Audouin & Finger, 2018). However, Whim has now offered access to city bikes and e-scooters since its opening. Customers can access information about mobility planning, options, and payments all from a single app (Audouin & Finger, 2018). As of August 2017, Whim customers have three payment options to choose from: “pay-as-you-go," “Whim Basic,” and “Whim Go.” That last option lets users pay “a monthly fee of €149 and would give them unlimited access to public transport within the city of Helsinki, as well as up to €124 of services in car rental or taxis.” (Audouin & Finger, 2018).

Results

Whim has had tremendous success since its first launch in 2017. Since its launch to June 2018, it has achieved 1 million trips and completed over 20 million trips (MaaS
Global). Whim has expanded to other cities such as Tokyo, Vienna, Antwerp, and greater

Switzerland. “MaaS Global has received several awards for mobility solutions, design, and smart city” (MaaS Global; Werner, 2020). Public transport, is considered the “backbone” of Whim (Maas, 2022). Users were also exposed to other alternative transportation modes, which have been found to possibly replace “about 38% of daily car trips” (Ramboll, 2019). These results show that Whim has proved to be a great application of the MaaS concept and can potentially replace daily car trips.

Lessons Learned

Whim and MaaS in Finland offer three valuable lessons for MaaS’s success and two things that still need work. The success factors are the right motivation, legislation, and organization. Getting the right motivation is critical. “Finland, MaaS is typically motivated by the idea that public spending on transport must be streamlined, and that economic growth will result from cross-industry collaborations and sound market competition.” (Smith et al., 2018). This more market-driven approach allowed for-profit firms to be both the “MaaS operator and MaaS integrator” in the Finnish MaaS ecosystem (Smith et al., 2018). Second, the Finnish Parliament's dedicated legislation in their Transport Code rewrite requiring the interoperability of the mobility providers made a single application and service possible (Audouin & Finger, 2018). Finally, the Finnish government had the proper organizational structure in government to make MaaS a reality. “In Finland, communication and transport are governed by the same ministry (LVM). This has enabled the Finnish government to make structural links between transport and information and communication technology (ICT). This is not the case in
Sweden.” (Smith et al., 2018). With the existing importance of ICT to the Finnish economy, along with companies like Nokia, Finland was well-positioned to create meaningful legislation to support novel mobility options. All these factors being said,
Whim still struggles with the “fact that the PTAs do not allow for third-party ticket resale.” (Smith et al., 2018). While indeed the most successful MaaS program, Whim has struggled with showing investors that it is a reliable business model given its novelty (Smith et al., 2018).

3.2. Ubigo: Sweden

History

Sweden has a long history of experimenting with MaaS, making it an ideal place to try MaaS. An early iteration of the MaaS concept was first done in 1993 by a group named Samtrafiken. This was "an initiative for combining various modes of public transport (e.g., combining bus and tram tickets) and for the implementation of a national ticketing and payment standard." (Fenton et al., 2020). This concept was furthered through various studies done in Sweden, including one in 2011 called "The Flexible Traveler." (Smith et al., 2018). This project "examined business opportunities associated with multimodal services and sought to initiate processes for their realization, concluded that the conditions were in place for services that provide metropolitan citizens with comprehensive, reliable, customized and usable mobility services that reduce costs, increase flexibility, and contribute to sustainable everyday travel" (Boethius & Arby, 2011; Smith et al., 2018). A second R&D project named Go: Smart from 2012-2014 was funded by the Swedish innovation agency VINNOVA to encourage "sustainable urban mobility." (Smith et al., 2018). This project consisted of the "six-month pilot of a multimodal service in the Gothenburg area, called UbiGo (e.g., Sochor et al., 2016)." (Smith et al., 2018). "The 2014 pilot of UbiGo in Gothenburg (SE) is often referred to as the first in real-life conditions" (Smith et al., 2018).

Program Description

UbiGo was launched in Gothenburg, Sweden, for six months by "195 individuals in 83 households" (Stromberg et al., 2018). Gothenburg is a city on the west coast of Sweden that offers an established public transport system (Stromberg et al., 2018). The service offered access to five transport modes: public transit, car sharing, car rentals, taxis, and bike-sharing (Eckhardt & Sochor, 2016). UbiGo offered each household a customizable and "modifiable subscription" they paid for each month (Stromberg et al., 2018). "The minimum household subscription level was 1200 SEK/month in prepaid credit (approximately €135/$185 at the time of the trial)" (Stromberg et al., 2018). Data would be collected from several questionnaires filled out by the users, interviews with users and households, and data, error reports, and customer service issues (Stromberg et al., 2018).

Results

UbiGo had tremendous success after the pilot program. Users wanted to continue using the service, and many changed their travel behavior. "Seventy-nine percent said that they would like to continue as customers, while an additional 18% wanted to continue, but with preconditions related to economic aspects of the service and the reliability of the technology" (Stromberg et al., 2018).

This makes a total of 97% of users wanting to continue the service. 69% of participants stated that "they become more satisfied with their traveling compared to before the trial" (Stromberg et al., 2018). Users had overestimated car use and developed more negative views towards private car use (Karlsson et al., 2016; Stromberg et al., 2018). Instead, users were taking public transport more and engaging in more active transportation modes, like walking and cycling (Stromberg et al., 2018). This is largely attributed to the fact that users were no longer "locked-in" to specific modes of transport (Stromberg et al., 2018). People are not as tied to a private car when they have other options and can rationally decide based on the specific needs of that trip (Stromberg et al., 2018). In the case of UbiGo, this led to participants choosing more sustainable modes of transportation. The pilot program won the 'Promising Innovation in Transport Award' from the International Transport Forum in 2015 (Fenton et al., 2020). Unfortunately, despite the pilot's success, UbiGo was shut down due to a lack of procurement because of stakeholder in-fighting (Fenton et al., 2020; Smith et al., 2019).

Lessons Learned

UbiGo offered a well-received service to the customers. However, the lessons learned are about the difficulty of scaling up a pilot program into a viable business model with a solid governance structure. Sweden struggled with three things: lack of goals, lack of a "MaaS Champion," and organizational inexperience.

First, MaaS in Sweden is seen to increase ridership on public transport (Smith et al., 2018). This narrow goal-setting approach makes it difficult for stakeholders from other modes to join if it risks their bottom line. It also makes it difficult for public transport to push other modes of transportation if it risks lowering ridership. This includes even more sustainable modes like walking or biking. Smith et al. recommend that lawmakers be more "outcome-oriented" for greater flexibility in achieving desired policy goals (Smith et al., 2019). With more explicit goals and flexibility, the numerous stakeholders will be more focused, and attracting new customers will be easier (Smith et al., 2019).

Second, Sweden did not have a 'MaaS Champion.' Surveys of stakeholders in the Swedish MaaS reported no "consistent set of key players" (Smith et al., 2018). The Swedish government also had been less outspoken on MaaS when compared to the Finnish government (Smith et al., 2018). Regional and operational stakeholders seemed to take more of the leading role in Swedish MaaS, leading to a patchwork of different 'MaaS Champions' and little from the national government

(Fenton et al., 2020; Smith et al., 2018). A lack of a 'MaaS Champion' also proved difficult when the various stakeholders could not agree on who would be the "face of MaaS for the end users (customers)" and refund or support users when the system has errors (Smith et al., 2019).

Finally, organizational experience issues are expected with novel mobility tools, but it proves to be an almost insurmountable barrier for Sweden. This is especially the case when writing contracts between various stakeholders. MaaS is a novel concept being tested out and involves actors "that have not previously collaborated, are of entirely dissimilar natures, and originate from different traditions (Smith et al., 2019). The literature suggests that lawmakers should "investigate new contract forms" and encourage bridging partnerships from pilot programs to full-scale programs (Smith et al., 2019).

3.3. Vamos: San Joaquin Valley, California

History

The San Joaquin Valley of California is in the northern central valley of California. It is considered one of the most productive agricultural regions in the U.S. (Rodier et al., 2022). At the same time, the San Joaquin Valley unfortunately suffers from "some of the worst air quality in the nation" and some of the most economically disadvantaged areas in the State (Rodier et al., 2022). Due to this, "the California Department of Transportation funded a study to examine new technology alternatives to transit in rural communities" (Rodier et al., 2022).

Description of Program

One such program is a pilot program called Vamos that took place "over 23 months from January 2020 through November 2021" (Rodier et al., 2022). Vamos served as both a "route planning tool and a transit fare payment tool" (Rodier et al., 2022). The service allowed users to access public transportation in the region along with "general use micro transit (Van Go!) and on-demand shuttles" (Rodier et al., 2022). The pilot program users tended to be younger, more educated, had lower access to a private vehicle, and had lower incomes than the region (Rodier et al., 2022). The distribution of Hispanic, Latino, or Spanish origins did appear to be like the region (Rodier et al., 2022).

Results

It is important to note that this 23-month program started just two months before the COVID-19 pandemic, so the number of users who used Vamos is low, but some insights were made. In all,

there were a total of 281 users of the application (Rodier et al., 2022). “Seventy percent of the users (196 out of 281) used the route search function only, eight percent of the users (23 out of 281) used the purchase function only, and the remaining twenty-two percent of users (62 out of 281) used both the route search and purchase functions” (Rodier et al., 2022). 58% of all users only used the application for one day and did not continue (Rodier et al., 2022). Less than 3% of users used the application over ten days (Rodier et al., 2022). Users who did purchase a ticket reported doing so because “It has been easier to pay for a transit” (Rodier et al., 2022).

LESSONS LEARNED

While Vamos’ uptake struggled, the application can be a “valuable transit fare payment tool” and provide a “more efficient method of payment for users” (Rodier et al., 2022). Given that the vast majority of users did not use it for more than a day, any MaaS offering should have quality “user engagement and retention” (Rodier et al., 2022).

Chapter 4. Review of Mobility Issues

4.1. Introduction

This literature review aims to summarize the key findings from over 150 studies and expand the current state of knowledge regarding these issues. This research aims to provide a comprehensive and current understanding of mobility issues and how they impact users in the Rio Grande Valley and worldwide.

4.2. Travel Behavior

This section will cover two broad categories of travel behavior and mode choice:
psychological and situational factors. The psychological trends will cover overarching transport rationales, decision-making, context dependence in travel behavior, and specific psychological factors. The situational factors influencing travel behavior include Car Availability, Income and Value of Time, Life Events, Travel Goals, Environmental Awareness, Technology, Built Environment, and Weather. It is essential to understand these broad categories to get a fuller picture of how people make choices in travel.

4.2.1. Psychological Factors

Transport Rationales

People's rationales when deciding on trips go to the heart of travel behavior. These different rationales can include "instrumental, safety-based, comfort-based, esthetic as well as affective dimensions" (Næss et al., 2018; Habermas, 1991; Tuan, 1977). Based on interviews in one study, researchers identified five rationales for activity location: "Choosing the best facility, minimizing the friction of distance, limiting other travel-related expenses, maintaining social contacts, and variety-seeking" (Næss et al., 2018). For travel mode choice, the main rationales were: "Convenience and comfort, Avoiding physical efforts, Mobility simplicity, Frustration aversion, and Time-saving" (Næss et al., 2018). "Secondary rationales included wishing for physical exercise, longterm habits, limiting travel expenses, safety, social contact and caretaking, esthetics, and environmental concerns" (Næss et al., 2018).

Several constraints exist for individuals, such as "earlier decisions, social obligations, organizational structures, the location and availability of resources, and from the distances between places" (Næss et al., 2018; Ellegard, 1999). The literature identifies different types of constraints: capability constraints, coupling constraints, and authority/steering constraints (Næss et al., 2018). Capability constraints are "limitations to individuals' activities due to their biological properties (e.g., need for sleep) and the capability of the tools they have at their disposal (e.g., means of transport)" (Næss et al., 2018). "Coupling constraints are regulations requiring persons, instruments, materials, and signs to be coupled into co-operating groups" (Næss et al., 2018). Finally, "Authority/steering constraints include spatial restrictions on who is entitled to move through or stay in different places, and temporal restrictions such as the length of working hours and opening hours of stores or kindergartens" (Næss et al., 2018).

Decision-making and Context-Dependence in Travel Behavior

An individual makes choices about where to travel and what mode of transportation to use to get there. These decisions "usually involve a complex decisionmaking process" (Zhang et al., 2004). "Individuals utilize different heuristics that will keep the information processing demands within the bounds of their limited capacity" (Zhang et al., 2004; Payne, 1976). Much of the literature on "behavioral decision theory and psychology has shown that task complexity and choice environment affect individual choice behavior" (Zhang et al., 2004; Rushton, 1969; Swait &

Adamowicz, 2001). Some theorize that people follow the traditional random utility maximization theory, which "assumes that individuals choose the alternative with the highest utility independent of context and learning, etc." (Zhang et al., 2004). Zhang et al. highlight that several pieces of research show "counter-evidence" to this and use the example of Simonson and Tversky, who "argued that context effects are both common and robust, representing the rule rather than the exception in choice behavior" (Zhang et al., 2004; Simonson & Tversky, 1992; Rushton, 1969; Swait and Adamowicz, 2001).

While the literature provides numerous definitions of context-dependence, one study defines it as "choice behavior being highly adaptive and context-dependent from a psychological viewpoint" (Zhang et al., 2004; McFadden, 2001). A literature review of this classified the pre-conditions of decision-making into three categories; "(1) alternative-specific context, (2) circumstantial context and (3) individual-specific context" (Zhang et al., 2004). The first "includes the number of alternatives and their attributes, the correlated structure of attributes, and the availability of alternatives" (Zhang et al., 2004). The second one includes the "status quo of choice over the population" (Zhang et al., 2004). Finally, the third option refers to "the individual's choice history, household or workplace attributes, and the cognitive status quo of the reference group such as the car ownership of their neighbors and acquaintances" (Zhang et al., 2004).

When it comes to decision-making, behavioral science and psychology have identified different factors that can impact an individual's decision-making. One of these factors is complexity (Zhang et al., 2004; Rushton, 1969; Swait and Adamowicz, 2001).

The literature shows that when "the complexity (defined by the number of alternatives, the number of attributes, the correlation between attributes, etc.) in choice tasks increases, decision makers usually use simple, local, and myopic choice strategies" (Zhang et al., 2004; Olshavsky, 1979; Payne et al., 1988, 1993; De Palma et al., 1994). Zhang points out that decision-makers, when faces with a highly complex choice may choose the strategy to "delay choice, seek new alternatives, or even revert to status quo option when the choice environment is made complex" (Zhang et al., 2004; Dhar, 1997a,b).

The literature offers a dominant theory for travel behavior: the theory of planned behavior. This theory states that human action is "guided by three kinds of considerations: beliefs about the likely consequences of the behavior (behavioral beliefs), beliefs about the normative expectations of others (normative beliefs), and beliefs about the presence of factors that may further or hinder the

performance of the behavior (control beliefs)" (Bamberg et al., 2003). Gärling & Axhausen states that even if the behavior becomes a habit after deliberation, the choice can still be considered rational unless the circumstances change (Gärling & Axhausen, 2003).

Specific Psychological Factors

The literature on the psychological factors influencing travel mode choice has come a long way in recent years (Klöckner & Friedrichsmeier, 2011). Psychological factors try to "identify overarching patterns in travel mode choice that relate – for example – to relatively stable intentions, norms or habits and therefore to look for the stable, person-specific aspects in travel mode choice" (Klöckner & Friedrichsmeier, 2011; Hunecke et al., 2001; Verplanken et al., 1994).

Behavior theories like planned behavior have been applied to travel mode choice (Klöckner & Friedrichsmeier, 2011; Bamberg & Schmidt, 1998). The theory of planned behavior in relation to travel mode choice assumes that an individual makes a decision based on their intentions and the amount of control a person experiences over their behavior, otherwise known as perceived behavioral control (Klöckner & Friedrichsmeier, 2011).

The theory of planned behavior is furthered by the role habits can play in an individual's travel mode choice (Bamberg et al., 2003). Klöckner & Friedrichsmeier says this is especially true when the trip is frequently made, such as a trip to work (Klöckner & Friedrichsmeier, 2011). Another implication of habitual behavior is that the individual has a stable context in which a habit can be formed (Klöckner & Friedrichsmeier, 2011).

"Verplanken et al. first introduced the construct "habit" into the theory of planned behaviour in its application on travel mode choice and were able to increase explained variation in the dependent variable travel mode choice significantly, a result that has been replicated many times since" (Klöckner & Friedrichsmeier, 2011; Verplanken et al., 1994; Gardner, 2009; Thøgersen, 2006). Others have shown that once habits are formed, intentions play a smaller role in planned behavior (Klöckner & Friedrichsmeier, 2011; Gardner, 2009; Thøgersen, 2006; Ouellette & Wood, 1998). These habits create an "automaticity" to travel mode choice, where intentions and attitudes are formulated only at the beginning of the process (Bamberg et al., 2003). The implication is that once habits are formed, they are difficult to change (Verplanken et al., 2008; Bamberg et al., 2003; Hull, 1943; Dahlstrand & Biel, 1997). Another implication is that "if for whatever reason a stable

context is disrupted, habits associated with that context are broken too, at least temporarily" (Verplanken et al., 2008; Wood et al., 2005).

To test this, a group of researchers offered a free bus ticket for one month to a group of drivers (Gärling & Axhausen, 2003). The hope was that when circumstances were no longer stable and the bus ticket was free, drivers would break from their car habits and use public transportation. The results confirmed this hypothesis as people began to have more positive views of the bus, and the frequency of use increased.

Another popular theory for travel mode choice is that of the norm-activation model (Klöckner & Friedrichsmeier, 2011; Hunecke et. al., 2001). This theory assumes that people act according to their "moral obligation to act a certain way," otherwise known as personal norms (Klöckner & Friedrichsmeier, 2011). Factors that activate this are social norms, perceived behavioral control, awareness of need, and awareness of consequences (Klöckner & Friedrichsmeier, 2011). "Awareness of need is a feeling of a necessity to act (e.g., that car use poses a threat to the environment)" (Klöckner & Friedrichsmeier, 2011). "Awareness of consequences is the belief that the actor's own actions pose a relevant contribution to the problem" (Klöckner & Friedrichsmeier, 2011).

Research has demonstrated that this theory is most suitable for mode choice regarding pro-environmental personal norms (Klöckner & Friedrichsmeier, 2011; Hunecke et al., 2001). This direct link has been questioned in recent years, however, and it has "instead been suggested a mediated relation with intentions as mediator between personal norms and behaviour" (Klöckner & Friedrichsmeier, 2011; Bamberg et al., 2007; Bamberg & Möser, 2007; Kaiser, 2006; Klöckner & Blöbaum, 2010). An example of this was proposed by Hoffmann et al., who demonstrated that "cycling may be viewed as good exercise (attitudes – environment and health) but also impractical when faced with high volumes of traffic (attitudes – transport environment)" (Hoffmann et al., 2017).

Habits can also moderate personal norms. "Klöckner et al. and Klöckner and Matthies have demonstrated that habits moderate the influence of personal norms on behaviour and are a predictor of travel mode choice parallel to personal norms under certain conditions" (Klöckner & Friedrichsmeier, 2011; Klöckner et al., 2003; Klöckner & Matthies, 2004).

An analysis of the Theory of Planned Behavior (TPB) and the Norm-Activation model (NAM) "support continued use of the TPB but offer less support for NAM because measures of PBC,

intentions and habit generated consistently higher average effect sizes than measures of norms" (Hoffmann et al., 2017).

Situational Factors

The literature offers various situational factors that influence travel mode choice. Several of these factors in the literature and their connections to the Rio Grande Valley will be discussed here.

Car Availability Car ownership is considered to be "an important determinant of travel behavior (Ding et al., 2017). Klöckner and Friedrichsmeier say that this is not surprising. "The easier a car can be accessed at the point in time when the decision is made, the higher – in general – the likelihood that a car is used" (Klöckner & Friedrichsmeier, 2011). Several articles have demonstrated the strong predicting power of car ownership (Klöckner & Friedrichsmeier, 2011; Simma & Axhausen, 2001; Ben-Akiva & Boccara, 1995; Dieleman et al., 2002).

However, the literature seems to be in a "which came first, the chicken or the egg" situation. Van Acker and Witlox pose the question: "Is car availability just an ordinary predictor of car use as other predictors, or does it have special characteristics as car availability is most likely a result of a decision-making process itself?" (Klöckner & Friedrichsmeier 2011; Van Acker & Wilcox, 2010). "On the one hand it is strongly predictive of travel mode choice and is therefore an independent variable, on the other hand car availability itself is the product of individual decision making and therefore depending on other variables" (Klöckner & Friedrichsmeier, 2011).

Currently, residents in the Rio Grande Valley have a high rate of car accessibility, with 95% of households having a vehicle available (Singh et al., 2020). This leads to the unsurprising result that nearly 90% of trips are done by car (Singh et al., 2020). "As expected, households with no vehicles available generally made fewer trips per household than those households that have vehicles available; however, note that households with no vehicles still make a meaningful number of trips" (Singh et al., 2020).

Income and Value of Time

Travel costs play a significant role in determining travel behavior. How much people have and are willing to spend on transportation costs impacts their travel behavior. While the travel barriers low-income individuals face will be covered in a future section, income's impact on travel behavior is worth noting. Zhu et al. state, "Income played a significant role in determining the

travel pattern changes" (Zhu et al., 2017). They explained that wealthier individuals are more likely to drive alone or pay for ride-hailing services, while low-income individuals are more likely to take public transportation (Zhu et al., 2017). Another study showed that "People's attitudes about the cost of travel were related to their income, but even people in lower-income households generally did not agree that they walked or took transit to save money" (FHWA NHTS Report: Changing Attitudes and Transportation Choices, 2019).

The Value of Time (VOT) and Value of Reliability (VOR) play significant roles in travel behavior. VOT is the "monetary values travelers (or consumers) place on reducing their travel time (i.e. savings)" (Carrion & Levinson, 2012). VOR is the "monetary values travelers place on improving the predictability (i.e. reducing the variability) of their travel time" (Carrion & Levinson, 2012). It is important to note that travelers may not always want to reduce their travel time and may enjoy aspects of travel (Morris & Guerra, 2015a; Mokhtarian & Salomon, 2001; Morris & Guerra, 2015b; Ory & Mokhtarian, 2005; White & Dolan, 2009). These enjoyments include "adventure-seeking, variety-seeking, independence, status, buffer, exposure to the environment, scenery and other amenities, synergy, escape, curiosity, conquest, and physical exercise" (Ory & Mokhtarian, 2005). 31% of the 1.3 million people in the RGVMAB are currently in poverty (The Rio Grande Valley Metropolitan Planning Organization, 2020). Despite this, most travel is done by motor vehicle instead of alternative modes of transportation. This is likely due to the area's lack of active transportation facilities and public transportation services.

Life Events

If habits are a significant reason for travel behavior, major life events disrupt those habits (McCarthy et al., 2017). Literature indicates that travel behavior changes are more likely during significant life events (Clark et al., 2014). A life event, defined by the literature, is one where "major or minor life events that may cause changes in one's life and relationships" (Clark et al., 2014). Examples include changes in "household composition, employment status, or residential or job location" (Clark et al., 2014). These life events disrupt habits and "provide a valuable opportunity to influence the adoption of sustainable transport modes" (McCarthy et al., 2017; Beige & Axhausen, 2012; Clark et al., 2014; Verplanken & Wood, 2006).

This is especially true for households who have young children. McCarthy et al. note that "households with young children face several spatial and time constraints in meeting their travel

needs (McCarthy et al., 2017; Dowling, 2015; Schwanen, 2011; Wheatley, 2014). Accommodating childcare, employment, and household responsibilities can restrict the time available for parents to meet their own and their child's travel demands" (McCarthy et al., 2017; Dowling, 2015) It is essential to understand the reasoning of these life events. Clark et al. point out that some life events "can be stimulated by an unsatisfactory travel situation (in particular, home and job changes in response to long commutes)" (Clark et al., 2014).

While it would be hard to measure life events in the Rio Grande Valley, or any region for that matter, this review can use households with children as a proxy for life events, considering that having children is one of the most significant life events that impact changes in travel behavior. The number of households with one or more people under 18 years old in Cameron County, Texas, is 42.5%; in Hidalgo County, Texas, the percentage is 46.6% (U.S. Census Bureau). This region is much younger and has more households with children than the state or the country (U.S. Census Bureau). This implies that there are many opportunities to break travel habits as people experience major life events, such as having children. However, the ability to change those habits has to be there.

Time of Travel

The time that travel is done can greatly impact travel behavior. This is seen as car trips are made at higher rates on the weekends, as found in several studies (Klöckner & Friedrichsmeier, 2011; INFAS & GIW, 2004; O'Fallon and Sullivan, 2003). Trips on Saturday and Sunday are lower than those made on weekdays (Klöckner & Friedrichsmeier, 2011; INFAS & GIW, 2004). "Trips during daylight hours are a little less likely to be conducted by car than trips during the night" (Klöckner & Friedrichsmeier, 2011). A representative analysis of German travel patterns (Klöckner & Friedrichsmeier, 2011; INFAS & GIW, 2004) shows that "40% of all trips as a car driver fall between 16:00 and 05:00, the respective number for public transportation is only 28%" (Klöckner & Friedrichsmeier, 2011; INFAS & GIW, 2004).

According to the 2018 Household Travel Survey for the Rio Grande Valley, the "peak hour for household travel was from 7:00 a.m. to 7:59 a.m., during which 18.3 percent of the trip starts occurred (Singh et al., 2020). The second highest hour for trip starts was from 3:00 p.m. to 3:59 p.m. when 12 percent of the daily trip starts occurred" (Singh et al., 2020).

Environmental Awareness

"Individual car use is one of the largest single contributors to CO2 emissions in the private sector" (Klöckner & Friedrichsmeier, 2011). One study found that "The greenhouse gas emissions generated from the transportation sector account for about 30% of the total emissions in the U.S." (Ding et al., 2017; Liu & Shen, 2011). The impact of transportation on greenhouse gas emissions is even more concerning as vehicle miles traveled (VMT) have increased over the last few decades (Ding et al., 2017). "The total climate impact is determined almost entirely by car (~46%) and air travel (~45%), with smaller contributions from public transportation" (Aamaas et al., 2013).

Some studies have shown that those more environmentally concerned are more likely to engage in sustainable travel behaviors and more willing to pay for it (Holmes et al., 2021). One study regarding university students showed that "participants who had recently moved and were environmentally concerned used the car less frequently for commuting to the university" (Verplanken et al., 2008). Other studies have found conflicting results. One study highlighted the cognitive dissonance and attitude-behavior gap of consumers showing that "although respondents were involved with environmental organizations where their daily tasks were to organize environmental protection or conversation, their behavior while traveling resulted in different outcomes" (Holmes et al., 2021). Other authors have shown the difficulty for tourists to "translate their attitude into sustainable vacation behavior" (Holmes et al., 2021). Given that "leisure trips make a substantial contribution to both the total volume and climate impact" it is essential that change leisure travel behavior given that they have a "higher share of air travel" (Aamaas et al., 2013).

No data regarding environmental attitudes in the Rio Grande Valley was found. However, the Rio Grande Valley has a long history of supporting environmental protection. The Rio Grande Valley is home to the National Butterfly Center and the Rio Grande River, and it is one of the world's top destinations for bird watching since it is the main migratory path for birds going south. The Rio Grande Valley is also largely an agricultural area that famously grows all kinds of citrus fruits (Valley Central, 2020). It is common to find schools in the region taking students to local city and state parks to learn more about the importance of environmental protection (Martinez, 2021).

Technology

The literature shows that "urban and settlement development has always been closely linked to transport and the development of technological mobility innovations" (Soteropoulos et al., 2019). This link makes new mobility technologies like automated vehicles (AV) disruptive to travel behavior. Several studies have demonstrated the impact of AVs on our mobility environment, such as increased VMT (Soteropoulos et al., 2019). Malokin et al. show that AVs promise that users will not have to "pay attention to the road," thus allowing users to use their travel time more "productively" (Malokin et al., 2019). This can have a potential negative impact on public transportation use.

Information, Communication, and Technology (ICT) also impact travel behavior (Lavieri et al., 2018). "Viswanathan and Goulias observed a positive correlation between phone call usage and physical mobility, whereas Internet use correlated negatively to time spent on travel" (Yuan et al., 2012; Viswanathan & Goulias, 2001). Much of this can be attributed to the blurring of the physical and digital worlds (Malokin et al., 2019). The internet can allow people to do things virtually rather than costly travel. Many activities, such as shopping and meeting people, can be done virtually. Others like Mokhtarian, point out that transportation problems will not go away because of internet substitution because "(1) not all activities have an ICT counterpart; (2) ICT is not always a feasible alternative to physical travel (e.g., the limitation of cyber-infrastructures); (3) ICT is not always a desirable substitute (e.g., hanging out with friends in a bar); (4) Travel carries some positive utility; (5) Not all ICT activities can replace travel. The authors also discussed seven aspects where ICT can be a substitute for physical travel" (Yuan et al., 2012; Mokhtarian, 2009).

The Rio Grande Valley is increasingly becoming a more connected and technology-focused region. SpaceX has chosen the RGV as its home for launching rockets and has helped Brownsville grow into a space travel town (Rosales, 2023). However, the RGV still faces serious challenges with ICT infrastructure. One study showed that four of the five least connected cities were in the Rio Grande Valley (Granham, 2021). Some communities are trying to improve this reality, like Donna, Texas, whose school district purchased internet towers early in the COVID-19 pandemic to connect students to online learning (Varma, 2020).

Technologies like ride-hailing services have also recently started in the region. Uber started providing services in the region in 2017 (Valley Central, 2017). As ridehailing services and new

transportation technologies become more common, the opportunity to change Travel behavior in the RGV will follow.

Built Environment

Researchers have started to investigate how the built environment influences travel mode choice behavior with mixed results (Scheiner, 2010; Ding et al., 2017; Yu et al., 2023; Etminani-Ghasrodashti & Ardeshiri, 2015; Cao et al., 2009; Cervero, 2002; Zhang, 2004; Lee et al., 2014; Khan et al., 2014; Munshi, 2016; Cervero et al., 2019; Cervero & Radisch, 1996; Ewing & Cervero, 2010; Frank & Pivo, 1994; Handy et al., 2002; Schwanen & Mokhtarian, 2005; Sun et al., 2017; Tennøy et al., 2022; Wang & Zhou, 2017; Zhao, 2013). A large reason for this is trip distance. A resident in a compact and mixed-use neighborhood will have shorter trip durations than a sprawled suburban dweller (Mouratidis et al., 2019). These shorter trips mean alternative modes of transportation are more attractive, whereas a long trip distance would mean a higher likelihood of using a car (Klöckner & Friedrichsmeier, 2011). "People in rural households were much more dependent on private vehicle travel, whereas people in urban households were more likely to walk or bike daily or use other modes of transportation such as a train, bus, or taxi" (FHWA NHTS Report: Changing Attitudes and Transportation Choices, 2019). Schwanen & Mokhtarian stipulate that the impact of the built environment "may differ across men and women, household types and socioeconomic groups and that "residential location choice may not be independent of commute mode choice" (Schwanen & Mokhtarian, 2005; Badoe & Miller, 2000). One study showed that the built environment may influence travel behavior despite attitudes about car usage, finding that suburban-minded residents in urban areas still had "travel patterns that are more beneficial to the environment than those of true suburbanites" (Schwanen & Mokhtarian, 2005).

According to the 2018 Household Travel Survey for the Rio Grande Valley, the average vehicle trip duration was under 10 minutes, with the average vehicle trip length being 5.8 miles (Singh et al., 2020). This is done in a built environment more representative of suburban sprawl than a compact mixed-use urban landscape. The walk scores for the largest cities in the Rio Grande Valley, Brownsville, McAllen, Edinburg, and Mission, each had a walk score of 35, 41, 26, and 30, respectively (Walk Score, 2024).

Weather

Weather influences travel mode choice and the number of trips taken (Cools et al., 2010; Klöckner & Friedrichsmeier, 2011; INFAS & GIW, 2004). Ice, snow, rainfall, and low temperatures reduce the number of trips taken and create a greater preference for car travel (Liu et al., 2017; Klöckner & Friedrichsmeier, 2011; Cools et al., 2010). The impact to cycling and walking is strongest with a significant drop in those activities when rain and snow occur (Klöckner & Friedrichsmeier, 2011). Klöckner & Friedrichsmeier found that the impact on the number of trips by weather appears stronger than the modal split (Klöckner & Friedrichsmeier, 2011). Al Hassan and Barker found that traffic activity increased on days of unusually good weather, whereas on days with higher-thanexpected rainfall, traffic activity naturally decreased (Klöckner & Friedrichsmeier, 2011; Al Hassan & Barker, 1999). The literature theorizes that the increased travel activity on days with nice weather (sunshine) is most likely due to extra leisure trips taken by car (Klöckner & Friedrichsmeier, 2011).

The Rio Grande Valley enjoys a high number of hours of sunshine (Best Places, 2024). Snow and ice are rare events in the region, but rain and the threat of extreme weather events like hurricanes and heavy rainfall continue to pose a risk. Also, while the warmer temperatures are enjoyable in the winter, they pose a serious threat in the summer. The summer of 2023 experienced 97 days of temperatures above 100 degrees Fahrenheit (Extreme Weather Watch, 2024). This poses a severe health risk to people engaging in active transportation or waiting at bus stops for public transportation. These high temperatures also limit the physical activity people engage in as they avoid outdoor leisure trips (Lanza et al., 2022).

4.3. Travel Barriers of Disadvantaged Groups

This section will examine travel behaviors and barriers to disadvantaged groups. These disadvantaged groups include People with Disabilities, Seniors, Children, Lowincome, Immigrants, and Hispanics. Each section will also include an analysis of the group in the Rio Grande Valley and other Rio Grande Valley-specific information relevant to that group.

4.3.1. People with Disabilities (PWD)

Travel Behaviors

The travel behaviors of people with disabilities can be as wide of a range as the different disabilities themselves. With over 25.5 million Americans aged five and older self-reporting travel-limiting disabilities, this is a serious issue (Brumbaugh, 2018). Several definitions exist for who is considered someone with a disability. "The World Health Organization distinguishes between an impairment, disability, and handicap" (Burnett & Baker, 2001). An impairment is "a permanent or transitory psychological, physiological, or anatomical loss or abnormality of structure or function" (Burnett & Baker, 2001). A disability is "any restriction or prevention of the performance of an activity, resulting from an impairment, in the manner or within the range considered normal for a human being" (Burnett & Baker, 2001). Handicap is a "disability that constitutes a disadvantage for a given individual in that it limits or prevents the fulfillment of a role that is normal depending on age, sex, and social and cultural factors for that individual (Burnett & Baker, 2001; Abeyraine 1995). The Americans with Disabilities Act (ADA) provides a different perspective. People with a disability are "those individuals with physical or mental impairments that substantially limit one or more of the major activities of life, such as walking, talking, caring for oneself, or working" (ADA 1990; Burnett & Baker, 2001). Studies have consistently shown that people with disabilities make fewer trips compared to those without disabilities (Brumbaugh, 2018; Park et al., 2023). One study showed that trip frequency can range between "5.7 and 10.2 per week while those without disabilities can be between 7.8 and 14 per week or 30% fewer trips" made by PWDs (Park et al., 2023). Another study showed that PWDs made 25% fewer trips (Park et al., 2023). Differences in trip frequency are most significant in non-work trips. PWDs who do not drive also take "significantly fewer routine visits (0.28 times fewer) and emergency care visits (0.27 times fewer) than those without disabilities" (Mattson, 2011; Park et al., 2023). Overall, the number of trips taken by PWDs has declined over time (Brumbaugh, 2018).

The literature demonstrates that trips taken by PWDs tend to be shorter than those without disabilities (Park et al., 2023; Brucker & Rollins, 2016; Shoval et al., 2011; Lucas et al., 2016; Montarzino et al., 2007; Neven et al., 2013). These distances can range on average from "1.6 kilometers for people with disabilities, while those without disabilities can travel between 9.0-14.6 kilometers" (Park et al., 2023; Lucas et al., 2016; Montarzino et al., 2007; Neven et al., 2013). Despite the shorter distances, PWDs take longer to make those trips (Park et al., 2023; Benjamin

& Price, 2006; Brög & Ribbeck, 1985; Brucker & Rollins, 2016; Taylor & Józefowicz, 2012; Jansuwan et al., 2013; Brucker & Rollins, 2019; Lucas et al., 2016; Shoval et al., 2011). This is likely due to the increase in "time spent preparing for trips, reaching an access point (Shen et al., 2023; Bascom and Christensen, 2017), and waiting for an upcoming trip at the access point (Shen et al., 2023; Marston et al., 1997) is much longer for PWDs than the general population" (Shen et al., 2023; Rimmer et al., 2004). Shen states that this is likely why PWDs are reluctant to travel (Shen et al., 2023; Wong, 2018a; Brumbaugh, 2018).

Another significant difference between the travel behavior of people with disabilities and those without is in travel mode choice. Travel mode choice can depend on the type and severity of a person's disability (Park et al., 2023; Neven et al., 2013, 2018). Several studies have produced a wide range of results for the use of public transportation by those with disabilities, ranging from 4.6% to 51.0% (Park et al., 2023; Bezyak et al., 2017; Douglas et al., 2012). Bezyak et al. showed that "among all the means of public transportation, buses are the most widely used, with a maximum of 74% of individuals using them for their trips" (Park et al., 2023; Bezyak et al., 2017). Paratransit service, when available, proves to be a relatively popular service, with "0.9% -30.2% of the population relying on them" (Park et al., 2023; Crudden et al., 2015; Deka, 2014). Taxis have also been used often by PWDs (Park et al., 2023; Marquez et al., 2019). "Riding with others is often used by PWDs and is the only mode that increases with the increase in disability severity" (Park et al., 2023; Neven et al., 2013, 2018). Again, this does depend on the severity of the disability since many "PWDs cannot drive or even travel to and board a car" (Shen et al., 2023; Bascom & Christensen, 2017; Henly & Brucker, 2019; Taylor & J'ozefowicz, 2012; Wong, 2018b, 2018a; Lindsay, 2020).

Travel Barriers

PWDs face numerous barriers to travel throughout the entire travel process. The barriers can be grouped into three broad categories: vehicle-related, out-of-vehicle features, and attitudes and perceptions of others. Firstly, "issues with on-vehicle access can include lack of deployed ramp for boarding and alighting, lack of accessibility into other modes of transportation, and high costs of retrofitting travel modes to allow for use" (Park et al., 2023; Gaber & Gaber, 2002). Out-of-vehicle issues for PWDs are extensive: uneven surfaces, long walking distances to transit stops, inaccessible or limited destinations, lack of accessible paths, extensive physical exertion caused by climbing steep slopes, etc. (Park et al., 2023; Faber & van Lierop, 2020; Gaber & Gaber, 2002;

Meyers et al., 2002; Naami, 2019; O'Neill & O'Mahony, 2005; Sabella & Bezyak, 2019; Velho, 2019). Finally, the attitudes and perceptions of others about PWDs can limit travel. "The unreliability of certain aspects of the built environment and out-of-vehicle travel experience increases anxiety and distrust in the use of the systems" (Park et al., 2023; Bezyak et al., 2017; Laliberte Rudman et al., 2016; Sundling, 2015; Sundling et al., 2014; Velho, 2019). "Fear of falling and colliding with other passengers, fear of treatment by other passengers and staff, and constraints on personal capability such as stamina and strength hindered individuals' travel" (Park et al., 2023; Bezyak et al., 2017; Carlsson, 2004; Meyers et al., 2002; Nordbakke, 2013; Sammer et al., 2012; Sundling, 2015; Velho, 2019). "The attitudes of staff, drivers, and other passengers were repeatedly mentioned throughout various studies as a hindrance to mobility. Negative interpersonal interactions with other transit users and staff have a major impact on the feelings of confidence, independence, security, and anxiety of transit users" (Park et al., 2023; Brouwer et al., 2008; Faber & van Lierop, 2020; Feldman et al., 2020; Kersten et al., 2020; Laliberte Rudman et al., 2016; Lamont et al., 2013; Lubitow et al., 2017; Marr, 2015; Middleton & Byles, 2019; Montarzino et al., 2007; Rose et al., 2009; Sundling, 2015). These barriers impose economic costs on PWDs in two ways. First, there is the direct cost of increased costs of accessibility equipment, healthcare, and more accommodating travel modes. Secondly, employment opportunities are more limited when travel is not reliable (Shen et al., 2023; Bascom and Christensen, 2017; Kastenholz et al., 2015; Lee et al., 2012; Luther, 2013; Marquez et al., 2019). PWDs are more likely not to own a vehicle and live with an annual household income of under $25,000 (Brumbaugh, 2018).

Rio Grande Valley Context

According to U.S. Census data, the percentage of people with a disability in Cameron and Hidalgo counties is 13.2% and 11.9%, respectively (U.S. Census Bureau).

4.3.2. Seniors

Travel Behaviors

The aging of the Baby Boomer generation has ushered in one of the most significant demographic changes in the United States: the graying of America. While the number of seniors in the country has drastically expanded, the travel habits of seniors remain largely unchanged over the years. "The proportion of seniors who reported making at least one driver trip increased slightly from 80% of all seniors in 2001 and 2009 to 82% in 2017" (FHWA NHTS Report: Travel Trends for Teens and Seniors, 2017). Trips overall made by seniors also had a slight increase, with "seniors

aged 65+ increased slightly from 12% in 2001 to 13% in 2009, to 16% of all trips in 2017" (FHWA NHTS Report: Travel Trends for Teens and Seniors, 2017). While senior men have historically been the drivers, that is changing with the percentage of women aged 65 and older who are drivers continuing to increase (Lynott & Figueiredo, 2009). "The percentage of older male drivers is now in decline" (Lynott & Figueiredo, 2009). Currently, the licensing rate for men far exceeds that of older women, but this is expected to change (Lynott & Figueiredo, 2009). The percentage of drivers who are seniors on the road is growing. Currently, the percentage of drivers who are 65 and older is around 15%, but "researchers project that one in every five drivers will be over the age of 65 by 2025" (Lynott & Figueiredo, 2009). Despite the slight increase in trips, seniors continue to be more immobile than they would like, especially with age. One study demonstrated that the immobility rate for seniors aged 65-74 was 21% in 2017, while the immobility rate for seniors 75+ was 33% (FHWA NHTS Report: Travel Trends for Teens and Seniors, 2017). A survey done by Lynott & Figueiredo showed that "among adults 65+ who report not having taken a trip outside their home in the past week, a little more than half reported that they would like to get out more often" (Lynott & Figueiredo, 2009). Another study confirmed that "one-third of older people wish to engage in more activities than they currently do" (Su & Bell, 2009).

While motor vehicles are the primary mode of transportation for seniors, other modes play a vital role in senior mobility. Walking is not only a common form of exercise for seniors but is the second most used mode of transport after cars (Lynott & Figueiredo, 2009). "Older adults now take 8.8 percent of their trips on foot" (Lynott & Figueiredo, 2009). Transit is also becoming a more used mode of transportation by seniors. "Transit use by people age 65+, as a share of all the trips they take, increased by a remarkable 40 percent between 2001 and 2009" (Lynott & Figueiredo, 2009). Transit use by seniors increases if transit is available and they are nondriver (Lynott & Figueiredo, 2009). Transit use is 23% among senior nondrivers compared to 13% of senior drivers (Lynott & Figueiredo, 2009). Senior nondrivers take about 9% of their trips on public transportation (Lynott & Figueiredo, 2009). Regardless of the mode of transportation seniors use, seniors make their decisions more based on travel cost rather than travel time (Su & Bell, 2009). Seniors are "more likely to choose cheaper modes and care less about longer travel times than others" (Su & Bell, 2009).

TRAVEL BARRIERS

Seniors, much like people with disabilities, face issues of accessibility, safety, and security. Their high immobility rates mean less access to healthcare, grocery stores, and loved ones. These and other factors can negatively impact their health and longevity. When there are few alternatives to driving, seniors can feel trapped in their homes.

RIO GRANDE VALLEY

Currently, the percentage of people over 65 in Cameron and Hidalgo Counties is 14.2% and 11.5%, respectively (U.S. Census Bureau). Seniors in the Rio Grande Valley make few trips. According to the 2018 Household Travel Survey for the Rio Grande Valley, the percentage of persons making zero internal trips who are 60-64 is 2.92%, with the number jumping up substantially to 4.61% for those 65-69 (Singh et al., 2020). This trend continues, with 9.01% of people aged 80+ making zero internal trips (Singh et al., 2020). It is important to note that this includes all modes of travel, including being a passenger in an automobile. With only 0.7% of trips being made by public transportation, seniors have few options to make a trip without an automobile (Singh et al., 2020).

4.3.3. Children

TRAVEL BEHAVIORS

The travel behaviors of children provide an interesting study since depending on the child's age, the amount of independence that child has in making their own travel decisions changes (Mitra & Buliung, 2015). Because of this dependency and the narrowness of children-specific trips, much of the literature on children's travel behavior is focused on school trips. This review will define children as individuals aged 18 and younger.

Over the last 60 years, school trips have moved away from active transportation modes like walking and cycling to private motor vehicles. One study demonstrated that the "share of children (from kindergarten through grade 8) walking or bicycling to school dropped from 47.7% in 1969 to 10.7% in 2009, with bicycling accounting for just 1.1% of school trips in that year" (Underwood et al., 2014; McDonald et al., 2011). Another study showed that in 1969, "42% of American students walked or biked to school (Beschen, 1972); by 2001, that number had dropped to less than 15%" (McDonald, 2007a; McDonald, 2007). "Overall, children now make nearly 80% of their trips by auto, and only 20% of U.S. students walked or biked enough to gain health benefits" (Kann et al., 1998; McDonald, 2007). Girls are much "less likely to walk than boys, with differences being most prominent at younger ages (Evenson et al., 2003; O'Brien et al., 2000) and in suburban areas" (McDonald, 2007; Vliet, 1983). "Transit ridership was higher (22%) among

14–15 years old youth than for children (5%), which is another indication of their perceived capability of independently navigating the neighbourhood environment and urban streets" (Mitra & Buliung, 2015). Ultimately, parental availability was the largest predictor of the child's school travel mode (Mitra & Buliung, 2015).

Travel Barriers

Due to children's dependency on parents for trips, children face barriers of immobility on their trips. Distance is considered a critical factor in a child's travel (McDonald, 2007; McMillan, 2007; McDonald, 2007b; Schlossberg et al., 2006; Black et al., 2001; Timperio et al., 2006). Another factor is household car ownership (McDonald, 2007; DiGuiseppi et al., 1998). The built environment significantly affects walking to school (McDonald, 2007). McMillan conducted a study in California that showed a modest relationship between urban form and walking by elementary school students (McDonald, 2007; McMillian, 2007). A prominent factor for parents in letting their children walk or bike to school was a concern for safety (McDonald, 2007). "Parents express concern about traffic dangers and the risk of abduction or harassment (Martin & Carlson, 2005). Geographers concerned with children's sense of place have noted that safety concerns have led parents to limit the time children spend playing in public spaces, and the safety-imposed restrictions are more severe for girls than boys" (McDonald, 2007; Valentine, 1997).

Another factor for children's travel behavior was perceptions about transportation modes by the children themselves. This is especially true for biking or walking to school. The transition from walking and biking to school to car use was most significant among teenagers as they gained the ability to get a driver's license (Mitra & Buliung, 2015). Teenagers get a more negative perception of walking and cycling, considering it as "less cool," "uncool," "nerdy, dorky, geeky, weird, lame, and for losers" (Mitra & Buliung, 2015; Underwood et al., 2014). Interestingly enough, most of these comments in the study were made by women (Underwood et al., 2014). Children's negative perceptions of active transportation to school are especially concerning, given that childhood obesity has risen at similar rates to children traveling to school by private car (Mitra & Buliung, 2015; Underwood et al., 2014).

These perceptions are interesting because they do not seem to be set in stone since multiple studies have examined that driver's licenses among young adults are declining as they avoid the costs associated with a private car along with a preference for residing in the city center as opposed to the more car-dependent suburbs (Bayart et al., 2020).

RIO GRANDE VALLEY

Currently, the percentage of people under 18 in Cameron and Hidalgo Counties is 28.6% and 30.9%, respectively (U.S. Census Bureau). With a lack of alternative transportation options combined with a suburban sprawl land development, it is not hard to imagine that children in the Rio Grande Valley make few non-school-related trips—only 3.5% of trips are made by school bus (Singh et al., 2020).

4.3.4. Low-Income

TRAVEL BEHAVIORS

Low-income households tend to have a larger radius for work trips than higherincome households (Methipara, 2014). "The data shows that the mean commute distance increased from 1995 to 2009 for low-income households" (Blumenberg & Thomas, 2014). While the to work has increased for low-income households, the travel radius for all trips made by low-income folks is smaller than for higher-income folks (Methipara, 2014). "They have the lowest rates of single occupancy vehicle use and the highest usage of less costly travel modes: carpool, transit, bike and walk" (Methipara, 2014). "One study found that low-income adults commuted by carpool at rates substantially higher than those for the nonpoor" (Blumenberg & Thomas, 2014). Transit use was "two times higher for low-income adults than for adults not in poverty" (Blumenberg & Thomas, 2014). Another study found that impoverished adults took about "three times as many transit trips as those in higher income groups" (Methipara, 2014). "They also have the greatest rate of bike trips and take walk trips, about 50% more than their higher-income counterparts" (Methipara, 2014).

TRAVEL BARRIERS

Low-income families face numerous travel barriers. "In 2009, more than a third of single parents in poverty did not have access to a household vehicle, and that figure stood at approximately one-quarter for all poor adults" (Blumenberg & Thomas, 2014). Methipara found that "about 24 percent of households in poverty do not own a vehicle while over 98 percent of $100,000+ households own at least one vehicle" (Methipara, 2014). Because of a lack of car availability, they use a higher share of alternative modes of transportation and have higher vehicle occupancy rates (Methipara, 2014). "Households in poverty spend a higher proportion of their income on transportation expenses and are disproportionately represented by race/ethnicity, with AfricanAmericans and Hispanics experiencing the highest poverty rates" (Methipara, 2014).

Rio Grande Valley

Currently, 31 percent of people in the RGVMAB live in poverty (The Rio Grande Valley Metropolitan Planning Organization, 2020). Some of the most low-income areas of the Rio Grande Valley are in places called Colonias. Colonia, in Spanish, means a community neighborhood (Federal Reserve Bank of Dallas, 2015). "The Texas Office of the Secretary of State defines colonia as a residential area along the Texas–Mexico border that may lack some of the most basic living necessities such as potable water, septic or sewer systems, electricity, paved roads or safe and sanitary housing" (Federal Reserve Bank of Dallas, 2015). An estimated 500,000 people live in 2,294 colonias in Texas, many of which are in the Rio Grande Valley (Federal Reserve Bank of Dallas, 2015). 40% of the residents in colonias live under the poverty line, and an additional 20% live at or just above the poverty line (Federal Reserve Bank of Dallas, 2015). According to the Census Bureau, "about 96 percent of colonia residents are Hispanic (mostly of Mexican-American descent), and the median age is 27" (Federal Reserve Bank of Dallas, 2015). A lack of transportation options in colonias in the Rio Grande Valley was best described by Ramona Casas, social justice coordinator for ARISE: "Transportation is one of the big issues. We don't have public transportation in the colonias. But our families need transportation to move from one place to another. To go to the doctor's, to go to the pharmacy" (Taylor, 2022).

4.3.5. Immigrants

Travel Behavior

"The United States is home to over 50 million immigrants (by far the most immigrants of any nation) who make up 13.7% of the population" (Delbosc & Shafi, 2023; Budiman, 2020). They bring travel habits and perceptions regarding certain modes of transportation that inform their mode choice. While the countries of origin for immigrants vary worldwide, the travel behavior and habits of immigrants remain largely the same, according to the literature.

Immigrants tend to drive less than native-born citizens and are "more reliant on non-driving modes of transport such as public transport, walking, and cycling" (Delbosc & Shafi, 2023; Barajas et al., 2016; Barajas et al., 2018; Chatman, 2014; Chatman & Klein, 2013; Pisarski, 2007; Smart, 2015; Welsch et al., 2018; Heisz & Schellenberg, 2004; Shafi et al., 2017; Handy et al., 2008; Blumberg & Smart, 2011; Blumberg & Smart, 2010; Shin, 2017; Allen et al., 2021; Lo et al., 2011). Bike-sharing use was higher by immigrants than by native-born residents (Delbosc & Shafi, 2023; Lee et al., 2021).

This is likely because immigrants hold "more positive views of transit than native-borns due to a lack of personal transportation options, or the perceived superiority of transit services in the country of immigration compared to their home countries" (Delbosc & Shafi, 2023; Kim, 2009). Factors such as income, age when the immigrant arrived, gender, presence of ethnic enclaves, and time in a new country can impact travel mode choice (Blumenberg, 2009; Delbosc & Shafi, 2023). A study found that "higher income immigrant groups were found to cycle less and drive more" (Delbosc & Shafi, 2023; Smart, 2010).

Older immigrants are more likely to engage in active travel (walking and cycling) than younger immigrants (Blumenberg, 2009; Delbosc & Shafi, 2023; Beckman & Goulias, 2008). Myers discovered that "immigrants who arrive in the U.S. at older ages are less likely to change their travel behavior than when they are young and more adaptable to learning new behaviors and skills" (Blumenberg, 2009; Myers, 1997).

Gender can play a role in mode choice for immigrants. "A study in Canada found that immigrant women were much less likely to drive to work and four times more likely to be driven to work, even when controlling for length of residence and other factors" (Delbosc & Shafi, 2023; Preston et al., 2022). In the Netherlands, there was a larger "gender gap" in cycling among women (Delbosc & Shafi, 2023; Haustein et al., 2020). Blumenberg found that "female immigrants are more likely to rely on alternative modes of travel than male immigrants" (Blumenberg, 2009).

The literature shows that immigrants tend to assimilate to the travel behaviors of the country they reside in; for the United States, that means more single-occupancy vehicle use (Delbosc & Shafi, 2023). Blumenberg and Evans showed that "transit use is likely to decline the longer the immigrant is settled" (Allen et al., 2021; Blumenberg & Evans, 2010). Other studies have shown that immigrants tend to adopt more autodependent travel behavior (Delbosc & Shafi, 2023; Bhat et al., 2013; Chakrabarti & Painter, 2019; Lee et al., 2021; Beckman & Goulias, 2008; Heisz & Schellenberg, 2004; Pisarski, 2007; Hu, 2017; Hu et al., 2021; Tal & Handy, 2010; McGuckin & Srinivasan, 2003; Purvis, 2003; Rosenbloom & Fielding, 1998). This "travel assimilation" is especially true within five years (Tal & Handy, 2010; Blumenberg and Shiki, 2007; McGuckin and Srinivasan, 2003; Purvis, 2003; Rosenbloom and Fielding, 1998). The literature offers a reason for travel assimilation because it relates to socioeconomic and residential location (Delbosc & Shafi, 2023). Immigrants who are settled longer tend to "live in neighborhoods similar to non-

immigrant groups, a process sometimes referred to as spatial assimilation" (Delbosc & Shafi, 2023; Andersen, 2010).

Carpooling is another popular mode of transportation for immigrant groups (Delbosc & Shafi, 2023; Blumenberg & Smart, 2010; Blumenberg & Smart, 2014; Lee et al., 2021; Pisarski, 2007). This is a result of two reasons: household size and the presence of ethnic enclaves. Immigrants tend to have larger household sizes, resulting in a higher likelihood of using carpooling (Blumenberg, 2009; Blumenberg & Shiki, 2007; Blumenberg & Smart, 2008). The second reason the literature offers is due to the presence of ethnic enclaves. This is the case because the proximity of social networks and work opportunities in the community makes carpooling more likely (Delbosc & Shafi, 2023; Shin, 2017; Nguyen, 2004; Smart, 2015; Lovejoy & Handy, 2011; Shafi et al., 2022). The carpooling rates in ethnic enclaves were found to be significant, "independent of the built environment" (Delbosc & Shafi, 2023; Shin, 2017).

Travel Barriers

Immigrants tend to face a plethora of different travel barriers that limit their ability to make trips. These barriers include lack of English skills, low-income status, added responsibility to female immigrants, and federal policies relating to immigration and immigration status.

Immigrants tend to have lower literacy rates, and language barriers can make it difficult to navigate public transportation and obtain a driver's license compared to native-born residents (Delbosc & Shafi, 2023). Research finds that certain immigrant groups have an especially hard time adjusting to driving conditions in the U.S. (Matsuo, 2016; Chatman & Klein, 2013; Garni & Miller, 2008). Immigrant groups also may face higher travel demand to reach culturally specific grocery stores or "health care providers who share a common language" (Allen et al., 2021; Farber et al., 2018; Wang, 2007; Asanin & Wilson, 2008).

Immigrants tend to have lower incomes, which burdens them as they try to afford the high commuting costs (Delbosc & Shafi, 2023). "Many studies have concluded that income and other economic factors are the most important determinants of mode choice and longer-term travel choices" (Delbosc & Shafi, 2023; Blumenberg & Smart, 2010). These commuting costs include fuel, maintenance, parking, distance traveled, and access to a vehicle. Other studies confirm that immigrants tend to be lower-income and thus face lower vehicle ownership rates (Delbosc & Shafi, 2023; Blumenberg & Smart, 2010). A lack of car limits employment opportunities and can be compounded when immigrants live in suburban and rural locations with limited transit service

(Allen et al., 2021; Clark & Wang, 2010; Tal & Handy, 2010; Farber et al., 2018). This is why carpooling has emerged to help immigrant groups travel in car-dependent areas.

Several studies have documented that females, especially immigrant females, face higher travel barriers than their immigrant male counterparts. Matsuo found that Hispanic female immigrants are "much less likely to be drivers than their male counterparts" (Matsuo, 2016). Female immigrants suffer from higher rates of immobility and thus rely on carpooling more than their male counterparts (Matsuo, 2016; Blumenberg & Smart, 2010, 2014; Bohon et al., 2008; Chatman & Klein, 2013). This immobility leads to lower employment rates (Matsuo, 2016). Females also tend to take more responsibility for "household-sustaining tasks than males do and make complex trip chaining to fulfill the role" (Matsuo, 2016; Rosenbloom & Burns, 1993; Kwan, 1999; McGuckin & Murakami, 1999; Levinson & Kumar, 1995; McGuckin et al., 2005; Assaad & Arntz, 2005). One study found that Hispanic female immigrants are "limited particularly by the process of becoming a driver" (Matsuo, 2016). "Hispanic female immigrants take around 15 years, the longest out of any group, in becoming a driver" (Matsuo, 2016).

Finally, federal and state policies can play a role in the travel behavior of immigrants. Driving is anxiety-provoking for both legal and undocumented residents (Matsuo, 2016; Garni & Miller, 2008). Federal policies that discourage immigration from low-income countries reduce travel demand and decrease the percentage of immigrants who rely on alternative transportation modes (Blumenberg, 2009). Recently, the State of Texas has made it a crime to enter the country illegally, setting up a challenge with what has traditionally been a federal policy area (García & Central, 2023). Policies like this make both undocumented residents who fear deportation and legal residents who fear being racially profiled nervous. When policies that target undocumented residents pass, these residents might reduce trips or switch to non-driving modes of transportation.

Rio Grande Valley

Currently, the percentage of people born in another country in Cameron and Hidalgo Counties are 21.9% and 26.3%, respectively (U.S. Census Bureau). The percentage of Limited English proficiency (LEP) in the RGVMAB is 17% (The Rio

Grande Valley Metropolitan Planning Organization, 2020). Travel in the Rio Grande Valley can be especially difficult for undocumented residents. Undocumented residents have a hard time making long-distance trips due to not having the proper documents to board airplanes and the internal border checkpoints in Falfurrias and Sarita that deter undocumented residents in the Rio

Grande Valley from traveling north. Short-distance trips are also difficult for all the same reasons stated earlier regarding immigration enforcement, including the most recent law allowing state and local police to arrest undocumented residents. The increased police presence discourages undocumented residents from making non-essential trips for fear of deportation (Matsuo, 2016; Garni & Miller, 2008).

4.3.6. Hispanics

TRAVEL BEHAVIOR

Hispanics are becoming a larger share of the United States population and will soon outnumber Caucasians in states like Texas (Jimenez & Mattingly, 2009). This is mainly due to Caucasian populations getting older, higher international immigration, and a high Hispanic birth rate (Jimenez & Mattingly, 2009). It is essential that the unique travel behavior of this large group be understood.

The literature says a few things about Hispanics' travel behavior. "Based on average daily trips, Hispanics have the highest person trips and vehicle trips per household than any other group" (Liss, 2016). Regarding trip length, Hispanics "average the shortest person trip length and vehicle trip length compared to non-Hispanics" (Liss, 2016). "As a whole, Hispanics and African-Americans have the lowest levels of mobility and also the highest levels of poverty" (Liss, 2016). Another study found that "U.S.-born Hispanics had much lower incomes than Caucasians, their average household size was greater, and vehicle ownership was significantly lower. The U.S.-born Hispanic cohort made a comparable number of work trips as the Caucasian cohort and family, and the production rate of personal trips was quite similar" (Jimenez & Mattingly, 2009). "From a person miles traveled per household standpoint, Hispanics travel more than African Americans but less than non-Hispanic whites and other non-Hispanics. This pattern holds for vehicle miles traveled" (Liss, 2016).

A possible reason the literature provides for why Hispanics have more trips per household is due to having, on average, a larger household (Liss, 2016). Hispanics are most likely to have additional related adults living together, while white families have the lowest percentage of related adults living under one roof (Liss, 2016). In one survey, "Hispanic respondents have the second-largest number of household drivers" (Jimenez & Mattingly, 2009). These larger households make carpooling an often-used mode of travel for Hispanics (Cline et al., 2009).

While the larger households do contribute to more trips, multiple studies have shown that even accounting for persons in a household, "Hispanics made more churchschool trips than Caucasians, which may indicate that Hispanics produced more nonwork-related trips than Caucasians" (Jimenez & Mattingly, 2009). Studies show that "U.S.-born Hispanics tended to emulate Caucasian travel behavior and attitudes more closely than any other minority cohort; however, sociodemographically, these cohorts were significantly different" (Jimenez & Mattingly, 2009).

"In terms of transit use, Hispanics have lower levels than African Americans but higher than others. NHTS data has shown a low drive alone trip rate for Hispanic females, which is likely due to the lower rate of female drivers in Hispanic households" (Liss, 2016). "Elderly (ages 65+) Hispanics are five times more likely to use public transit than their non-Hispanic counterparts. This is likely because elderly Hispanics are twice as likely to live in urban areas with rail than their non-Hispanic counterparts. 44% of Hispanic households with elderly members also live at/below the poverty line" (Liss, 2016). "The largest percentage of elderly non-Hispanics live in non-urbanized areas while the largest percentage of elderly Hispanics reside in urban areas with subway or rail. Over 50% of U.S. immigrants also live in urban areas with subway or rail, and 31.1% of immigrant households are at or below poverty level" (Liss, 2016).

It is important to note that several parts of Hispanic travel behavior overlap with the literature on immigrants' travel behavior. This is unsurprising given that "according to 2014 Census data, almost 50% of immigrants are Hispanic" (Liss, 2016). Hispanics, like immigrants, face a higher likelihood of being low-income and not having access to a private vehicle. Hispanics, like immigrants, are also particularly known to carpool more than others (Matsuo, 2016; Cline et al., 2009; Lovejoy and Handy, 2008; Lovejoy and Handy, 2011; Valenzuela et al., 2005).

However, the travel behaviors of Hispanics and immigrants differ in some ways. One study used a multivariate analysis to show that "Hispanic immigrants drove less than U.S.-born Hispanics, even after sociodemographics were taken into account" (Jimenez & Mattingly, 2009). Hispanic immigrants also had far lower vehicle accessibility rates than U.S.-born Hispanics (Jimenez & Mattingly, 2009).

Travel Barriers

Hispanics face several travel barriers that impact their travel behavior. Hispanics have lower household incomes than other racial/ethnic groups (Cline et al., 2009). This lower economic status places a higher burden on households for commuting costs (Cline et al., 2009). "In 2006, average

earnings for Hispanic workers were 70.9% of that of all workers (Cline et al., 2009). At the same time, median household incomes for Hispanic households were 78.4% that of all households" (Cline et al., 2009; DeNavas et al., 2007). This also limits the ability to have a private vehicle. To overcome this, many Hispanics tend to carpool to their place of employment, especially in locations where public transportation is not available active transportation is not feasible (Cline et al., 2009; Pucher & Renne, 2001; Pisarki, 2006; Teal, 1986; Morney, 2007). These informal transportation services can include "jitney type van services or "camionetas," whereby riders pay drivers a flat fee to access work or other destinations" (Cline et al., 2009; Polzin et al., 2001; Bohon et al., 2008; Valenzuela, 2003; Toole-Hult et al., 2005). Hispanics also can face racial profiling regarding immigration status, which causes anxiety for Hispanics making trips by motor vehicle (Matsuo, 2016; Garni & Miller, 2008).

RIO GRANDE VALLEY

Currently, the percentage of Hispanic people in the RGVMAB is 91% (The Rio Grande Valley Metropolitan Planning Organization, 2020). This makes the Rio Grande Valley one of the regions with the highest percentage of Hispanics. The 2018 Household Travel Survey for the Rio Grande Valley aligns well with the research that Hispanics tend to carpool more frequently (Singh et al., 2020). While exact percentages of carpooling were not found, the distribution of person trips by mode of travel showed that 31.7% were by "Automobile - Passenger." (Singh et al., 2020). This means that automobile passengers were the second-highest mode of travel for people, and it is not a reach to say that many traveled by carpool (Singh et al., 2020). This also makes sense when looking at the weighted average household size in the study, which was 3.1 persons per household, with 23.1% of households having 5+ people (Singh et al., 2020).

4.3.7. Overall

This section covered the travel behaviors and barriers of several disadvantaged groups. This review covered the relevant literature and demonstrated the connection to the Rio Grande Valley that impacts each group. The travel barriers of each group were also demonstrated and can provide lessons on how to address these challenges to improve accessibility to transportation for all disadvantaged groups.

4.4. Health Impacts on Users

According to the World Health Organization, transportation is one of the top ten social determinants of health (Wasfi et al., 2013; Wilkinson & Marmot, 2003;
Commission on social determinants of health, 2008). With so much time spent traveling, this makes sense. This section will review travel's negative and positive impacts on mobility users' physical and mental health.

4.4.1. Negative Physical Health Impacts

Numerous studies have demonstrated that commuting by motor vehicle negatively impacts a mobility user's health. Negative impacts include higher blood pressure, obesity, poor sleep quality, fatigue, low self-rated health, hypertension, decreased cardiovascular fitness, stress, low energy, and illness-related work absences (Hansson et al., 2011; Hoehner et al., 2012; Evans et al., 2002; Gottholmseder et al., 2009, Kluger, 1998; Sandow et al., 2014; Bopp et al., 2013). A study by MacDonald showed that "spending more time in passenger cars is associated with a statistically significant increase in obesity" (MacDonald et al., 2010; Tajalli & Hajbabaie, 2017). A similar study conducted by Frank demonstrated that "obesity increases about 6% for each hour spent in a car per day" (Frank et al., 2004; Tajalli & Hajbabaie, 2017). These health effects were "all prognostic for heart disease, diabetes, and some forms of cancer" (Hoehner et al., 2012; Sandow et al., 2014).

"Noise exposure from motor vehicles also creates negative health impacts. Noise is a pervasive component of day-to-day life and is associated with both auditory and nonauditory health effects like cardiovascular diseases, diabetes, anxiety, and depression" (Basner et al., 2014; Ising & Kruppa, 2004; Lusk et al., 2004; Mette & Andersen et al., 2013; Dzhambov & Dimitrova, 2017; Wang et al., 2023). Noise from commuting creates an environmental stressor. Despite the numerous studies, some, like Matthews, argue that "existing studies on the causal relationship between noise exposure, noise perception, and health have yielded inconsistent findings which may be attributed to conceptual and methodological issues" (Matthews, 2008; Wang et al., 2023).

4.4.2. Positive Physical Health Impacts

Traveling is not all doom and gloom for one's health, but the mode and matters. Ultimately, reducing car usage and replacing as many of those trips with active transportation like walking or cycling improves one's health. An overwhelming number of studies confirms that walking and cycling are linked to better health outcomes like lowering the rate of obesity (Tajalli & Hajbabaie, 2017; Edwards, 2008; Vuori & Oja 1999; Merom et al., 2010; Oja et al., 1998; Kaczynski et al., 2012; de Geus et al., 2007; Dill, 2009; Scheepers et al., 2014; Liao et al., 2016; Schauder & Foley, 2015; Hemmingsson et al., 2011; Litman, 2010; Hamer & Chida, 2008a; Genter et al., 2008). Walking is a common exercise, especially among older adults, and has been "directly linked to reduced risk for cardiovascular health complications" (Voss et al., 2016; Ashe et al., 2009; Hamer & Chida, 2008a, 2008b). Even replacing car commuting with public transportation can improve a user's health since users often walk to bus or train stations (Tajalli & Hajbabaie, 2017; Rojas-Rueda et al., 2012; Lachapelle & Frank, 2009; Humphrey, 2005; Rundle et al., 2007; Liao et al., 2016; Sener et al., 2016; MacDonald et al., 2010; Wener & Evans, 2007; Noorbhai, 2022; Tight et al., 2016; Rissel et al., 2012; Bopp et al., 2013; Morabia et al., 2010). One study by Zheng "noted that those commuting by public transportation were 44.6% less likely to be overweight due to an increase in walking or biking associated with transit use" (Bopp et al., 2013; Zheng, 2008). According to a study by Rabl and de Nazelle, active transportation "helps reduce air pollution, which in turn contributes to reducing the risk of cancer" (Tajalli & Hajbabaie, 2017; Rabl & de Nazelle, 2011; Litman, 2010). Others have confirmed that reducing car usage improves the air quality and health outcomes for people (Tajalli & Hajbabaie, 2017; Rojas-Rueda et al., 2012; Sælensminde, 2004).

4.4.3. Negative Mental Health Impacts

Traveling takes a toll on a user's mental health, so much so that we even have a special term for it: road rage. This term has only entered our vocabulary because driving on congested highways can provoke "anger, hostility, and sometimes overt aggression" (Novaco, 1991; Sleek, 1996; White & Rotton, 1998; Vest et al., 1997). "The strain of commuting is associated with raised blood pressure, musculoskeletal disorders, lowered frustration tolerance, increased anxiety and hostility, being in a bad mood when arriving at work and coming home in the evening, increased lateness, absenteeism and turnover at work, as well as adverse effects on cognitive performance"

(Koslowsky et al., 1995; Stutzer & Frey, 2008). Multiple studies have found that both the distance of a commute and the lack of perceived control as a result of congestion on the road are responsible for increased stress and negative mental health effects (Sandow et al., 2014; Hansson et al., 2011; Hoehner et al., 2012; Hassink & Fernández, 2018; Gimenez-Nadal & Molina, 2019; Gimenez-Nadal et al., 2018a, 2018b; Kluger et al., 1998; Tajalli & Hajbabaie, 2017; Wener & Evans, 2011; Bellet et al., 1969; Ferenchak & Katirai, 2015; Gatersleben & Uzzell, 2007; Künn-Nelen, 2015; Rissel et al., 2014 Evans et al., 2002; Gottholmseder et al., 2009; Koslowsky et al., 1996). Lengthy commutes and lack of transit can manifest in an increased chance of being screened for depression (Wang et al., 2019). These negative feelings can also manifest in several other ways, as Gimenez-Nadal & Molina show that "more time spent in commuting is positively related to higher levels of sadness and fatigue during childcare activities, pointing to longer commutes being associated with a lower quality of child care activities of working parents" (Gimenez-Nadal & Molina, 2019). Lengthy commutes can lead to less time for other daily activities and insufficient energy or time for work and family (Sandow et al., 2014).

People who commute further distances sometimes do so because of increased pay or cheaper housing, but the compensation rarely outweighs the cost from negative health impacts (Fults, 2010; Stutzer & Frey, 2008; Sandow et al., 2014). Gimenez-Nadal & Molina put it plainly that better health would allow someone to increase the amount of time available to produce monetary earnings in the future and reduce inequalities among children's wealth, which impact future earnings (Gimenez-Nadal & Molina, 2019).

4.4.4. Positive Mental Health Impacts

The literature clearly shows that travel satisfaction is relevant to subjective wellbeing (SWB), and the main factor influencing travel satisfaction appears to be travel mode (Norgate et al., 2020). The mode of transportation that is associated with the highest travel satisfaction across all geographical settings is active travel modes (Olsson et al., 2013; Sandow et al., 2014; Tajalli & Hajbabaie, 2017; Morris, 2015; Norgate et al., 2020). Walking and cycling are not only related to less negative health outcomes but are considered more pleasant, exciting, and lower stress than commuting by car, train, or bus (Olsson et al., 2013; Sandow et al., 2014; Tajalli & Hajbabaie, 2017; Norgate et al., 2020; Scheepers et al., 2014; Morris, 2015; Bloomberg MRTAF, 2009). While some, like Mouratidis et al., have found that public transportation is associated with lower travel satisfaction, others have found that it is associated with higher travel satisfaction when compared to cars due

to experiencing a lower level of stress because they do not experience traffic congestion and feel less isolated (Mouratidis et al., 2019; Tajalli & Hajbabaie, 2017; Wener & Evans, 2011; Evans et al., 2002; Boniface et al., 2015). Travel satisfaction can go down if the public transit is overcrowded, unreliable, or if the trip duration is long (Tajalli & Hajbabaie, 2017; Gatersleben & Uzzell, 2007; Singer et al., 1974; Cox et al., 2006). This is especially true when the urban form is compact, leading to shorter trip durations (Mouratidis et al., 2019).

Tolerance for commuting can increase if other activities can be conducted while traveling that can "add positive utility to the commute" (Sandow et al., 2014). Sandow et al. states that examples can include: "reading, listening to music or relaxing, mentally shifting between one's work and home, or using the time to work with modern information technology" (Sandow et al., 2014; Gottholmseder et al., 2009; Lyons & Urry; 2005; Ory & Mokhtarian, 2005).

4.4.5. Rio Grande Valley Context

Understanding the role of transportation on health is essential to understanding some of the contributing factors to the Rio Grande Valley's current health status.

Unfortunately, the Rio Grande Valley currently suffers some higher-than-average rates of obesity, Alzheimer's, hypertension, and diabetes (The Associated Press, 2004). The RGV was particularly hit hard during the COVID-19 pandemic, with higher-than-average mortality rates (Champagne, 2020). While several factors contribute to this, the lack of sidewalks, bicycle lanes, and the ability to engage in active transportation certainly play a role (Platoff & Central, 2017). The RGVMAB in the RGVMPO 2045 MTP showed that there are only 2,200 miles of sidewalks for the entire region, 114 miles of hike and bike trails, and 2 miles of protected bikeways (The Rio Grande Valley Metropolitan Planning Organization, 2020). According to the 2018 Rio Grande Valley Household Travel Survey conducted by TxDOT, only 2.8% of trips were on foot and 0.4% by cycling (Singh et al., 2020). Increasing the ability of residents in the Rio Grande Valley to take trips through active transportation modes would help improve the physical and mental health of residents.

4.4.6. Overall Health Impacts

This review covered the positive and negative physical and mental health impacts of an individual engaging in travel. The mode of transportation makes a large difference in the well-being of an individual; active transportation has a far greater positive health impact on an individual than

engaging in motor vehicle travel. This review also examined how these health impacts affect travel in the Rio Grande Valley.

4.5. Conclusion

This literature review aimed to analyze and summarize over 300 research articles relating to user mobility issues. This review identified and explained the myriad mobility issues faced, covering transport rationales, psychological and situational factors, travel barriers faced by several disadvantaged groups, and the health impacts of travel from a physical and mental health standpoint. This review also connected the different mobility issues to the Rio Grande Valley.

Current studies have focused on mobility issues broadly, with little research in the Rio Grande Valley, or even the state of Texas. Furthermore, most of these mobility issues research was focused on urban environments, with little covering suburban or rural areas. This is evidenced in the amount of literature assuming that a user has access to public transportation or is an option in that individual's city.

Chapter 5. Local Rio Grande Valley Context

5.1. Rio Grande Valley Case Study

5.1.1. Local Context Introduction

At the southernmost tip of Texas is the Lower Rio Grande Valley. The area is known as the Rio Grande Valley or simply "The Valley." The three counties of Hidalgo, Cameron, and Starr County make up the region, and it sits along the Rio Grande River on the US-Mexico border. The two Metropolitan Statistical Areas include McAllen-Edinburg-Mission in Hidalgo County, with a population of 898,471 people, and BrownsvilleHarlingen in Cameron County, with a population of 426,710 people (U.S. Census Bureau, 2023). A smaller Micropolitan Statistical Area is in Starr County, known as Rio Grande City-Roma, with a population of 65,934 (U.S. Census Bureau, 2023). The region shares a border with Mexico, making it a growing urban area. The population on the Mexican side is around 1.38 million people, and they mostly live in the two major cities of Reynosa and Matamoras. The U.S. side has around 1.29 million, and the region is expected to double by 2045 (Gomez et al., 2022).

The Rio Grande Valley has a unique demographic profile compared to the rest of the country. The population in the region is 91% Hispanic, 17% Limited English, and much younger on average (RGVMPO 2045 MTP, 2020). The rapidly growing area makes novel transportation options necessary to handle the dramatic increase in travel.

Traditionally, the Rio Grande Valley has been a predominantly agricultural economy. With water access to the Rio Grande, the Valley has become one of the country's most productive agricultural areas (Santa Ana, 2017). The warmer climate has allowed for several more growing seasons. The crop of choice is overwhelmingly citrus fruits, with grapefruit being the primary fruit grown. This productivity led to the initial dramatic population growth of the Valley when farmers, mainly from the Midwest, were recruited to start farms in a campaign known as "Magic Valley" (Brannstorm & Neuman, 2009). The Valley also gains much economic activity through tourism. Folks from all over the world travel to the RGV to birdwatch. The migratory paths of the birds all come through the RGV, making it one of the premier spots for bird watching. Mission is home to the National Butterfly Center, which is gaining a ton of ecotourism activity. Around spring break, people pack South Padre Island's beaches to enjoy the nice weather and ocean.

Since ratifying The North American Free Trade Agreement (NAFTA) that allows for free trade between Canada, the United States, and Mexico, the RGV has become one of the main points of entry for products made in Mexico imported into the United States. The largest economic driver in Mexico, Monterrey, is only a two-hour drive from McAllen. Large amounts of freight on trucks pass through the Pharr-Reynosa International Bridge. The bridge is ranked the #1 border crossing in the U.S. for produce and the third largest trade hub on the Texas-Mexico border (Bazan, 2024). If someone buys an avocado from Mexico, it almost certainly goes through the Pharr bridge.

Other growing industries in the area have been education and aerospace. In 2013, the Texas State Legislature created The University of Texas Rio Grande Valley. It is an R2 research university and is in the top ten largest universities by student population in Texas. UTRGV is a predominantly Hispanic institution, with more than 95% of students being Hispanic (Taylor-Uchoa, 2023). It also has a medical school helping serve a historically underserved area (Gomez et al., 2022).

SpaceX, an aerospace company founded by Elon Musk, has created its "Starbase" in Boca Chica, a small town near Brownsville on the Gulf Coast. It has become the primary launch site for the SpaceX rockets. While it is controversial among residents, primarily because of environmental and affordability concerns, it has grown the area's economic activity (Hooks, 2021). The City of

Brownsville has leaned into this industry and is hoping for Brownsville to become the future space tourism destination (Lingle, 2024).

Almost all RGV trips start and end within the MSA. The map below shows that the bulk of these trips are in the McAllen-Edinburg-Mission MSA (RGVMPO 2045 MTP, 2020).

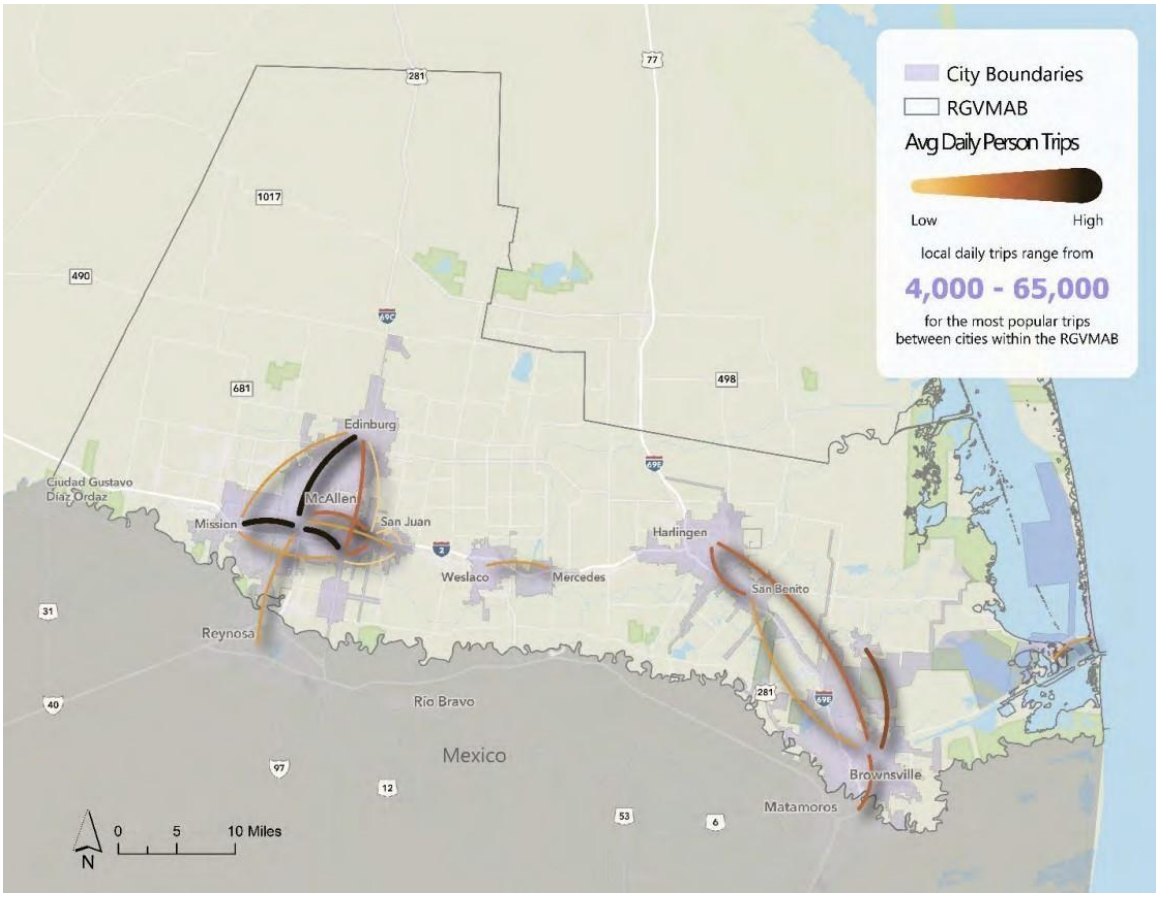

***Figure 5-1**: RGVMAB Desire Lines (RGVMPO 2045 MTP, 2020)*

The current mobility options in the Rio Grande Valley are limited. Private motor vehicles remain the largest mode of travel, encompassing 90% of all personal trips according to the 2018 Household Travel Survey (Singh et al., 2020). Public transportation makes up 0.7% of all trips. Five major transit providers serve The Rio Grande Valley: B

Metro, Island Metro, Metro McAllen, UTRGV Transit, and Valley Metro (RGVMPO 2045 MTP, 2020). As of 2020, only 38% of the population of Hidalgo and Cameron counties are "within a 0.25-mile walkshed to a regional transit route" (RGVMPO 2045 MTP, 2020).

Active transportation in the RGV is also underdeveloped. Hidalgo and Cameron counties had 178 miles of bike lanes and cycle tracks, with only 2 miles (1%) being protected bicycle lanes (RGVMPO 2045 MTP, 2020). The counties also have around 2,200 miles of sidewalks, with 75% of transit provider connections having "poor sidewalk connectivity" (RGVMPO 2045 MTP, 2020).

Chapter 6. Interviews

For this project, the interviews aimed to identify mobility challenges users faced in the Rio Grande Valley along with information to draw further conclusions about the ability and willingness to try a multi-model subscription service like MaaS.

6.1. Who Was Interviewed?

This research involved over 20 participants from the Rio Grande Valley. A snowball sampling method was employed to identify and hear from as many participants as possible. The participants ranged from Hidalgo and Cameron counties and came from various backgrounds. Interviews were conducted face-to-face, over Zoom, or by telephone, and the time it took to conduct each interview ranged from around 20 to 55 minutes.

6.2. What Questions Were Asked?

To get the most helpful information out of the interviews, careful consideration was given to what questions were asked and in what order they were asked. The interviews aimed to identify mobility challenges users faced in the Rio Grande Valley along with information to draw further conclusions about the ability and willingness to try a multi-model subscription service like MaaS. The first set of questions related to travel habits in general. Interviewees would be asked which mode of transportation they use on the weekdays: drive alone, drive together or driven by family members, share ride with co-workers, take a bus or train, bike/walk/scooters, Taxi or Uber/Lyft, demand-responsive, or other. This question helps identify the modes of transportation most used and how much they use other modes. Next, travel distances to familiar places like workplaces,

schools, grocery stores, healthcare facilities, and other everyday non-work trips (coffee shops, gyms, parks, places of worship, etc.) were asked. The answers could be <2 miles, 2-5 miles, 5-10 miles, 10-20 miles, or more than 20 miles. This would help enlighten people on general trip distances and see if other modes of transportation could be possible. Another helpful set of questions related to traffic and the time it took to get to work. Interviewees were asked how much time it generally took to get to and from work and about their perception of traffic. This is useful in seeing if respondents believe traffic is getting worse and how their time to work might be impacted by traffic. Finally, for this section, the approximate monthly costs interviewees spent on different transportation modes were asked. The modes asked were driving, public transit, taxi, Uber/Lyft, and demand-responsive services. The interviewees could respond with the following answers: never used it: <$50, $50-$100, $100-$200, $200-$500, or $500 or more. These questions help clarify how much users spend on different transportation modes and what they include or do not include in those cost estimates.

The next set of questions related to transit and ride-hailing service use. Each interviewee was asked about the frequency with which they use the service. The answer choices could be daily, 2~3 days a week, occasionally, or never. Next, they were asked about issues they encountered with each service. For transit, they were asked about the following issues:

- Route and stop location information
- Schedule information
- Fare payment methods (how and where to pay)
- Access (how to get to/from bus stops)
- Parking near stops/terminals
- Convenience (number of transfers to get to the final destination)
- Safety
- Cleanness (stop place, vehicle)
- Privacy
- Weather
- Self-image (negative perceptions about people who use transit)
- Other issues

Interviewees were asked to provide examples of the issues they identified. After elaborating, interviewees were asked whether they believed RGV should provide more public transportation

services and why. These questions would get at the core of the mobility issues that users in RGV face. The same questions were asked about ride-hailing services such as taxis, Uber, or Lyft. Users' issues with ride-hailing services could be reservation (easy or difficult or not know how), cost, access: no smartphone or internet access at home or work, safety, security, etc. MaaS involves many of these issues, so identifying those issues now would help in knowing what to expect should a MaaS offering be made.

The third section involves asking interviewees about access and use of technology. Since any MaaS offering would involve technology, access and frequent use of technology is necessary. Interviewees were asked if they had access to a smartphone and, if so, if that smartphone had a data plan allowing them access to the internet. Then, interviewees were asked if they had internet access at home and the workplace, and if so, whether that speed was high, medium, or low-speed internet. To inquire about the usage of technology, interviewees were asked if they shop online using smartphones or computers frequently, occasionally, or never. They were also asked if they handle personal/family/or travel business using a smartphone or computer. This could draw conclusions about a user's ability to purchase a MaaS offering using their smartphone or computer. Finally, interviewees were asked about whether internet infrastructure in the Rio Grande Valley needed improvement.

The final section asked interviewees about basic person and household characteristics. These included gender, age, possession of a driver's license, employment, number of people in the household, number of children 14 or younger, number of people aged 65 or older, number of people with jobs, number of cars/trucks in the household, number of bikes in the household, owning or renting a home, location of household, and a range of annual household income. Interviewees were finally asked if they had general comments, thoughts, and suggestions about transportation services in the Rio Grande Valley.

6.3. Interview Questions for Maas Research

6.3.1. Travel Related

1. How do you get around on weekdays? (which mode you use the most, which mode secondary, third, etc.)
2. How far is your home from your workplace?

3. How far is your home from your (or your children's) school?

4. How far is your home from your family doctor or the healthcare/clinic/hospital that you visit the most?

5. How far is your home from your grocery store?

6. What are non-work trips you frequently take and about how long does it take you to get to them? (gym, park, shopping, food, coffee shop)

7. How do you typically get there?

6.3.2. Travel related concerns or issues

8. Time: spent in travel to work (one way average)

9. How often do you experience traffic?

10. Is traffic getting (better, worse, or about the same)

Cost: approximately dollar amount spent MONTHLY by the person (interviewee) in travel for all travel purposes

11. Driving (combining costs in gasoline, parking, toll):

12. Taking bus or train:

13. Using Taxi/Uber/Lyft:

14. Using Demand-responsive service:

15. Main issues, concerns

6.3.3. Experience in Using Transit and Ride-Hailing Service

16. How frequently do you use the bus?

17. What are the issues of using or not using bus services? (please describe with examples)

18. Should RGV provide more bus (public transportation) services? (please elaborate)

19. How frequently do you use Uber/Lyft/Taxi or any form of ride-hailing services?

20. What are the issues of using or not using ride-hailing services? (please elaborate with examples)

21. Should RGV provide more ride-hailing services (please elaborate)

6.3.4. Access to and Use of Technology

22. Do you have a smartphone (Does everyone in your family have a smartphone?)

23. If you do have a smartphone; do you have a data plan that gives you internet access on the phone?

24. Does your home have internet access? If so, high-, medium-, or low-speed?

25. Do you have internet acccess at the workplace? If so, high-, medium-, or lowspeed?

26. Do you shop online using computers?

27. Do you shop online using smartphones?

28. Do you handle personal/family business (paying bills, banking, etc.) using computers?

29. Do you handle personal/family business (paying bills, banking, etc.) using smartphones?

30. What other activities do you do with smartphones? (e.g., book airline tickets or hotels, search for rental car or public transit information in cities you are traveling to)

31. Should RGV improve further its internet infrastructure? (please elaborate)

6.3.5. Person and household characteristics

32. Gender?

33. Age?

34. Driver's license?

35. Employed? Full-time or part-time?

36. If employed, occupation type? (e.g., construction, services, education, business, government, etc.)

37. Number of people in household?

38. Number of children 14 or younger?

39. Numbe rof people aged 65 or older?

40. Number of people with jobs (full or part-time)

41. Number of cars/trucks in household

42. Number of bikes in household

43. Own or rent home?

44. Location of home: City? Neighborhood?

45. Range of annual household income

46. General comments, thoughts, and suggestions about transportation services in RGV.

Chapter 7. Interview Results

In order to understand further what mobility issues transportation users in the Rio Grande Valley face, twenty interviews with residents were conducted in both English and Spanish. This chapter will discuss who was interviewed, respondents' travel habits, their views on public transit and ride-hailing services, their access to technology, and general demographic and household data regarding the respondents. These interviews give color and nuance to the data and literature regarding mobility issues and the Rio Grande Valley up to this point. These responses also offer lessons beyond MaaS. The issues that respondents face is not dissimilar to the issues mobility users around the United States face. Understanding the responses from these interviews grounds this report for how MaaS may or may not have a future in the Rio Grande Valley.

7.1. Personal and Household Characteristics

Overall, twenty interviews were conducted with residents. Eighteen of these interviews were in English, with two in Spanish. Interviews in Spanish were done by translating the questions originally written in English. Responses were written in their original Spanish and later translated to be aggregated with the remaining eighteen responses. The respondents' genders are 55% male, 40% female, and 5% non-binary.

The selection of interviewees started as people I know personally and through them, I employed a snowball sampling method. It is important to note that this means the respondents are not considered representative of the region. However, given that these interviews are one of less than a handful of original research into transportation issues facing the Rio Grande Valley, the answers of these respondents offer a lot of insight into the current state of transportation experiences in the region.

Because the interviewee selection process started initially with people I personally knew, the ages of respondents skewed younger. 40% of respondents are between the ages of 25-34, 35% are between 18-24, 20% between 45-54 and 5% between 35-44. It is crucial to keep in mind that the Rio Grande Valley is, on average, a younger region than most, with a median age of 29.4 years for McAllen MSA and 31.7 years for Brownsville MSA (Gomez et al., 2022). These numbers are younger than the median USA age of 38.2 years (Gomez et al., 2022).

The percentage of people with a driver's license is 90%, with 10% of respondents not having one. In terms of employment, all respondents are employed. 75% are employed full-time, with 25% employed part-time. The industries employed varied significantly. These industries included, but are not limited to, education, service, healthcare, financial services, manual labor, law enforcement, art, and transportation services.

The respondents' households were like the existing census data for the Rio Grande Valley. Figure 7-1 below shows the breakdown of responses to the question, "Number of people in the household."

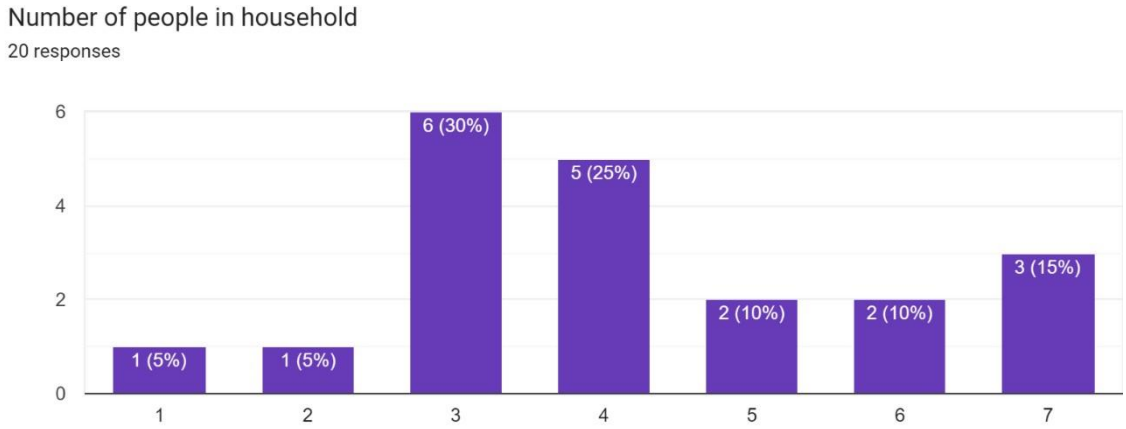

Figure 7-1: Number of people in household

The median number of people per household is four. Six respondents live in households with people fourteen and under. Five of those six households have two people fourteen and under. On the other side of the age spectrum, three households have people 65 or older, with sixteen respondents not living in households with people 65 or older.

Access to transportation, specifically vehicles and bicycles, plays a significant role. Every single respondent has access to a vehicle. All but one respondent lived in a household with more than one vehicle available. The median number of cars/trucks in the household is three. 25% of respondents have four or more vehicles in the household, with one respondent having six. The opposite result was true for the number of bikes in the household. 50% of respondents do not have

a bicycle in the household. 20% of respondents have one bike, 15% have two, 5% have three, and 10% have four.

For the household itself, 60% of respondents owned the home they lived in, with the remaining 40% being renters. Home ownership is much more common in the Rio Grande Valley due to the affordable prices. The cities that respondents live in are from much of Hidalgo and Cameron Counties. 30% live in McAllen, 20% live in Brownsville, 10% live in Edinburg, 15% live in Mission, and the remaining 25% live throughout the Rio Grande Valley.

The household incomes of respondents were broadly similar. 55% of respondents have a household income somewhere between $50,000 and $80,000. The next most common household income range was $30,000-$50,000, with 25% of respondents making this much. The remaining 20% of respondents were outliers, making over $80,000 or less than $10,000.

7.2. Travel Habits

The travel habits of the respondents offer a lot of useful information when considering a MaaS offering. While these results are not representative of the region, they do provide useful insight into travel habits, because the answers were largely consistent with each other and the 2018 Household Travel Survey. Considering distance and time to locations, respondents frequent and how they get there can offer lessons when creating a viable MaaS offering. This section will go through each question and the responses given.

Starting with "How do you get around on weekdays?" The respondents overwhelmingly said they do so by driving alone. Fifteen respondents chose this option as their primary mode of transport, with the remaining respondents saying they got around by carpooling with either family or coworkers. One respondent listed that they also bike places in addition to driving. Cars are overwhelmingly the primary mode of transportation in the Rio Grande Valley. Some respondents were even surprised to hear that other options were available for traveling often in the Rio Grande Valley. This response aligns with the current literature stating that 90% of trips in the Rio Grande Valley were done so by car (Singh et al., 2020). The next part of this question series asked interviewees about the distance they would have to travel to locations they often frequented. First, respondents were asked about the distance from their homes to their workplaces. The breakdown of the responses is represented in Figure 7-2 below.

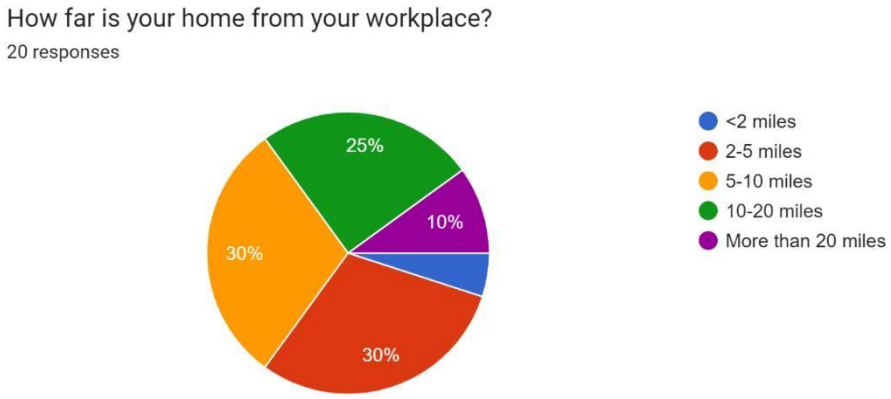

Figure 7-2: Breakdown of responses for distance in miles from home to workplace

The distances were realistically short, with 65% of respondents living 10 miles or less from their workplace. The next 25% lived between 10 and 20 miles, with only 10% living more than 20 miles. The next question asked respondents how far they lived from their or their children's school. Given the young age of the respondents, many were either not in school or did not have children in school. This was the case for twelve of the respondents. Of the remaining eight respondents who were able to answer this question, 50% lived between 2 and 5 miles, with 25% under two miles and the other 25% more than five miles.

Many struggled to answer the question about the distance to the family doctor or the healthcare clinic/hospital that the respondents visited the most. Before answering, most respondents communicated that they do not have a family doctor or frequently visit any healthcare facility. When answering, many said that the distance to the nearest hospital. The breakdown of responses to this question is represented in Figure 7-3 below.

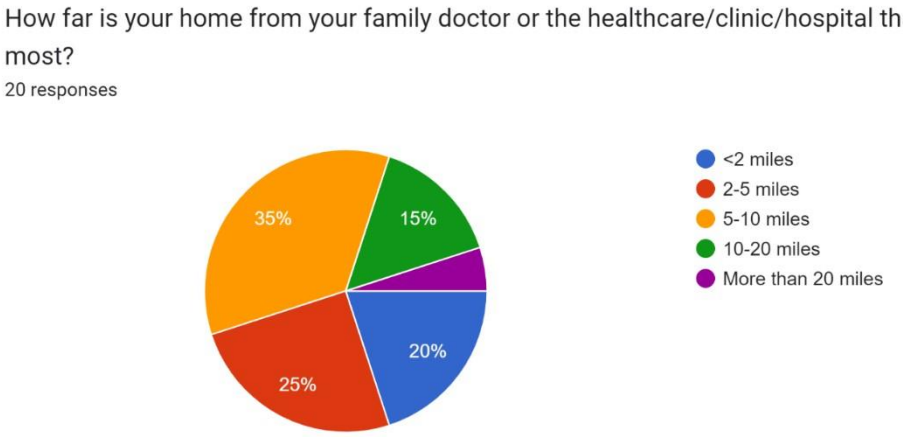

Figure 7-3: Breakdown of responses for distance from home to healthcare facility

Most respondents (80%) lived within ten miles of their healthcare facility, and the remaining 20% lived ten or more miles away. These respondents live in more rural parts of the region, so a longer distance makes sense.

When asked how far respondents lived from the grocery store, they frequent the most, 65% of respondents said less than two miles, 30% said 2-5 miles, and the remaining 5% said 10-20 miles. Lastly, respondents were asked about the non-work trips that they frequently took and how long it took them to get there. Most respondents listed places like the gym, church, parks, and places they shop or eat at. Almost all were accessible by car in under fifteen minutes. Interestingly, when respondents were asked how they typically got to these nonwork locations, the percentage of people who drove alone went from 75% to 50%. Many more people drove with family to these locations or biked/walked there. This was especially the case when the destination was a place like a church or a shopping mall.

The next set of questions is related to travel-related concerns or issues. Initially, no questions were asked about traffic specifically, but after the first interview, it became apparent that this was needed. Interviewees were first asked about the time spent traveling to work. 45% said 5-15 minutes, 45% said 15-30 minutes, 5% said less than five minutes, and the remaining 5% said 30-45 minutes. This opened the door to comments on traffic. 75% of respondents said they experience traffic daily, with 15% saying they do so 2-3 times a week. 10% of respondents who answered "Occasionally" tended to live in more rural areas. When respondents were asked if they believed

traffic was getting better, worse, or about the same, 75% responded that traffic was getting far worse, with 25% believing that traffic was about the same. Many people cited the construction on the highway as the reason for this, with some also saying that the dramatic increase in population was also contributing to increased traffic.

Respondents were asked how much they spend a month on various modes of transportation. These modes of transportation include driving, public transit, ride-hailing services, and demand-responsive. Respondents were free to include whatever they believed should be included in calculating the amount for those modes. This is especially relevant in the case of monthly driving costs. When asked about driving, 10% said they spend $500 or more, 25% said $200-$500, 35% said $100-$200, and 30% said $50-$100 a month spent on driving-related costs. As a reminder, Average transport costs in the United States for 2018 were $813 a month (United States Department of Labor, 2018; Liljamo et al., 2020). In response to driving-related costs, most respondents would say how much they spent on gas a month. This shows that many of the other driving-related costs that a person pays are not accounted for when considering approximate monthly driving costs.

As for the other modes, people were much more uniform in their answers. When asked about how much, on average, an interviewee spent a month on taking the bus or train, 70% said they had never used the bus or train, and the remaining 30% said they spent less than $20 a month on it. For ride-hailing services, like Uber/Lyft or taxis, 50% responded that they have never used it, with 40% saying they spend less than $50 a month on it. 5% spend $50-$100, and the remaining 5% spend $100-$200 monthly. 100% of respondents answered that they have never used it for demand-responsive service.

The last question in the travel habits section of the interview asked respondents if safety, security and privacy, pollution/air quality, traffic, or some other reason contributed to their decision-making of which modes of transportation to use. Respondents could pick as many issues as they wanted or did not. Twelve respondents said that safety played a role. Six respondents said security played a role. Two respondents said pollution/air quality and three respondents said traffic.

Luckily, people had much to share when asked if there were any other issues or if they wanted to describe the issues they selected. When describing safety, the thing that came up the most was other drivers. Many felt that increased traffic made people more impatient and started acting erratically while driving. Traffic was not the only reason people felt unsafe driving. Surprisingly,

drunk drivers came up a lot in people's responses, with one respondent even saying they "Def would not be driving late at night."

The safety concerns did not just end with driving. Many respondents expressed that they worried about their safety when walking or biking. One respondent said, "A lot of times I wanted to bike but drove for safety reasons." Another mentioned, "pedestrian safety, lack of sidewalks, and loose dogs prevented me from taking the bus or walking."

Security concerns were raised, especially regarding ride-hailing services. Many of the respondents, especially the female respondents, cited security concerns about using a ride-hailing service alone with a stranger driving the vehicle.

A few people brought up air quality, saying that it prevented them from walking outside or that when they drove, they felt that they needed to roll the windows up. One respondent said they believe this is the case because older cars are more common in the Rio Grande Valley.

7.3. Experience in Using Transit

The next section of the interview involved asking respondents about their experience using transit and ride-hailing services. Respondents were asked how frequently they use it, what issues they have faced in using it or deciding not to use it, and what they think about expanding that mode in the Rio Grande Valley. This section will start with people's experiences with transit first.

7.3.1. Public Transit

When asked how frequently respondents use the bus, the results were similar to those from the earlier question about monthly costs. Seventy percent of respondents never took the bus. The remaining 30% fell into the following categories: 25% used the bus "occasionally," and the remaining 5% used it 2-3 times a week.

Interviewees were then asked what barriers they faced in using or deciding not to use the bus. The top reasons were the lack of knowledge and information about how to use the bus. 75% of respondents listed route and stop location information as a barrier. 70% said schedule information was an issue. 40% of respondents did not know where or how to pay. Many respondents were unaware that even a public transit system was offered in their town. Respondents generally said they had never seen a bus stop or a bus in their town. The low frequency of buses and the lack of visible bus stops were listed as typical reasons why this may be the case. Respondents said, "I don't

really know when or where it (the bus) is going." Another respondent said they "don't know where to look for information on routes" and "don't know how to plan routes for destination." One respondent was aware of where to find schedule information, but said that because of an outdated website and "trouble finding accurate timetables" that taking the bus was not a "convenient option."

Speaking of convenience, this issue came up a lot as well. 70% said that it was inconvenient for them to use the bus. Respondents said this was due to a combination of four general things: lack of routes, low frequency, and easy access to cars. Many interviewees said that the routes generally do not go anywhere they want to. One respondent said they thought public transit was "more for the neighborhoods than for public places." Because of plentiful parking and easy access to a vehicle, most respondents said they would rather drive themselves.

The responses about not using transit continued, with 65% of respondents saying that bus stops were not easily accessible to them. Most said this was due to a lack of sidewalks and not being easy walking distance. One respondent described their negative experience saying, "I would walk along a crappy street to get there." Another said, "the main thing was having a car, and things were too far to walk."

Another reason brought up a lot was the weather, specifically the heat. 60% of respondents listed the weather as an issue when using the bus. "It's too hot, and I always have my car." said one respondent. "The weather is too hot, and hardly any sidewalks," said another. Bus stop design was brought up often when talking about the hot weather. "No roofs for the bus stops so people would stand in 100-degree weather." Another said, "The lack of bus stops made it hard to endure the weather." "There was rarely shading at bus stops."

Other reasons were brought up, but these played a much smaller role. 10% said there was not enough parking near stops or terminals. 15% listed safety as a concern. 5% listed privacy. 10% listed the cleanliness of the bus stop and the vehicle. 5% listed negative self-image of using the bus. This was a surprising finding because issues of safety, negative self-image, cleanness, and lack of parking are often assumed to be why public ridership is low. This may be the case in other regions of the country, but this is not true in the Rio Grande Valley.

When asked if they support more public transportation in RGV, every respondent said they do. Many wish it would begin to serve their area and be more frequent. Many people indicated it would be great if it went to more places that people frequent, such as the McAllen Convention Center

and South Padre Island. Others said it would be great if there were more night services for people who go out to drink at bars on the weekends.

People said more awareness and education about the transit system would help increase ridership. "It should be clearer how to route plan, more stops in frequent locations, more efforts to promote access to the general population." Other respondents also stated that they need to improve the bus stops for people waiting in the heat. "There should be improved bus stops to help people stay out of the heat." Another respondent said, "I would want to improve the waiting times for the buses and bus stops to better prevent adverse weather effects."

Respondents stated clear reasons why RGV needs improved transit. One respondent stated, "There are a lot of people who can't drive for many reasons, can't afford or get a driver's license, especially immigration." Another said, "It would help give more people the freedom to travel and would not require a car to get somewhere." One respondent who works in education said they supported improved transit because "the kids I work with who come from low-income families have trouble getting to and from school."

While all respondents supported improved public transit, some said they would still not use it even if it was improved. The reasons for this were all generally about already having easy access to a car and the convenience of moving around in it. "I think they should, but I don't think I would use it because I have my car." One respondent from Brownsville stated that as long as the cities in RGV were not walkable, they would not take it. "I would never take a shuttle to McAllen because once I get there, I would struggle to move around."

7.3.2. Ride-hailing

The usage of ride-hailing fared better than the use of transit. 55% of respondents said they "occasionally" used ride-hailing services like Uber or Lyft, and 45% said they never have. Cost was listed as the most common reason with 35% of respondents saying it was an issue. 30% said the ability to get a ride quickly was an issue. 20% said safety and security were the reasons. People said that Uber and Lyft tended to be more situational than a mode they can regularly use. The two destinations respondents used ride-hailing services for were the airport and the club. Convenience came up as a reason for just about everyone. For some, that was the convenience of ride-hailing services, which meant not worrying about parking at an airport or unsafely driving while intoxicated. For others, their access to a car made paying for a ride-hailing service inconvenient. "Prefer to use my own car," "I always have a car," and "Siempre tengo un carro" were a few of the

responses. People also said they feel they can always ask others for a ride. "It wouldn't make sense to pay for that service. If you need a ride, you could ask a friend and pay for their meal."
Another said, "I can always rely on others to drive."
Respondents said they did not necessarily feel like the cost was expensive but would prefer a "free" ride, whether driving themselves or being picked up by others.
Security and safety were also brought up a few times. People felt a perceived loss of control when using ride-hailing services and did not trust the driver to be safe or that the driver may be a threat. "I feel like the drivers don't care about quality of the ride like stars because there aren't many drivers to begin with." Another stated that they did not feel comfortable riding alone in a ride-hailing vehicle, as a woman.
Interviewees were asked if they wished ride-hailing services were improved and if there was more. Nearly everyone said "No," mostly stating it is because using a car is already far more convenient. The few who stated that they wished to see expansion and improvement said it in the context of doing more to prevent drinking and driving. One respondent mentioned that they believe Brownsville does an "activation night" where the city pays for pedicabs to take people home in a certain zone for free to prevent drunk driving. Two respondents mentioned that they wanted to see easier access for folks in the more rural areas of the counties to get rides.

7.4. Access to Technology

After establishing the travel habits and experiences of the interviewees, the respondents were asked about their access to technology and their experience using it. The responses were nearly unanimous.
100% of respondents have a smartphone and have a data plan for their smartphone that gives them access to the Internet. Regarding the Internet, 100% of respondents had
Internet access at home at varying speeds. 70% said they have high speed, with 15% saying medium speed and an additional 15% saying low speed. Access to the Internet at the workplace was lower, with 90% saying they have access and 10% saying they do not. 60% have access to high-speed Internet at their workplace, and 20% say they have medium speed. A single respondent said they did not have a fixed work location where the Internet could be available. Respondents

were asked how often they shop online using a computer and a smartphone. A comparison of the responses can be seen below in Figures 7-4 and 7-5.

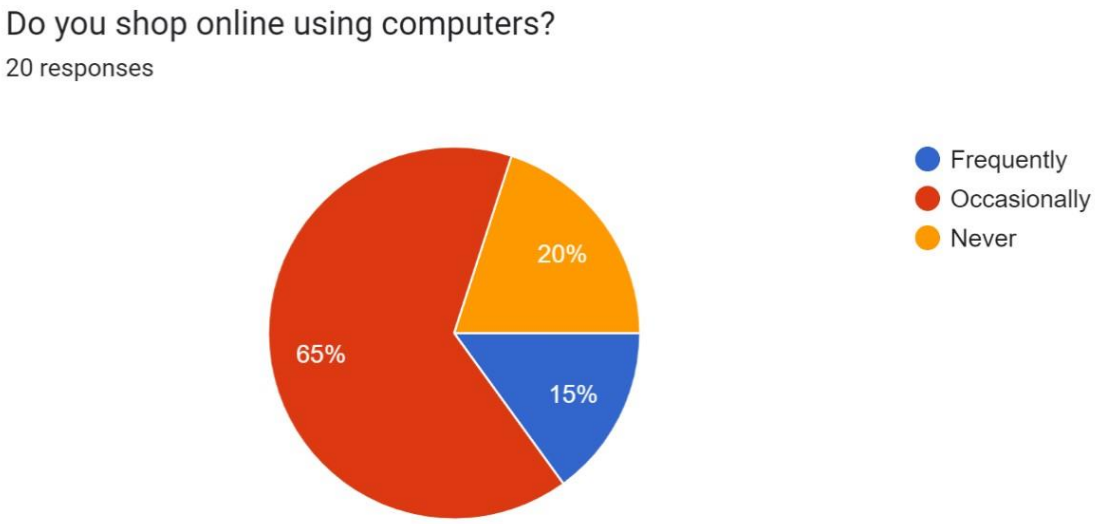

Figure 7-4: *Frequency respondents use a computer to shop online.*

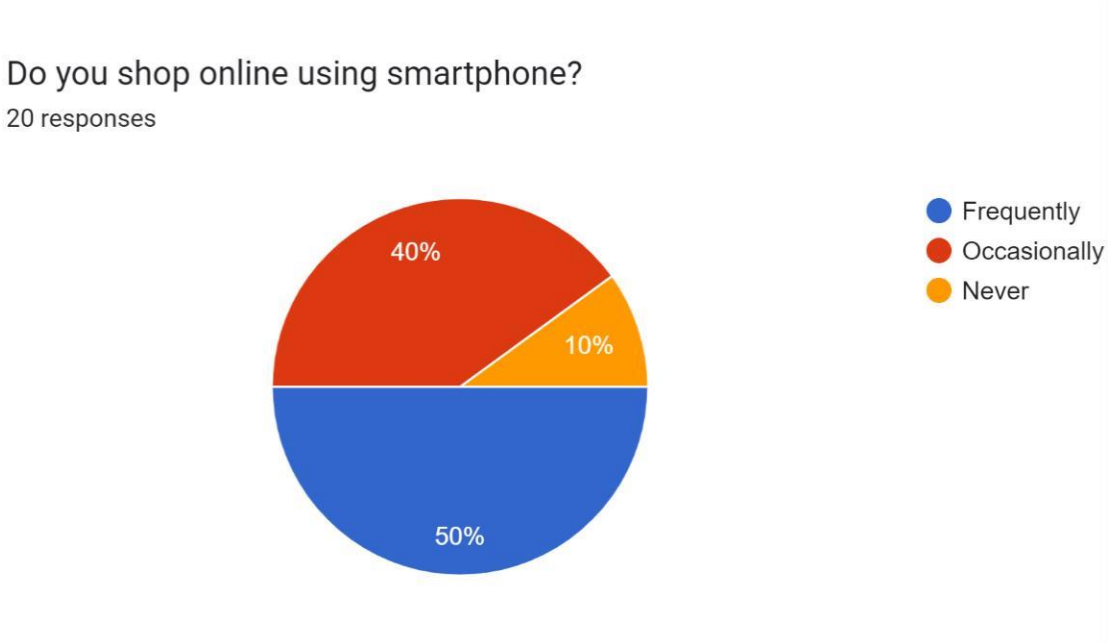

Figure 7-5: *Frequency respondents use a smartphone to shop online*

The higher use of smartphones was an interesting but unsurprising finding, given the general ages of the respondents. The higher use of the smartphone compared to the computer did not stop there. When respondents were asked if they handle personal/family business using a computer, 80% said they do. When that same question was asked for a smartphone, 100% of respondents said they did. Interviewees said that their smartphone was the go-to device for transportationrelated activities. Almost all said that they use their smartphones for activities like booking airline tickets, hotels, car rentals, transit information, and route mapping using applications like Google Maps or Apple Maps. Many stated that they use route mapping almost daily.

This round of technology questions ended with respondents sharing what improvements to internet infrastructure they would want to see. The general comments related to the availability of fast speeds and affordability. People said that the internet speeds are slower compared to their experience in other parts of the country and that it is relatively more expensive. Several said they only have one internet service provider in their area and can charge whatever.

Most respondents stated that they were aware that not everyone in RGV has access to the Internet, especially in the more rural areas. Some said there are tons of "dead spots" in the region. "Yes, growing up, it was an issue getting internet access. Other areas need it." Another respondent who used to live in a more rural area of Hidalgo County said, "Nothing loads even if it says 5g. Have to be in particular spots." Some respondents suggested they would want to see more public Wi-Fi spots throughout the region. A respondent in McAllen said they wish there were more public WiFi in parks and other public places. Another respondent who lives in the smaller town of Weslaco felt that only big cities like McAllen and Edinburg get public Wi-Fi, while smaller cities like Donna and Alamo do not. Ultimately, access and affordability are the main issues people want resolved.

7.5. Final Thoughts

Every interview ended with the interviewee being asked if they had any final thoughts, comments, or suggestions about transportation in the Rio Grande Valley. Many reiterated prior points on improving public transit and the issues they face. However, the mood and tenor that many had was the most interesting thing.

Mood is not something that can be quantified, but it is experienced. Most of the respondents felt that RGV had a cemented car culture. "RGV is super car driven, I don't know anyone who has

taken the bus." Others felt that the traffic problem would only get worse, saying that traffic is no longer just on the expressway but has also moved into the smaller city streets. One respondent joked that with a million car washes opening, that must mean a million new cars are driving around. Of course, potholes also came up quite a bit. Despite all the challenges respondents listed, the one thing that came across from almost all was a belief that transportation in RGV could be better. The situation does not have to be this bad. Several interviewees wanted to emphasize the need for a more connected region. "I feel like it (transit) leaves out underserved communities." They concluded by saying, "We are all one RGV."

Chapter 8. Analysis of Results

This report outlined the interviewees' answers in the last chapter. This chapter analyzes those results and connects them to MaaS. This report identifies the challenges and opportunities of existing conditions in the Rio Grande Valley.

8.1. Travel Behavior: Challenges

The respondents almost exclusively use motor vehicles to travel. Even when not driving alone, respondents carpool with others. This is the case for all work commutes and leisure trips. This poses a significant challenge for a multimodal MaaS offering to take place. Any MaaS offering must focus on car-sharing, car rentals, or ride-hailing. It is important to remember that two realities exist in this situation. The first is that travel habits are challenging to change (Eckhardt et al., 2020). The second reality is that, according to the literature, unimodal car users are some of the least likely to adopt MaaS (Feneri et al., 2022; Geurs et al., 2018). One can argue that RGV has, on average, a higher willingness to carpool than most communities, but sharing rides with others seems to be more based on personal relationships like friends, family, and coworkers rather than strangers.

Another challenge MaaS would face in RGV regarding travel habits is that people are disconnected from their driving costs. As stated earlier, the average transport costs in the United States for 2018 were $813 monthly (United States Department of Labor, 2018; Liljamo et al., 2020). If a MaaS offering came about and offered users a subscription for, say, half that at $400 a month, it is not unreasonable to assume people would be unwilling to pay this. Even though mobility users would

save an average of $400 a month, they are not connected to their actual driving costs. Car users tend to have car payments, gas, insurance, maintenance, and repairs. When asked approximately how much interviewees spent a month on driving, they tended to list how much they spent on gas that month. This disconnect in cost estimation would make it incredibly challenging for a MaaS offering to convince people to pay for a subscription more than what they pay in gas.

The lack of a built environment that supports other modes of transportation plays two significant challenges to MaaS. First, it creates a lack of multimodal experience with users in RGV. Seventy percent of interviewees had never used the bus before. Fifty percent did not own a bike. When the environment is designed so the automobile is the most convenient option, one will likely be a unimodal car user. This leads to the second thing, a lack of experience in using other modes, which reduces the likelihood of using MaaS. According to the literature, those most likely to use a multimodal MaaS system frequently use public transportation or multimodal travel (Alonso-González et al., 2020; Cisterna et al., 2021; Zijlstra et al., 2020; Tsouros et al., 2021; Hoerler et al., 2020).

8.2. Travel Behavior: Opportunities

Interview results capturing travel habits suggest a few opportunities for MaaS. The first is that interviewees' distances to places they frequently visit are less than 5 miles. These close distances are more conducive to other modes of transportation aside from the automobile.

Another opportunity for MaaS is that it could be offered as a solution to alleviate traffic. Traffic was consistently brought up as a major concern for people, one that they felt was only getting worse. MaaS could be seen as a way to reduce this issue and save people time.

8.3. Maas in Relation to Thoughts on Transit: Challenges and Opportunities

While interviewees' experience with public transit was low, the opinions about public transit were not antagonistic either. People were generally not opposed to it but just lacked the information on how to use it. MaaS could serve as a one-stop shop for people to travel plan and pay through a single application. This can be especially effective because people do not know where to get information for routes, payments, or timetables. If people had easy access to a single application

where they could do travel planning and payment for various modes of transportation, they might be more likely to use other modes of transport where it makes sense. It can potentially reduce the barrier to using a bus or ridesharing service.

Another opportunity for MaaS in RGV became evident during the interviews. Suppose a MaaS offering was used to supplement public transportation in places that offered it. Frequency was brought up as a barrier to using public transit. If other modes of transportation could be used to help users move around the region, especially between cities that are underserved by public transit, this could provide a compelling reason for users to subscribe.

Weather, specifically the extreme heat that RGV frequently faces, poses a challenge to a more multimodal MaaS offering. If it is too hot for people to walk or cycle outside, they will likely opt for more comfortable options like driving. RGV should be taking steps to mitigate extreme heat impacts on people regardless, but this would especially need to be addressed if RGV wants people to engage in more active transportation.

The ultimate factor that was brought up as to why people used a car over other modes of transport was convenience. The car is, frankly, the most convenient mode of transport for people using RGV. A Maas offering in RGV would likely need to be seen, as Strome puts it, "a complement- rather than a substitution of-private car use" (Strome et al., 2020). The argument of convivence could work in MaaS' favor if it is used for places where a car may be inconvenient, such as airports, nightclubs, South Padre Island, or locations with big events.

8.4. Maas in Relation to Thoughts on Ride-Hailing Services

Based on the interviewees' responses and experiences with ride-hailing services, MaaS has a difficult road ahead. The first issue is the lack of drivers for ride-hailing services. If a MaaS system in RGV is based more on motor vehicle travel and the built environment does not lend itself to an effective car-sharing system, then ride-hailing must be employed. However, this would not be competitive without enough drivers to meet users' needs in RGV. People have a low tolerance for waiting and a willingness to pay. Any delay or increase in cost would turn people off from a MaaS service. Low availability also poses a challenge for people living in more rural areas or the edges of the urban core, where drivers may not be as willing to travel.

Safety and security also challenge a MaaS system reliant on ride-hailing services. Interviewees expressed concern about riding in a vehicle driven by a stranger. This was because of the loss of perceived control, making users worried about the driver getting in a crash and security concerns about the driver being a threat themselves. This security concern was especially brought up often by female respondents traveling alone. This loss of control was brought up earlier as a concern in the literature. While it was talking specifically about algorithms, it is well documented that the loss of perceived control would also be a challenge in this context (Tomaino et al., 2020; Mick and Fournier, 1998).

8.5. Maas in Relation to ICT Access and Availability

Based on the interviews conducted, access to smartphones and the internet appears to be widespread enough in the MSAs for MaaS to be used. People have access to and the technological literacy to use MaaS effectively. Of course, any regionwide MaaS offering would also need to be available in Spanish for the residents who have Limited English Proficiency, but technological literacy appears to be present.

Internet availability regionwide poses a significant threat to MaaS in RGV. As discussed in earlier chapters, MaaS requires an immense amount of ICT in order to operate. Any MaaS offering that serves the region as a whole would require ICT infrastructure that prevents the frequent "dead spots," interviewees stated.

The lack of affordable internet would also be a challenge. If a person requires faster internet to properly use MaaS, it may price people out of the offering. Expensive internet will come to mind for people and will likely be included in people's cost estimates of MaaS, which they will already be aware of.

8.6. Maas in Relation to Personal and Household Characteristics

Several opportunities and challenges to MaaS became apparent during interviews regarding personal and household characteristics. Starting with opportunities, RGV tended to be younger on average than other regions. "Age is inversely related to the likelihood to use MaaS" (Zhang and Kamargianni, 2022; Matyas and Kamargianni, 2021). The literature universally states that younger

people are more likely to use MaaS. RGV's younger population poses an opportunity for MaaS adoption.

MaaS can also be an opportunity for people who may not be able to drive more easily to travel in RGV. Some specific populations include children, seniors, disabled folks, and immigrants. People who do not have a driver's license or the ability to operate a private vehicle would benefit from easier access to other modes of transportation and services to move around.

The lower average household incomes in RGV can be seen as an opportunity or a challenge. On the one hand, lower household incomes tend not to be MaaS users, given the high expenses involved. On the other hand, it could be a great opportunity if MaaS could be a cost-saving service for people who would no longer need to pay for all the expenses related to car use. A more fixed subscription cost could offer predictability to expenses where users would not have to worry about an unexpected repair cost.

Interviewees tended to live in households with easy car access. This is one of the most considerable challenges MaaS in RGV would face. To reiterate the literature, "The easier a car can be accessed at the point in time when the decision is made, the higher – in general – the likelihood that a car is used" (Klöckner & Friedrichsmeier, 2011). Several articles have demonstrated the solid predicting power of car ownership (Klöckner & Friedrichsmeier, 2011; Simma & Axhausen, 2001; Ben-Akiva & Boccara, 1995; Dieleman et al., 2002).

Interviewees also expressed low access to bicycles in the household. This can challenge MaaS in two ways. First, it reduces the ability to meet the first-/last-mile issue of users getting to public transit. Second, if users did not grow up with a bicycle, the likelihood they would know how to operate a bicycle or feel comfortable riding one is low. This could make a bike-sharing option for MaaS less useful.

8.7. Conclusion

Maas faces several opportunities and challenges, but these interviews highlighted a general need for better access to and education about other modes of transport. While further education and access would not bring about a mass adoption of MaaS, it can help mobility users be able to access the information needed to make multimodal travel decisions. The lack of experience and the built environment only reinforces travel habits that are already difficult to change. The challenges an

integrated MaaS offering faces in RGV are likely insurmountable, but the convenience that further integration of modes and payments could bring offers a large enough benefit that should be explored further.

Chapter 9. Considerations for an RGV MaaS Offering

9.1. Introduction

Most of this report has discussed the literature on MaaS and how it can connect to mobility users in the Rio Grande Valley. This chapter will discuss some of the things required to get a MaaS offering available. As with any significant project, especially one as novel as MaaS, there are unknowns and uncertainties. This chapter hopes stakeholders or those interested in creating a MaaS offering can keep these things in mind. This chapter will review the basics of MaaS feasibility, organizational questions, geographic areas for a MaaS offering, ICT infrastructure, and land use recommendations to support more multi-model transportation.

9.2. Basics of Maas Feasibility

A helpful graph in Figure 9-1 comes up when determining the feasibility of MaaS in a location.

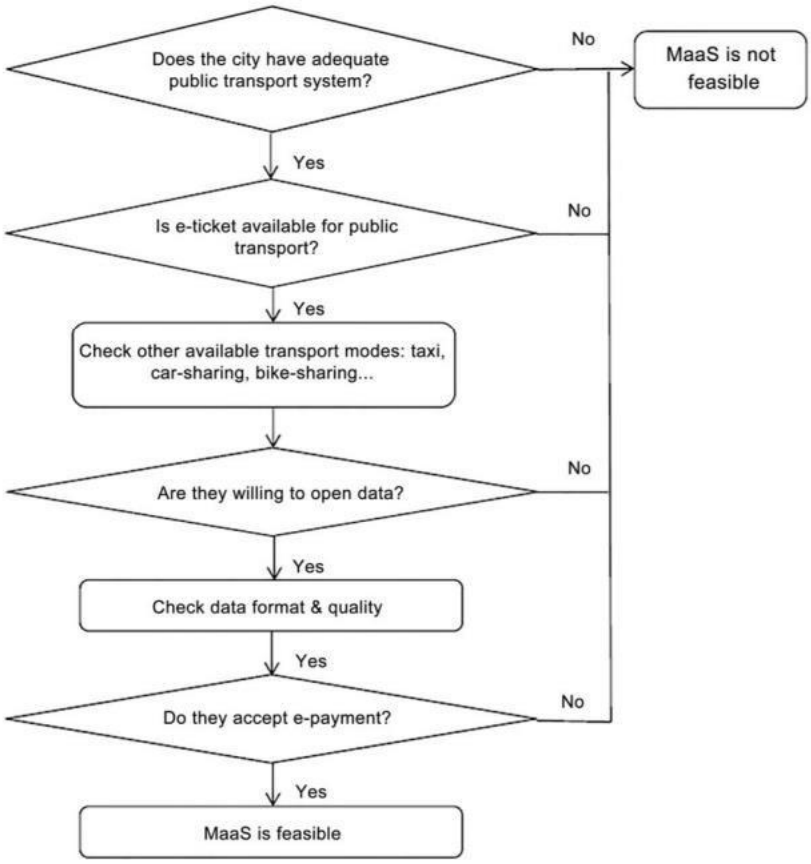

***Figure 9-1**: Ingredients for Successful MaaS (Hietanen & Sahala, 2016)*

One can see that the graph goes through a series of questions, and someone will answer either yes or no. If a person answers no at any point, MaaS is not considered feasible. If a person answers yes to a particular question, they can move on to the next question until they reach the point where MaaS is considered feasible. Mark Werner summarizes the graph well, saying that, ultimately, the following are required:

1. "Several transportation modes available
2. Much of mobility operators' data be open to a 3rd party
3. Most mobility operators allow 3rd party organizations to sell their services
4. Mobility operators offer electronic payment methods for their services" (Werner, 2020)

This chapter will cover more in-depth the different aspects that can help make MaaS feasible in the Rio Grande Valley, but it is vital to be grounded in a basic framework for achieving this.

9.3. Organizational Structure

As reviewed in the literature, organizational structure and arrangements are among the largest barriers to realizing MaaS. The different types of organizations for MaaS are discussed in the previous chapters, so they will not be reviewed again here except concerning the Rio Grande Valley. Generally, two organizational structures are considered: government-led and Public-Private Partnerships.

9.3.1. Public-led Effort

Consider, for a moment, a government-led effort to create a MaaS offering in the Rio Grande Valley. This type of structure has several benefits at face value. A solely public endeavor would allow more flexibility for the government to create a MaaS structure since there would be no messy contracting negotiations or legislation required to open the data of private operators to third parties. The different transit agencies also share a goal of public service rather than profit motive. Finally, partnerships between the different transit agencies are more common in the real world than public-private partnerships in transportation. For example, the Dallas Area Rapid Transit working with Trinity Metro in Tarrant County and Denton County Transportation Authority to offer universal tickets and service across the whole of the Dallas-Ft. Worth Metroplex. At face value, a public-led effort seems ideal, and it might be in several locations, but it would not be ideal in the Rio Grande Valley for several reasons.

Transit in the Rio Grande Valley is currently minimal. RGVMPO looked at RGVMAB's transit access. As shown in Table 9-1, they found that just 38% of the population has access to transit. Around 60% of employment destinations are accessible by transit.

Measure		RGVMAB	Within Regional Transit Walkshed	% Covered by Transit
Transit Potential	Population	1,271,139	478,554	38%
	Employment	384,205	229,571	60%
Transit Need	Target Transit Rider Population	1,472,664	572,526	39%
Destinations	All Businesses	32,149	21,556	67%
	Key Destinations	895	566	63%

***Table 9-1**: RGVMPO Transit Summary*

To offer a competitive MaaS offering, a massive revamp of the public transportation system would need to occur, especially to cover the areas outside of the McAllen and Brownsville metro areas. This would require massive funding and organization, which the current transit providers do not seem to have.

Additionally, the current modes of transportation offered by the transit providers are too narrow for a competitive MaaS offering. Transit providers in the Rio Grande Valley currently offer buses, paratransit, and city bikes for rent. To be more competitive, many more modes would need to be offered. Given these limitations and the overwhelming literature on the subject, a public-private partnership seems to be the most viable option.

9.3.2. Public-Private Partnership: Government

As reviewed earlier, a public-private partnership is the most viable structure for a MaaS offering. In the context of the Rio Grande Valley, it has certain advantages. From a government perspective, a private partner will help expand the limited offerings of public transit region wide.

In a public-private partnership, the government has the advantage of being the best candidate to be a "MaaS Champion" for all the aforementioned reasons. There are two possible candidates for this role. Both are responsible for transportation activities on a region-wide level. They are UTRGV and RGVMPO.

The first one, UT-Rio Grande Valley, currently operates a bus system that connects its Edinburg campus to its Brownsville campus, with stops along the way. UTRGV, being a research university, can win research grants and test experimental MaaS offerings. However, the university is likely not a long-term partner, given its focus and responsibility to its students and the advancement of research. UTRGV would likely be an essential partner in the pilot program phase of the process.

The other candidate is RGVMPO. As the MPO in charge of regional transportation, an offering that provides greater regional transportation options is undoubtedly a focus of theirs. The MPO also has relationships with stakeholders locally and at the state level. While they are not likely to operate a MaaS offering, they have the platform and ability to advocate for one and gather the stakeholders necessary to make it happen.

A MaaS offering in the Rio Grande Valley, or anywhere, would require significant legislation to make the creation as smooth as possible. While much could be discussed about the different types of legislation relating to MaaS, such as loosening restrictions on transport operators and licensing

requirements, a particular one to note is legislation relating to data—two parts of data: data-sharing and data interoperability.

The first one requires transport operators, from public transport to private companies, to be open to sharing data. If a single MaaS service is to offer multiple different modes of transportation, the different operators must be willing to share data such as payment, user profile, availability, etc.

The second part relates to the interoperability of the data. As stated earlier, data can be immensely complicated, even more so when there is no standardization of data naming. Where one platform may call a particular thing one thing, another could have a different naming system. If a user can seamlessly navigate a single application across many different modes of transportation, the data naming needs to be standardized to allow maximum interoperability.

9.3.3. Public-Private Partnership: Private

From the private side, private companies have a lot more flexibility and incentive to experiment with different modes of transportation. For a MaaS offering to offer a wide range of modes of transport, private operators would need to be involved. Some of the different private operators that would make great partners would be Uber, Lyft, and local taxi operators for ride-hailing services, Enterprise, Hertz, Budget, Alamo, Avis for car rentals, e-scooter companies, SpaceX (if space travel becomes a more common thing), and of course technology companies that could develop a userfriendly application for MaaS.

For MaaS to remain competitive, it requires as many different modes of transportation as possible. Public transport alone cannot accomplish this. The government will have to incentivize these companies to participate. While it may seem easier to go it alone, government and private operators must collaborate.

9.3.4. Recommendation for Building Trust

Trust proves an incredible barrier to the creation of a MaaS offering. The different public-/private-sector stakeholders have different and often competing interests. The governance structure, business model, and contracting are all novel. Developing trusting relationships will not occur overnight but will result from years-long engagement. That is why the Rio Grande Valley would best do two things. First, city and county leadership in RGV need to think more about the region and less about their specific jurisdiction. When working together, this region can leverage its size better, especially when considering the Mexican side of the border. This will help develop trust

and relationships with different operators throughout the region. Thankfully, both the RGVMPO and Lower Rio Grande Valley Development Council are the perfect institutions for this given their ability to bring local leadership together. Finally, the stakeholders should first engage in a pilot program. A pilot program will allow the different operators to test their interoperability and develop a governance and business model that best suits everyone's needs.

9.4. Geographic Area

Another consideration related to a MaaS offering would be the geographic area of the offering. Three options exist: the metro areas of McAllen and Brownsville, the county areas of Cameron, Hidalgo, and Starr counties, or a corridor area such as Business 83 or the expressway. Each option has its pros and cons.

For the metro areas option, those areas benefit from an existing public transit system with a customer base of riders. The areas are denser than the outer towns, allowing for more multi-model opportunities. Fewer partners would be required in a smaller geographic area, which can leave fewer opportunities for discontent. The downside to this option is that more rural and less connected areas would be left out. The areas that need the most transportation options would have the least options. Another downside is that it would not be straightforward to connect the two metro areas if the service only extends to the borders of the metro areas. Customers wanting to go from McAllen to Brownsville and vice versa would need to rent a car or ride with someone.

Another possibility is what RGVMPO designates as the Lower Rio Grande Valley, the three counties of Cameron, Hidalgo, and Starr. This would cover everyone from urban to rural in the region. Coverage of the region can help create a more explicit goal and sense of teamwork to help the entire RGV. This extensive coverage would require a significant investment to start and maintain. Wait times may be long, especially for rural areas, and ICT infrastructure may not be sufficient. Infrastructure improvements to expand cell service and internet would be required.

The final possibility is a specific corridor that has a MaaS system. This would allow more regional transportation between the different cities and towns. A person in the middle of the valley in Donna, TX, could easily travel to McAllen or Brownsville, where they may have greater job opportunities. A simple corridor would be cheaper and more direct between cities. The RGVMPO or some regional actor would not need to partner with as many cities. A corridor that could provide

this would be either the expressway or Business 83, which runs through the downtown areas of almost every city and town in RGV. Some downsides would be the limited area that it covers. People would be responsible for getting to the corridor from their homes. The corridor plan would also only really assist with intercity travel rather than travel within the city. Finally, a corridor-only area would only lend itself to a few modes of transportation, such as a commuter rail, bus, or car service. You could set up bike-sharing stations throughout the town to allow customers to get to the corridor, but this would be costly, cycling infrastructure is not widespread enough, people may not be able to ride a bike, and it would be dependent on the weather.

9.5. ICT Infrastructure

MaaS requires an immense amount of ICT infrastructure. For MaaS to work, customers must have cell coverage and internet access to use the application. The Rio Grande Valley has some of the least connected cities in the United States. 67% of homes in Brownsville have no access to broadband internet. Pharr has 69% of homes without broadband internet access (Digital Inclusion, 2019). While no data could be found regarding smartphone access, computer access was low for many in RGV. According to the Dallas Federal Reserve, households with a computer in the MSA regions of McAllenEdinburg-Mission and Brownsville-Harlingen were 75.6 and 71.7 percent respectively (Taylor, 2015). This is compared to Austin's MSA, which has 92% of households with computers (Taylor, 2015). For MaaS to be competitive, broadband internet coverage must be affordable and more widespread. Since the Covid-19 pandemic, a greater focus has been on closing the "digital divide" in Texas. Significant funding from different levels of government is trying to close this divide. Texas Comptroller Glenn Hegar announced that "his Texas Broadband Development Office (BDO) was allocated $3.3 billion in federal funding for broadband expansion. The funds, provided by the bipartisan Infrastructure Investment and Jobs Act, are part of the national $42.5 billion Broadband Equity, Access, and Deployment (BEAD) Program" (Texas Comptroller of Public Accounts, 2023) MaaS users will likely engage with MaaS through an application. Creating an application requires, in part, writing the code for the application and designing it to keep users engaged. User design makes a world of difference in the likelihood that people continuously use the application. As we saw in the San Joaquin Valley pilot test, user engagement was low, which made customer retention difficult. A MaaS authority needs to either

construct or hire a firm to construct a well-running application focusing on user engagement to guarantee customer retention.

9.6. Land Use Changes to Support Multimodal

So far, this chapter has discussed a whole host of ways to improve the feasibility of a MaaS offering, but something substantial has so far been unsaid: Land use. Jarrett Walker is an American transit consultant and author of the book Human Transit. He described this issue by saying, “Technology never changes geometry” (Walker, 2016). The interviews show that people want public places and more walkable areas in RGV. If a multimodal system is to succeed, the town must be designed to support walking and cycling beyond simply throwing a bicycle lane or sidewalk next to a road. There are several ways to support multimodal travel through land use.

One way to help support multimodal travel is to eliminate parking requirements. Cities nationwide have minimum parking requirements that force businesses and homes to dedicate a certain number of parking spots. This places an undue financial burden on buildings and homeowners to construct what could be unnecessary space and leads to the giant empty parking lots at the local Walmart. Parking minimums make it more challenging to create a walkable space when so much land is legally required to be parking. For example, in McAllen, multiple pages of ordinances are dedicated to the topic, and parking requirements are listed as specific as bowling alleys. “Five parking spaces for each alley” (McAllen Code of Ordinances, 2024). A great book on the topic is The Free Cost of Parking by Donald Shoup for more.

Another way to change land use to support multimodal travel is by eliminating minimum lot sizes. These ordinances require a certain amount of land for each building. For example, Brownsville’s minimum lot size requirement is 5,000 sq ft for a Residential Single-Family house (Brownsville Code of Ordinances, 2024). Like the parking minimums, this requires much more land than may be needed and prevents more compact development conducive to multimodal travel. Eliminating the minimum lot size will allow for more compact development. Streets are another area of improvement. This can come in two primary ways:

block size and street width. The longer the block, the less walkable it is. Shorter block lengths make traveling from end to end easier than longer block lengths. Street width also plays a role. This comes in both the number of lanes and the width of lanes. The wider the lanes and the greater

the number of lanes, the more difficult it is to cross streets safely. If you look at a place like Weslaco's Texas Blvd along its historic downtown, it has two lanes going in opposite directions. This makes it easier to walk across the street safely and safer to bike with the slower car traffic. Compare that to Col Rowe Blvd in McAllen, which runs four lanes across and takes a while to cross the street. Col Rowe Blvd also has a parallel pedestrian trail that users must cross to continue the trail.

These measures are a few ways to allow for multimodal travel, but ultimately, cities need to create places where people can live, work, and play. These cities need mixed development. The current zoning practice generally mandates residential, commercial, or industrial areas. Separating these uses forces people to live further from the stores where they shop, the restaurants where they eat, and the offices where they work. Encouraging mixed-use development and public spaces creates the demand for multimodal travel. Imagine living in Donna, Texas, and being able to walk outside your house and grab a coffee at Twisted Sista's Co on your way to the office and for it all to be within easy walking, biking, or bus distance. Mixed development gives people purpose in their travel and lowers the distance to those places.

9.7. Conclusion

This report has outlined some things stakeholders in the Rio Grande Valley should consider when considering implementing a MaaS offering. While this report is far from answering every question or topic that would need to be considered, starting with these topics puts RGV in a good direction toward a future where MaaS is possible.

Conclusion

To conclude, this report showed several insights regarding MaaS and its possible applications in the Rio Grande Valley. The Rio Grande Valley is a unique region. It is a rural metro area with a large but mostly dispersed population. The area has an automobile-dependent urban form, making it challenging to move around without a vehicle. After reviewing the literature on both Mobility-as-a-Service and travel habits and behaviors, a list of questions was created to interview residents of the Rio Grande Valley about their transportation habits and experiences. These questions were

designed to gain insight into the opportunities and challenges a Mobility-as-a-Service offering would have in this unique region. The questions asked about a respondent's travel behaviors and habits, issues and concerns with different modes of transportation, their access to the internet and technology, and some personal and household characteristics. The interviewees were selected using a snowball sampling method. This method has limitations and cannot be considered representative of the region. Despite this, the answers were broadly similar and consistent with each other and the current literature on travel behavior in the Rio Grande Valley.

During the interviews, several challenges and opportunities for a MaaS system were discovered. The following are the insights from these interviews.

CHALLENGES

- Respondents almost exclusively use automobiles to travel alone or with others. This makes a multimodal MaaS offering difficult because travel habits are incredibly difficult to change, and unimodal car users are less likely to adopt MaaS.
- Respondents confirmed the literature's findings that users are disconnected from their actual driving costs and perceive their costs to be much lower. Respondents provided how much they spent on gas rather than all the other car-related costs involved.
- The built environment of RGV is oriented towards the car, making it difficult for a MaaS offering to be competitive with owning a private vehicle. Easy access to parking, sprawled development, and a lack of safe biking and walking routes make having a multimodal MaaS offering difficult.
- Respondents widely did not have experience or knowledge about where and how to use transit, making a multimodal offering difficult. The literature shows that knowledge of how to use public transport is critical to MaaS's success.
- The current transit system in RGV is insufficient for a MaaS offering. The lack of coverage, frequency, and routes makes it difficult for MaaS to offer a competitive service and move people away from their private vehicles.
- Respondents listed weather as a concern for active and public transportation. Extreme heat was mainly brought up and must be addressed for any successful MaaS offering.
- Safety and security regarding ride-hailing services came up multiple times. Many listed that they were concerned about the perceived loss of control in operating the vehicle.

- Respondents tended to live in households with easy car access and almost no bicycle access. The literature demonstrates that the convenience of a car and the lack of ownership of a bicycle pose challenges to a MaaS offering.

Opportunities

- Interviews showed that respondents' trip distances tended to be short. These short distances lend themselves to a multimodal MaaS offering having success given the right built environment.
- Almost everyone thought traffic was worsening and that more multimodal travel could help alleviate this issue. If MaaS is advertised this way, it will likely find more support.
- Respondents generally supported transit and would consider using it if it was convenient. MaaS could help make transit more accessible and convenient for users to use transit.
- While access to fast and affordable internet is not widespread in the region, access to smartphones and the internet was widespread among respondents. Easy access to the internet and technology and knowledge of how to use it lend themselves well to a MaaS offering.
- As seen in the literature, MaaS tends to be more enticing to younger mobility users. Census data shows that the Rio Grande Valley has a younger-than-average population and thus would be more likely to use a MaaS service.

Limitations

There are several limitations to this report. First, the interviews were conducted using snowball sampling, meaning the people identified for interviews were not done randomly, nor can they be considered representative of the entire Rio Grande Valley.

Second, there is little existing transportation data or even research on the travel preferences or behaviors of residents in the Rio Grande Valley. This meant that much of the data outside the original research from this report was from a limited number of sources.

Future Research

Several areas relating to this topic is open to future research. Further research in RGV for MaaS is needed. Interviewing stakeholders on the feasibility of a MaaS offering would provide more knowledge on the challenges and opportunities of a MaaS offering in RGV. The current research on MaaS is almost universally in a European context. This makes it difficult for stakeholders in the United States or countries with a similar governance structure to draw practical conclusions

from this. Much more research regarding MaaS is needed better to understand this concept's future in the United States. Second, much more research must be conducted on transportation in rural-metro areas. Much of the literature regarding mobility issues and MaaS relates to dense urban contexts or barren rural areas. Small metros and rural metro areas have hardly any research, which makes it challenging to conclude current research regarding these unique geographic areas. Finally, much more research is needed for transportation in the Rio Grande Valley. Finding transportation research on this region, let alone general research, was arduous, with a handful of articles. As the second largest border community in the United States, only behind San Diego-Tijuana, this region is grossly overlooked.

Overall

Overall, the challenges MaaS faces are numerous, but if further research is done to show the feasibility of this concept in fulfilling the promise of broader access to transportation at a lower cost to users, then the people of the Rio Grande Valley would be most deserving.

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