

**Studying Volunteer Driver Programs to Inform Transportation Planning for  
Autonomous Vehicles in Rural Areas**

by

David K. Copp

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Supervisor: Trevor Hanson, PhD, P.Eng, Department of Civil Engineering

Examining Board: James Christie, PhD, P.Eng, Department of Civil Engineering  
Bruce Wilson, PhD, P.Eng, Department of Civil Engineering  
Laura Romero-Zeron, PhD, Department of Chemical Engineering

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## ABSTRACT

Rural areas and non-driving older adults are a target location and clientele for Autonomous Vehicles (AVs), yet there is a lack of information regarding the operational environments, demand for service, and the physical needs of the older adults with respect to AV operation in rural areas. Car-based Volunteer Driver Programs (VDPs) in New Brunswick already serve a rural, primarily older adult membership; therefore a study of aspects of these programs could provide insight into the necessary considerations for AV adoption. Surveys from 37 VDP volunteer drivers in New Brunswick identified tasks beyond driving provided to clients (of any age) on their most recent drive, as well the purpose for each stop during the drives. Origin and destinations from one year's worth of one VDP's travel data were used to assess the roadway-operating environment. Finally, a stated choice experiment was developed that could be used to better understand the mode choices of rural older adults.

Clients depended on additional services for the majority (68%) of reported stops. The road classification estimated to have the highest percentage of travel (41% of kilometres) was "divided multi-lane" highways, though "collector" and "local" highways accounted for 40% of kilometres. These results suggest that if AVs were deployed, they would only be useful in situations where tasks could be automated and would need to be effective in several different road classification environments, which may require changes to roadway maintenance practices (e.g. line painting). Future work includes: better understanding of the individual needs of the users by age, as well as to finalize and deploy the stated choice experiment.

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## **List of Symbols, Nomenclature or Abbreviations**

AV	Autonomous Vehicle
GIS	Geographic Information System
GPS	Global Positioning System
MNL	Multinomial Logit Model
NB	New Brunswick
O/D	Origin/Destination
REB	Research Ethics Board
VDP	Volunteer Driver Program
VMT	Vehicle Miles Travelled
V2V	Vehicle-to-vehicle communications
V2X	Vehicle-to-infrastructure communications

## **1.0 Introduction**

The development of Autonomous Vehicle (AV) technology is introducing a new form of transportation into the existing non-AV public road system and can be expected to change the way engineers approach transportation facility design and planning. This includes developing and incorporating intelligent infrastructure to support AV and planning for efficient transportation networks to be used by a mixed stream of traffic. In a fully autonomous system, these vehicles should help to alleviate traffic congestion, allow for reduced travel times, as well as lower collision rates, compared to the existing non-AV network (KPMG, 2017); these benefits will be reaped by freight transport as well as passenger transportation.

In addition to improving current traffic operations, this technology promises to allow people who have never been licensed to drive or who can no longer operate a vehicle due to the health effects of aging or medical conditions, to be able to meet their transportation needs independently. The most often discussed demographic group in this situation are older adults or “seniors”, a heterogeneous group of individuals classified as age 65 years and older, as the health effects of aging can make driving difficult or impossible over time (Turcotte 2012). When older adults are faced with driving cessation, they become dependent on others to meet their transportation needs. In urban locations, there are usually alternatives available such as public transit or taxi services at reasonable prices; however, in rural communities that is often not the case. The transportation options can be very limited and, with large distances to the nearest grocery store or medical office, those individuals who do not have access to a personal vehicle are left at a disadvantage.

The new access to transportation with AVs has the potential to improve the quality of life for rural older adults who rely on others for transportation by providing them with an alternative for independent transportation; users could complete their trips without relying on their friends and family for transportation. In the case where friends and family trips are preferred but drivers are not available, theoretically, AVs could fill the gaps in service.

Since AVs are still a new entity in transportation, there has not been extensive research to assess the practical potential of these vehicles to service rural older adults. The problem associated with this lack of research is that there remain a number of contributing factors that must be understood before any practical application of AVs can be determined in this context. The question remains that when AVs are publically available will they be an accepted and effective transportation alternative for older age groups? In addition, the necessary attributes (costs, level of convenience, travel time, etc.) contributing to a successful AV transportation service for older rural residents must be determined. Another concern is the deployment of AVs, such as if the vehicles will be fully operational in rural environments or if the autonomy will be limited due to environmental factors. Other considerations include assessing how receptive the rural seniors of today will be to the idea of AVs, which can be compared to future groups as AVs become publicly available to monitor how public perceptions of the mode change. There are several reasons listed above that justify the need for further research, in order to develop a better understanding of the future role autonomous vehicles have in helping rural older adults meet their transportation needs. With a growing senior population, ensuring

available transportation alternatives for future rural seniors will be integral to maintain their quality of life.

### **1.1 Problem Statement**

Transportation planning to help seniors with their mobility and safety needs can often be a challenge due to the diverse range of driving capabilities and individual needs, and that challenge is amplified with the addition of a rural setting. For many non-urban areas there is high dependence on personal vehicles to satisfy any transportation needs. In New Brunswick, 91.3% of residents rely on personal vehicles on their daily commutes either as a passenger or driver, higher than the national value of 70.5% (Statistics Canada 2017). According to the results from data the 2009 Canadian Community Health Survey – Healthy Aging, 14% of Canadian women and 5% of Canadian men aged 65 and over had difficulty with transportation to locations out of walking distance (Turcotte 2012). In New Brunswick the numbers were higher for both men and women; 16.7% of women and 7.8% of men aged 65 and over required assistance with transportation (Turcotte 2012). When in need of transportation, seniors can often turn to friends and family for assistance; the challenge is that they may not always be available to supply transport services.

One of the major factors associated with this issue is the growing proportion of older adults with respect to other demographic groups, at 16.9% of the total Canadian population according to the 2016 Census, up from 14.8% in 2011 and 13.7% in 2006. The proportion of older adults in Canada is projected to increase to between 23.8% and 27.8% by 2063 (Bohnert et al. 2015). As both the absolute number and proportion of

seniors continues to outpace the growth in the younger population, there may come a time when older adults who cannot drive will not have friends or family readily available when needing transportation.

Seniors that require assistance may turn to transportation alternatives like public transit or taxis; however, these options are typically unavailable in many smaller rural communities (Transport Canada 2010). When friends and family cannot provide transportation, seniors risk missing appointments and performing errands. The response in some communities, including several in New Brunswick, has been the development of organized Volunteer Driver Programs (VDPs). VDPs are typically non-profit or charitable organizations that rely on volunteers and their vehicles to provide door-to-door transportation service to a region that has underserved transportation needs. The main charitable focus of these VDPs is the provision of transportation to a membership that generally lacks transportation options. This differentiates these programs from charities where transportation serves as an extension of a charity's overall mandate (e.g. Canadian Cancer Society transportation to cancer treatments), making VDPs more like a rural taxi service.

VDPs are growing as alternatives for non-driving older adults, and others without transportation, in rural areas of New Brunswick (Hanson & Goudreau, 2017). While VDPs can offer a solution to some of the transportation issues faced within rural areas, they rely on volunteers and volunteer vehicles to deliver services. It is possible that in the future, with the expected growth of the older adult population, an organization may encounter the situation where they cannot meet user demand due to limitations in the volunteer supply, necessitating a new model for service delivery. One of the most

prominent examples of new technology that may form the basis of this service delivery is AVs. The time when AVs will be operating on public roads is fast approaching, with many major cities around the globe pilot testing AVs and preparing policies to accommodate the new transportation advancements (Bloomberg Philanthropies 2017). Once these self-driving vehicles are operating on public roads, they may be a potential solution for rural transportation issues faced by seniors (Kalra 2016).

Although there is extensive research currently underway for AVs, it is primarily focused in major cities and urban areas, leaving a gap in AV research for a rural focus. Further research in this area will help reveal the potential for AVs to service rural communities, based on how the vehicles would be used and the required conditions for users to consider AV transportation. It also remains unknown whether rural seniors would welcome the autonomous transportation alternative, given that older groups tend to resist new technologies (Haboucha et al. 2017).

While the AV concept seems like a perfect fit to address rural older adult transportation needs, as it provides direct on demand services without needing a supply of human operators, little research has been done to understand the technical and policy implications of deploying this concept for meeting this need. Several questions that require addressing are how to estimate the demand for rural AVs, as well as the modal split among other available rural transportation alternatives. In addition, what are the necessary steps for technological development to facilitate the implementation of AVs on rural roads with varying road conditions, for example? This knowledge gap supports the research opportunity. Further data is required on how rural seniors in need of

transportation assistance meet their needs as well as their degree of dependence on those alternatives.

Arguments in the literature, such as that by Kalra (2016), suggest that the target clientele for AV in rural areas would be older adults who do not drive. By extension, this could be expected to be much of the same clientele that are currently using VDPs to meet their transportation needs (or would use it if such a program existed). It could also be expected that the clientele would intend to use AVs for similar purposes and destinations as they already do with VDP.

## **1.2 Hypothesis**

The research questions for this study were:

1. What are the tasks performed by the volunteer driver to support the needs of VDP users in addition to operating the vehicle, and how suitable would autonomous vehicles be to replicate the trips taken by rural VDPs?
2. What would be the expected operational environment of AVs if replicating the travel taken with volunteer driver programs?
3. What type of transportation planning tool could be used to elicit prospective user preferences and estimate modal split involving AVs?

The hypothesis for this study was:

The study of VDP vehicle travel and the role of volunteer drivers will provide a basis for determining potential of AVs to replicate trips, based on the tasks and frequency of additional services by the driver other than operating the vehicle. It is possible to create

a survey tool that would permit the estimation of modal split among several transportation options available to rural older adults.

### **1.3 Project Significance**

This research contributes to the knowledge surrounding a successful rural transportation alternative (VDP) by quantifying operational aspects (driver tasks and operational environment) that support the transportation needs of rural non-drivers (including rural older adults). Understanding these operational characteristics is important for the transportation planning field if the success of VDPs is to be replicated in other locations or by other modes, including AVs. The integration of AVs into rural senior transportation may have the potential to meet the needs of the public, but there is limited research on the practical implications, including whether AVs are even a desired transportation alternative for rural older adults. The application of a stated choice experiment initiated in this research can help answer this by using the choices of participants to determine which attribute levels (e.g. cost, travel time) they most highly value for each mode, thereby influencing their choice.

This research can provide a practical lens to policy makers by providing a clearer understanding of how VDP clients are supported by the driver, and informing broader debates around transportation alternatives, including AVs, which may focus solely on the provision of mobility. For example, if the volunteer assists clients into/out of the vehicle or accompanies them on appointments/errands once arriving at the destination, it is unclear how these tasks would be provided if travel is done by AVs, or even a point-to-point bus service. The results are also practical for present-day VDP operations, by

providing information on what the volunteer drivers do to support the users in addition to driving, which can assist with driver training, recruitment, and determining resourcing requirements for the provision of new services. This work can also provide a foundation for understanding what the operational environment of AVs would be to service the rural senior population, and where to implement future roadway improvements to support seamless autonomous travel between different road categories.

This research is most important to the non-driving older adults living in rural communities who cannot independently meet their transportation needs, as well as the people involved in supplying that transportation, such as their family and friends. Studying these topics will ensure both established and new programs can better understand and meet the needs beyond driving for their existing or prospective clients. Research in this field can also position future mobility solutions like AVs to be more effective for servicing the targeted users, rural older adults.

#### **1.4 Research Goal and Objectives**

The objective of the study was to better understand transportation habits in existing driver programs with a focus on the activities of the driver. This information provided a means for assessing the potential for AVs in the transportation planning for rural older persons.

The following list outlines the main objectives of the study:

- Develop and administer survey for volunteer drivers;
- Analyse VDP origin and destination data to determine the typical operating environments;
- Assess survey results to determine the role of the volunteer during VDP trips;

- Evaluate results to determine the practicality of AV use to replicate VDP trip making;
- Create stated choice experiment that could be deployed to develop modal split estimations between modes available to rural seniors, including VDP and AVs

While these objectives were completed, there were limitations associated with the precision of data available for the operational environment analysis. All limitations and assumptions for this work are discussed in the later sections of this document.

## **1.5 Scope**

This research focused on determining the factors associated with potential autonomous vehicle transportation by rural seniors for completing a variety of trip types. A survey for volunteer drivers was developed and distributed to willing VDPs operating locally. Three VDPs of varying sizes agreed to participate, and 60 surveys were mailed out. There were 37 completed and returned surveys, for a response rate of 62%. The travel data from one year of operation of a New Brunswick VDP was used to identify the roads being frequented by volunteer-based travel. Finally, a stated choice experiment was designed using computer software, which can be deployed in the future to identify the potential modal preferences amongst rural seniors.

## **1.6 Thesis Organization**

Chapter 1 of this thesis provided introductory and background information regarding the subject matter of this research. The remaining sections of this document are organized the following way:

- Chapter 2 provides further background and reviews the prominent literature on the topic of AVs and rural senior transportation;
- Chapter 3 contains the methodology used to complete the research, including survey development, ethics review, data collection and analysis procedures;
- Chapter 4 presents the results of the analysis;
- Chapter 5 contains a discussion of the results, alongside conclusions that were drawn from the study. Recommendations for future work are also included in this chapter.

## **2.0 Literature Review**

The Canadian Council of Motor Transport Administrators (CCMTA) defines an autonomous vehicle (AV) as “a driverless vehicle; a vehicle that does not require human monitoring or interaction”. This technology permits the driver to be removed from the vehicle operation, which creates an option for those individuals who live in car dependent environments, but who currently rely on others to meet their transportation needs. While autonomous vehicles present an option for rural seniors to meet their needs, little research has been done to determine the demand for this new travel alternative and the necessary attributes for success of these systems. The following review of literature sources outline some of the relevant data available in relation to seniors in Canada and New Brunswick, older drivers, and autonomous vehicles, to be used to assess the potential for autonomous vehicles to service rural older adults.

### **2.1 Growing Senior Population**

The number of older adults (or “seniors”, people aged 65 years and over) is steadily growing across Canada. The older adult population in 2013 was 5.4 million people; a value that is over three times greater than the number of people aged 65 and older in 1963, 50 years earlier (Bohnert et al., 2015). The Statistics Canada Population Projections (2013-2063) reported that seniors accounted for 15.3% of the total Canadian population in 2013, a number that is projected to increase to between 23.8% and 27.8% by the year 2063 (Bohnert et al., 2015). The largest increase to the senior population is likely to occur within the first 25 years of the projected period (between 2013 and 2038)

due to these being the years when the baby-boom cohort reaches the age 65 (Bohnert et al., 2015).

According to the 2016 Census, 19.9% of the New Brunswick population is aged 65 and over, meaning approximately one in five people are seniors (Statistics Canada 2017). The total number of seniors in the province is projected to increase to between 30.9% and 32.6% by 2038 (Bohnert et al., 2015). The Government of New Brunswick developed a provincial growth strategy in 2013 to address the declining overall population throughout the province, which also discusses the rising number of seniors. Outlined in the provincial growth strategy discussion paper, the increasing senior population is also a function of New Brunswick experiencing a significant outmigration of youth from the province, travelling to other provinces/territories seeking employment opportunities. The provincial government associates this outmigration to several factors, including an aging work force in New Brunswick that remains working for much longer than previous generations, and lack of major investment and creation of new jobs in the province. This outmigration of young people, combined with the rapidly increasing senior population in the province will influence future New Brunswick policy development to prioritize the needs of the large senior population (Province of New Brunswick, 2014).

## **2.2 Senior Driver Health, Safety and Travel Behaviour**

With the rapidly increasing population of older adults, it can be expected that the transportation issues previously experienced by only a small group of the older population will increase with the growth of the aging cohort. These mobility issues will be experienced on a much larger scale, and will pose serious challenges for the

independent movement of all those people who will lose their driving independence. In 2012 Statistics Canada published an article titled “Profile of seniors’ transportation habits”, applying data collected in the 2009 Canadian Community Health Survey (CCHS) to examine the transportation issues faced by older adults in Canada. According to this article, in 2009 there were 3.25 million people aged 65 years and older who held a driver’s license, which was about three quarters of the senior population of Canada at the time. The author specifies that although aging itself does not cause direct obstacles to driving capability, it is the negative health conditions resulting from advanced age. One of the major health issues faced by today’s seniors is dementia, a deterioration of an individual’s memory and cognitive abilities. In 2009, 28% of seniors who had been diagnosed with some form of dementia held a license, while 73 percent of those diagnosed had reported driving within the past month when asked (Turcotte, 2012).

The transition from driver to passenger can represent a major shift in lifestyle and, for someone with declining physical and cognitive abilities, it is difficult to know exactly when driving cessation should occur (Alzheimer’s Association, 2015). The Alzheimer’s Association recommends a joint approach between the affected person and their caregivers/family to establish driving safety precautions. Several suggestions include limiting driving to daytime hours, remaining within familiar areas, and adopting some driver assisting technologies. When there is uncertainty in the remaining driving ability of the driver, a physician should conduct an evaluation to determine if the license should be revoked (Alzheimer’s Association, 2015). The challenge is ensuring that when faced with a situation of driving cessation, the rural older adult has access to effective

alternatives to facilitate that transition, as suggested by Hanson (2010). The 2010 study was conducted with the goal for better understanding the transportation habits of seniors living in rural areas. The major conclusions from this study include the need for rural transportation alternatives for seniors and for enhanced travel data collection in rural areas (Hanson, 2010).

One of the major social benefits that is anticipated from the application of autonomous vehicles for rural senior transportation is the reduced risk of vehicle collisions caused by medically at risk drivers who should no longer be operating vehicles. A comparative study of collisions involving rural and urban senior residents of New Brunswick showed that older drivers (aged 81 years and over) from rural areas have the highest collision rate ratios versus their urban counterparts at 4.1 collisions per million km (Hildebrand et al., 2000). Comparatively the younger age groups of 26-45, 46-65, and 66-80 had rural collision rates of 1.25, 0.75, and 1.6 collisions per million km driven. Based on the same driver data associated with senior drivers, seniors aged 80 years and older were found to have fatal collision involvement rates four times greater than middle-aged drivers. This study also reported that seniors are more likely to be involved in right-angle collisions at intersections compared to any other age groups (Hildebrand and Myrick, 2001). The National Highway Traffic Safety Association (NHTSA) states that over 90 percent of collisions are caused by human error (USDOT, 2017). The removal of human driving in autonomous vehicle networks has the potential to eliminate collisions resulting from human errors. This suggests that in addition to improved access to transportation for mobility restricted populations, the overall safety of road users would be improved by

passing the control of the vehicle over to the vehicle operating systems. Even though these vehicles present an option for improved transportation access and safety, it will take some years to progress to the point at which these vehicles are commonplace on the roads.

### **2.3 Autonomous Vehicles**

The automobile has maintained a consistent presence for many people in the developed world since it became a popular means of transportation in the early 20<sup>th</sup> century. Over time there have been improvements and upgrades in terms of safety features (e.g. seatbelts, airbags, etc.) and extras to improve the overall driving experience, such as the addition of radio units to vehicles, as well as heated/cooled seats and cruise control. These improvements were largely incremental in terms of driving safety and comforts. The new emerging technology of the autonomous vehicle is changing the one driving aspect that has remained constant since its invention: the need for a human driver. The incorporation of AVs onto the roads is expected to take years of gradual technological integration to build towards the final stage of full autonomy for vehicles (USDOT, 2017).

This process of integrating advanced technology into vehicles has been underway for decades, with computer-based technology integration typifying the past 20 years. The National Highway Traffic Safety Administration (NHTSA) has identified the “Five Eras of Safety” in regards to personal vehicles and their features:

The first “Era of Safety” was labelled as Safety/Convenience Features (1950-2000’s). This category includes the implementation of things like cruise control, seat belts, as well

as anti-lock brakes. Next came the Advanced Safety Features (2000-2010), with features like blind spot detection, collision warnings, and lane departure warnings. Advanced Driver Assistance Features (2010-2016) brought about the availability of automatic emergency braking, rear-view video systems (commonly called backup cameras), and lane-centering assist. At the time of this research the current period is identified as Partially Automated Safety Features (2016-2025) and includes lane keeping assist, adaptive cruise control, and self-parking. The final stage, from the year 2025 onward is Fully Autonomous Safety Features, which is expected to include full autopilot modes for vehicle driving. This progression through time shows how technology has developed and become incorporated into modern vehicles to facilitate improved safety and convenience on the roads (USDOT, 2017).

These safety and convenience features are associated with the different levels of vehicle autonomy. The Society of Automotive Engineers (SAE) defines six levels of autonomy for vehicles, which have gradually been developed through the different periods of vehicle technology previously outlined from the NHSTA. Level 0 indicates no vehicle automation whatsoever, meaning that the driver must perform all driving tasks. Level 1 is Driver Assistance, where the vehicle is still operated by the driver but there may be some driver-assist features available. Level 2 is for Partial Automation, when there are some automatic features like steering or acceleration, but still requires human control of the vehicle. Other tasks that can be performed autonomously at Level 2 include self-parking and lane keeping assist. Level 3 is labelled Conditional Automation, where a driver is necessary and must be prepared to actively take over driving if needed, but they are not

required to monitor the outside environment due to the advanced automation systems of the vehicle. Level 3 automation would permit vehicles to be capable of overtaking slow moving traffic without input from the driver (SAE International, 2018).

The final two categories, Level 4 (High Automation) and Level 5 (Full Automation) present an advanced level of automation. At Level 4 a vehicle is capable of driving in most conditions without intervention from a human operator, although the vehicle will have the option available for manual override in the case of extreme weather or unusual terrain. Level 5 completely eliminates the need for human interaction with vehicle operations and maintains a much more advanced degree of automation capable of handling virtually all driving scenarios independently. These vehicles would contain no steering wheel, braking or acceleration pedals or any other tools used by drivers to operate the vehicle. Many vehicles operating currently (2019) fall within the range of Levels 1 through Level 3 with popular application of driver assist features, and it will be at least six years before Level 5 autonomy is available to the public (SAE International, 2018).

The safety benefits of AVs are expected to accrue from the removal of human error in traffic. In 2016 there was a reported 1717 fatal collisions in Canada, resulting in the deaths of 1898 individuals. In addition there were 115956 personal injury collisions resulting in 160315 total injuries, 10322 of which were considered serious injuries. In terms of collision locations, over half (55.8%) of the fatal collisions occurred in rural locations, defined by Statistics Canada as lying outside the boundaries of an established municipality, town or village (Government of Canada, 2018). This is likely due to the

higher speed facilities in rural areas compared to that of urban locations, as well as the reduced traffic volumes permitting free flow movements. The critical reason for collisions was found to be the fault of the driver in 94% of crashes in a 2015 study by NHTSA, suggesting that by relieving the driver of operation steering wheel will result in a significant reduction in vehicle collisions (Singh, 2015). Level 5 AVs will one day be able to do just that, and hopefully the actual reduction in collisions without human drivers can be quantified.

#### **2.4 Autonomous Vehicle Studies**

Harper et al. (2016) attempted to estimate the upper bounds of potential increases in VMT (vehicle miles traveled) in the United States resulting from vehicle travel in a fully autonomous environment. The expected increase in VMT with AVs results from improved access to transportation for the following social groups: seniors, currently non-driving adults, and adults with medical conditions that restrict mobility. Data from the 2009 National Household Transportation Survey was applied, and suggested an annual VMT increase of up to 14%. This 14% increase was a result of new demand from underserved populations (non-drivers, elderly, those with medical conditions). The potential increase in VMT for seniors in the underserved groups was 5.1%, due to the fact that the older cohorts were considered to drive less than adults aged 19-64. This study assumed that in a scenario of full vehicle automation, the older drivers would increase their annual travel (VMT) to levels similar to the younger generation for each gender. In addition to this, only personal vehicle driving data was applied (i.e. no public transit travel); however, it was considered when determining the upper bounds of potential VMT

increases. This study did not consider the willingness of older adults to accept AVs, which will have a role in the overall travel increases resulting from AVs.

Fagnant and Kockelman (2014) developed a model to describe the travel and environmental consequences of a shared autonomous vehicle (SAV) fleet, specifically how SAVs would affect wait times and vehicle miles travelled (VMT). The model was used to run a simulation of 100 days of travel in a medium-sized urban centre (Austin, Texas was the provided reference example) that indicated each SAV in the base case serviced approximately 31-41 passengers per day. In this urban setting with SAVs, less than 0.5% of passengers had to wait more than five minutes for their ride, and at the peak hour 97% of the vehicles were occupied. The results of the simulation showed that one SAV would be capable of replacing almost 12 regular personal vehicles for travel, and that approximately 11 parking spaces could be eliminated for each SAV used. This study was focused on primarily shorter trips (under 15 miles) and in urban areas, so for longer trip ranges or further outside city centres these results would vary.

The benefits and barriers posed by AVs in the future markets was analysed in a 2015 paper by Fagnant and Kockelman. In addition to the barriers and benefits, the authors also suggest several policy recommendations regarding the future application of AVs. Several of the benefits outlined in the paper include improved safety, congestion and traffic operations. When discussing the safety improvements that AVs promote, Fagnant and Kockelman cite work done by Hayes (Hayes, 2011), which suggests that with the application of AVs that motor vehicle collision rates (in person-miles travelled) could drop as low as 1% of their current rates. The congestion savings are an expected result of

efficient route choices and reducing vehicle gaps with autonomous technology, which are reliant on vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communications. The authors cite the FHWA stating 25% of congestion is related to traffic issues, about half of which are collisions (FHWA, 2005). The reduction in vehicular collisions with the removal of a human driver will not only improve the road safety, but consequently reduce traffic congestion as well.

Another major section of the paper by Fagnant and Kockelman (2015) outlines the potential travel behaviour impacts resulting from AV usage. This portion discusses the increase in vehicle-miles-travelled (VMT) caused by previously underserved groups gaining access to transportation (i.e. older adults, children, persons with a disability, etc.). Despite the impending increase in demand from transportation through AVs, the authors suggest that the safety and congestion benefits may just outweigh the negative impacts of the consequential increase in VMT. Included is a citation from Smith (2013) that indicates with the VMT increasing as AVs rollout, at peak periods the vehicle delays are not likely to decrease considerably despite the improved V2X communications and efficient route choice making of the AVs. Additionally, the same research suggests that while the emissions per VMT will decrease, the added vehicles will likely contribute to an overall increase in emissions (Smith, 2013). Similarly to the conclusions by Smith (2013), another study estimated a reduction in emissions for VMT, due to an approximate 20% reduction in accelerations/decelerations with autonomous driving; the reduction in accelerations/decelerations lead to a fuel consumption and fuel emission reduction of 5% (Berry, 2010).

Fagnant and Kockelman (2015) conclude their paper with three major policy recommendations suggested in regards to the regulation and implementation of AVs:

- 1) Expand federal funding for AV research: since AVs remain new technology, more information is necessary for planning and forecasting the effects and usage of AVs, as well as the infrastructure and systems requirements to facilitate the vehicles.
- 2) Implement a federal AV certification program: at the time the paper was written, certification of AVs in the United States was regulated at a state-level. Developing a federal system for AVs would streamline the process and provide consistency for all states in the country.
- 3) Develop standards for liability, data privacy, and security: liability issues remain a major concern for many people regarding data AVs, and the sooner governments address the regulations for AVs and privacy the better it will be for developers and consumers.

## **2.5 Transportation Planning Efforts to Incorporate AVs**

Although there have been many studies focused on understanding the system wide implications of AVs, the research with respect to user perspectives has been somewhat limited, especially when discussing rural populations. The following studies outline some of the work done to better comprehend the propensity for users to utilize AVs across the globe when they are readily available to the general public.

The study done by Krueger et al. (2016) conducted surveys to identify the characteristics for likely users of shared autonomous vehicle (SAV) services in Australia. The procedure included a questionnaire to determine the socio-demographic characteristics of each participant, followed by online stated choice surveys to assess hypothetical mode choices. The alternatives presented in each choice set comprised of two autonomous vehicle choices (one with ride sharing, one without) and a transit option. The trip attributes included travel cost (three levels), travel time (one level), and wait time (three levels), resulting in nine possible choice sets. Results revealed that ride sharing had a significant impact on the mode choice, and suggested that individuals who acted as driver in their reference trip were more likely to choose SAV without ride sharing, compared to individuals who acted as passenger in their reference trip. Those participants whose reference trip was taken with public transit indicated a propensity to choose public transit over autonomous options. However, in the context of senior rural individuals, public transit is likely not an option; therefore, the choices of passengers prove the most valuable from Krueger et al. This shows the potential for SAV ridesharing applications among rural residents, which would reduce individual travel costs while improving access to transportation services.

A similar study, performed by Haboucha et al. (2017) had the objective to gain insight into the motivations to own or use AVs as well as to develop a model for mode choices. The research was conducted by surveying 721 participants from various parts of the world (Israel, USA, Canada), in which they selected a mode based on several trip attributes. Although there was representation of all age groups in the participants, the

proportion of participants aged 65 and older was only 3.4 percent. Three alternative modes were presented in this study: to continue driving with a traditional vehicle, to use a privately owned autonomous vehicle, or to use a shared-autonomous vehicle. The methods included applying an initial questionnaire to determine participant characteristics, followed by the stated choice survey. In this experiment, the four attributes were assigned to each alternative, which were purchase cost, membership cost, trip cost, and parking cost. The results revealed that 44 percent of respondents indicated a mode choice of maintaining use of traditional vehicles, 32 percent choosing private autonomous vehicles, and 24 percent selecting shared autonomous vehicles. These results suggest that while people are likely to choose familiar alternatives, there is a large portion that are willing to embrace AV transportation in either private vehicles or shared vehicles. Moving forward, research can narrow the scope and focus on individual groups, rural seniors in this case, to understand the mode choices and potential for AV application.

Public opinion about AVs will have an impact on their adoption. Researchers are studying the current public impressions with respect to the innovative technology and the likelihood of acceptance when it becomes available. Kyriakidis et al. (2015) administered an electronic survey worldwide with 5000 respondents to determine use acceptance, willingness to pay, and concerns about AVs. Correlations between personal variables of the respondents (e.g. age, sex, etc.) and their support (or lack thereof) for AVs were determined. The study found that 33% of respondents indicated that fully autonomous

driving would be highly enjoyable, but the major concerns included security of the vehicle software, liability, and safety.

AVs are such a recent development in the transportation industry that although they are gaining popularity through pilot tests across the globe and access to advanced driver assistance features, they remain primarily a foreign concept to most drivers today. The study by Payre *et al.* (2014) studied *a priori* acceptability, attitudes towards AVs as well as intentions to use AVs. The author outlines *a priori* acceptability of a technology to be an evaluation of a given technology without having had first-hand experience with that item. Data were collected via questionnaires distributed to participants with a diverse range of knowledge on the subject of AVs, with the concept of AVs clearly described in plain language for ease of comprehension. More than two thirds of respondents indicated they would be favourable of using fully automated vehicles, and there was a strong positive correlation between the attitudes towards AVs and intention to use AVs. Situations where driving was considered “monotonous” like highway driving, or “stressful” like high traffic situation were identified as the most desirable situations for AV usage.

The study performed by Hohenberger *et al.* (2016) investigated the differences between men and women and their willingness to use AVs. The data were collected using online questionnaires administered to a sample of 1603 participants of average age 48.5 years, with 51.3% of respondents being female. The questionnaire was divided into several parts, the first of which was in reference to the participants’ demographic and psychographic background. The second section presented a description of three levels of

automation for vehicles, partially-automated, highly-automated and fully automated based on the NHSTA and German Federal Highway Research definitions of vehicle automation. Survey participants were asked to indicate their willingness to use AVs (at each level of automation) as well as their emotions in regards to each level of autonomy. Results of this study showed men were more likely than women to use AVs as well as reporting higher levels of expected enjoyment from travelling in AVs. Elevated levels of anxiety were most common in female respondents, which likely resulted in the lower likelihood of using AVs. When examining age, the data suggest for both sexes the level of pleasure from AVs would decrease with age, however the level of anxiety would remain fairly unchanged.

Another study was performed recently in an attempt to understand the factors influencing the adoption of driverless vehicles. The study by Kaur and Rampersad (2018) investigates factors for AV adoption based on two major components: the first is factors associated with technology adoption, like reliability and performance; and the second is specifically related to AVs, like users concerns and the driver scenarios an AV might encounter. The study used an online survey with a 5-point Likert scale for a variety a situations like security, privacy, safety, and adoption scenarios. Results of the study indicate the surveyed individuals are more likely to adopt AVs for situations when looking for parking, using autonomous public transport with the presence of a vehicle chaperone, and highway driving with the option of manual override. It should be noted that this study focused on university students/employees. This allowed for a more

specific insight into AV adoption when compared to the more generalized studies that are often performed.

## **2.6 AVs and Older Adults**

The perception of AVs by older populations who are considering driving cessation or have already ceased driving for health or safety purposes remains an integral part of planning for AV implementation. To best serve older adults, researchers must understand what features an AV presents that are desirable to this cohort. In a study by Bellet *et al.* (2018), 30 drivers, ranging in age from 70 to 81 were presented with a questionnaire regarding driving difficulties faced in their day-to-day lives as well as their expectations regarding Advanced Driving Aid Systems (ADAS). Of the 30 participants, 62% indicated they would accept the concept of giving control of the vehicle to automation. The autonomous feature that was most highly favoured by these drivers was automated parking, with the highest utility at 65% of participants, 63.4% indicated acceptance of this feature, and desire to have autonomous parking was reported by 60.3% of the seniors. The values with respect to a fully autonomous vehicle usage were lower than those for autonomous parking; 54% indicated AVs having perceived utility, 50.2% were willing to accept fully autonomy, but only 38.7% wished to have an AV themselves. Despite the lower percentage of participant indicating a desire to own an AV, the authors reiterate that with the rapidly growing senior population, older groups should be considered the target users for AVs and could reap the most benefits (Bellet *et al.* 2018).

## **2.7 Transportation Network Companies**

It can be expected that the deployment and operation of AVs will likely follow the progression to that of app-based transportation companies that have become prevalent to the transportation in today's major urban centres. Transportation network companies (TNCs) like Uber or Lyft are options outside of public transit or taxi services that are available on demand to the users. Due to the rapid popularity of these alternatives in recent years, the Transit Cooperative Research Program (TCRP) is asking the important question: how are TNCs affecting the use of personal vehicles and public transit systems? The TCRP Research Report 195, is dedicated to understanding the scope of these impacts by analysis of origin-destination data from five major cities in the United States. Some of the conclusions from this report suggest that TNCs are used mostly during evenings and weekends, rather than for daily commutes. Another finding suggested that even with TNC usage, the overall transit ridership did not experience any significant decreases as a result. This document also provided recommendations for municipalities to incorporate TNCs into their transportation operations, not to replace transit, but to complement the routes where there are service gaps (Feigon and Murphy, 2018). Since this document analyses the TNCs in major urban centres, it leaves the question of the potential for these programs to operate in rural regions as well. With further trip distance to rural regions, the fares are likely to increase to offset the travel costs; however, with appropriate pricing and management, on demand systems like these could have a great benefit to rural communities where there are no public transit alternatives available.

## **2.8 Ethical Issues Surrounding AVs**

Controversial technological advances can present some degree of uncertainty with regards to successful regulation and implementation in the future. This issue is discussed in an article by a British newspaper The Sunday Times: Driving, published in July 2018. In this article, there are several quotes from major automobile manufacturers in regards to the life-and-death decisions by AVs. The major issue revolves around the ethical implication involved with allowing a vehicle to make emergency decisions for itself, in particular, in dire circumstances when it must decide to harm either the vehicle passengers, or other vehicles/pedestrians on the road network around it. A BMW representative for the UK suggested that fully autonomous vehicles will never become permissible on public roads in the UK for this reason, as liability should remain with the vehicle owner; this means that while highly autonomous features will be available, there will always need to be a steering wheel and acceleration/breaking pedals with a human positioned in the driver's seat to take over in case of emergencies. This issue was echoed by a fellow automaker from Mercedes that said their AVs could potentially hit a pedestrian if it meant ensuring the safety of vehicle occupants (Allen, 2018).

This is a global issue when moving forward with the rollout of public AVs, and although the manufacturers continue to improve their technology to ensure the safety of those inside and outside the vehicle, it will be some time before the system is perfected. The ethical controversy, while important and should be acknowledged, is not the focus of this research. The studies conducted in regards to AVs are operating with the assumption that

the appropriate technological developments will one day be put in place, as well as the necessary regulations to allow for fully autonomous driving on all public roads.

## **2.9 Studying Rural Volunteer Driver Programs as a Proxy for AV Usage**

One of the major limitations to the previous studies focused on AVs, is that most people have yet to personally use a self-driving vehicle first hand, and as such there is no way to study how people truly use it yet. Work has focused on the technological and computer programming to support the vehicle operations, as well as using surveys to understand how people will incorporate AVs into their travel. The studies make attempts to quantify the expected travel impacts and user preferences; however, these results will need to be validated by the true AV usage values when they have sufficiently infiltrated the road network. In addition to this, the user studies have been limited geographically, and tend to focus in major urban regions. Limited research is available with a direct focus on rural application of AVs, and by extension the rural older adults who may benefit from AVs.

While many AV studies provide insight into the expected implications to the traffic networks and attitudes towards adoption of AVs, because the technology has yet to be accessed by the public there is no way to know for certain what the demand will truly be and how they will be used. Car-based VDPs provide transportation on a regional basis to individuals who cannot independently meet their mobility needs, and service predominantly rural communities. This group of users, mainly the rural older adults with limited transportation access, is identified as one major groups posed to benefit from the deployment of AVs. VDPs can provide a means to understand how the clientele of rural driver programs utilize transportation networks, including the purposes for their travel,

what kind of roadways they frequent between origins and destinations, as well as understanding the scope of duties assigned to the volunteer driver in support of the passengers.

Without operational use cases involving AVs, it is difficult to know what the operational demands will be; however, these driver programs provide a platform that currently mimics AV driving services, and some travel patterns that might be expected for AVs in similar situations. The role the driver plays to support the users can identify scenarios in which an AV would be capable to replicate the trip making of a VDP, as well as to assess the practicality of a driverless vehicle when serving older rural populations. VDPs can be used as a proxy for understanding what the operational demands will be for AV services in rural areas, which will permit an assessment of whether or not the self-driving cars are properly suited to meet that demand when they are made available.

## **2.10 Summary**

The rapidly growing senior population presents an issue for the future of transportation planning. As the cohort of “baby-boomers” continues to age with the accompanying health issues that cause driving to become more difficult or even dangerous, alternatives must be available to replace their automobiles. While urban centres present options of public transit or taxi services (and in the larger regions, TNCs), the transportation needs of non-drivers in rural communities are not often understood, leaving those in need of transportation assistance at a disadvantage.

With the development of AVs as a potential transportation solution for those rural older adults, there still remains questions regarding the suitability of AVs for these populations. Rural VDPs are serving this group that may include potential AV users, and can act as a proxy for understanding the necessary AV service requirements by studying the driver activities performed and the roadways they commonly travel. The studies discussed in the previous sections suggest that the majority of current research is focused on urban areas, and general user acceptance scenarios, rather than considering rural areas and the lens of senior vehicle occupancy. The limited research available regarding seniors and AVs indicate the acceptance and desire for several autonomous driving features for higher-stress situations, but there remains some apprehension towards full vehicle autonomy. None of the studies presented here focus their research in a rural context, nor do they consider the mode option of VDP as an alternative. This work will provide a context for assessing the potential of AVs to service rural seniors as a transportation alternative, and the limitations they might possess.

## **3.0 Methodology**

This section contains the methods used throughout the research, with three main components: development of a volunteer driver survey; identification and analysis of VDP origins/destinations and the roads used in between; and the creation of a stated choice experiment to determine mode split between alternatives of AV, VDP, transit, or being a vehicle passenger.

### **3.1 Driver Survey**

The following sections outline the process that was followed to develop, design, and distribute a survey to understand what additional services a volunteer driver provides while on duty with a VDP.

#### **3.1.1 Survey Terminology**

Throughout the survey, there are a variety of terms used that were previously known to participants as they are commonly used during their reporting procedures. These terms include items like stop-purpose categories and the interpretation of items like stop and drive. The definitions of each term are as follows, as outlined by Hanson and Goudreau (2019):

- Stop – a stop represents the one way travel activity from an origin to a destination during a drive and is associated with a physical stop by the vehicle
- Drive – consists of all the sequential one-way stops to a destination and ends when the commitment to the client ends and the volunteer is free to serve other clients

- Stop Purpose – the primary reason for the stop, broken into one of four of the following categories:
  - Health – stops associated with the health of users (hospital, doctor’s appointments, etc.)
  - Life Maintenance – stops associated with meeting the daily needs of life (groceries, banking, errands, etc.)
  - Quality of Life – stops that are non-essential to continuing life
  - Work/Education – stops that are associated with the employment or education of the user

### **3.1.2 Driver Activity Selection**

The information that was considered to be the most valuable for assessing the potential of AVs to replicate VDP transportation services for rural older adults was the tasks or activities performed in addition to driving by volunteer drivers. These activities demonstrate the level of service provided by VDPs to their users and can allow for the assessment of AVs to meet these needs. Although there can be a wide range of tasks a driver can perform for the clients, a limited number of significant options needed to be identified in order to facilitate a uniform system of reporting by the participants of the survey.

The tasks were identified based on prior knowledge of the operating services that local VDPs provide, a result of discussion with regional VDP coordinators as well as brainstorming what additional services an older user may require in the case of poor

mobility or diminished health. The following driver tasks were identified for use in the survey:

- Opening/closing the vehicle door for clients
- Physically assisting clients into or out of the vehicle
- Escorting the clients to the vehicle door from pickup location, or from vehicle door to the drop-off location door
- Escorting clients from the vehicle into the destination location to provide additional support
- Assisting clients with objects, such as placing mobility equipment (e.g. wheelchair, walker, etc.) into the vehicle/trunk of the vehicle, or carrying items such as groceries for client

### **3.1.3 Survey Development**

The survey was designed to require as little effort as possible on the part of the volunteers with the intention of encouraging more responses to be returned. The questions were limited in length to ensure that only one sheet of paper would be necessary, which would reduce the risk of survey pages becoming separated and misplaced before being returned by the participants. The survey was divided into four questions:

**Question 1: What is your age (in years)?**

**Response Options: Less than 65 years, or 65 years and older**

The purpose of this question was to develop a better understanding of the demographic profile of the volunteer drivers. Further information about sex, income, detailed age groups, employment status, etc. were considered for inclusion in the survey; however, due to the nature of the VDPs, as well as REB requirements for anonymity, these items were excluded. The addition of these characteristics on the survey would have resulted in obtaining identifiable personal information about the drivers as some groups are very small in size and therefore to ensure anonymity only the broad age category was used.

**Question 2: How often do you volunteer as a driver?**

**Response Options: 1-2 hours/week, 3-4 hours/week, 5-6 hours/week, 7-8 hours/week, or Over 8 hours/week**

This question was included to provide further information about the frequency of volunteer driving. This showed the time spent volunteering, as well as what a typical work load for volunteering would require.

**Question 3** was not a multiple-choice question like Questions 1 and 2. In Question 3, participants were asked to consider their most recent volunteer driving experience. For that drive they were told to indicate within the provided table: the destination for each stop, the stop purpose, the tasks performed to assist clients, if they considered that typical activity, and how many passengers were assisted at that stop. There was enough space provided for eight stops, which was considered to be sufficient as previous VDP studies have indicated most drives consist of only one or two stops (Hanson & Goudreau, 2019). The destinations were reported by volunteers writing each destination (e.g. Hospital,

Pharmacy, etc.) in the provided space, and checking a box for each stop to assign it a purpose (Health, Life Maintenance, Quality of Life, or Work/Education), checking a box to indicate the tasks other than driving and if it was typical activity, and finally writing the number of passengers.

**Question 4** was used to supplement the destination-purpose-activity log provided in Question 3. The participant was asked to indicate, in their overall experience as a volunteer, how often they provide additional assistance to a passenger and for which stop purpose category. This question was divided into parts a, b, c, and d, each part corresponding to one of the stop purposes. The responses were selected from a five-point Likert scale of frequency choices: Never, Rarely, Sometimes, Very Often, and Always.

The final version of the survey included in Appendix A1.

#### **3.1.4 Ethics Review**

This survey was subject to an ethics review by the Ethics Review Board at UNB, and is under file as REB 2018-133. This process focused primarily on risks associated with the research and the procedures put in place to reduce risks. The details of the ethics review and the informed consent letter for participants can be found outlined in Appendix A2.

#### **3.1.5 Data Collection**

A partnership had been established with seven VDPs operating throughout New Brunswick during previous research studies at UNB. These seven groups were contacted via email with an invitation to participate in the volunteer driver survey. Within that email, an overview of the project was presented, along with instructions for those groups

willing to participate. The final number of groups that expressed interest in participating in the study was three out of seven. Each program was asked to indicate how many questionnaires they would require for their drivers, as well as the preferred language of the surveys.

### 3.1.6 Survey Distribution

The total number of surveys that were distributed was 60. The number of surveys each groups requested is presented in Table 1, divided into the number of English and French versions.

**Table 1 Number of surveys distributed to participating VDPs**

Group No.	Number of Requested Surveys	
	English	French
1	24	1
2	20	0
3	15	0

The surveys were distributed in packages to the participating VDP coordinators. Within each package were a number of postage-paid un-addressed envelopes, aligning with the number of surveys each group requested. Within each of these blank envelopes was one copy of the questionnaire and one copy of the informed consent/explanatory letter, along with a pre-addressed postage-paid envelope for participants to return the completed surveys. The VDP coordinators were asked to address each envelope to their participating volunteer drivers, and then proceed to mail their package of surveys out. Over a period of several months, the completed surveys were returned from participants. There were no questions from the volunteers with regards to the surveys.

### **3.1.7 Data Entry**

The data from the questionnaires were catalogued into a spreadsheet using Microsoft Excel. Each completed survey was numbered upon opening the envelop to ensure nothing was misplaced, as well as to provide a means of referring back to the original in case of abnormalities in the entered data.

### **3.2 Determining VDP operating environment**

Travel data from VDPs provided a source for the analysis of their operating environments. Although GPS-based travel data was initially considered for the data collection, due to the detailed information and accuracy, a pre-existing data set from local VDPs was already available for the research. This contained origin and destination locations, which could permit a broad assessment of the VDP vehicle-operating environment, without the need to instrument vehicles with GPS trackers.

One year of travel data were previously provided to the research team by seven VDPs operating throughout New Brunswick. This study made use of one major component from those data, which was the origin and destination for the reported trips. Data from the single largest VDP in the province were used due to the presence of specific community names in the origin/destination data.

Origins and destination pairs were identified from the reported data. This step involved some data cleaning to account for slight variations in the reporting of locations. These included misspelled place names, abbreviated locations, and minor variances in capitalization or punctuation. An example of this issue is the reporting of the City of

Saint John. Different reporting styles of this city were “Saint John”, “SJ”, “St. John”, “saint john”, etc. These items were corrected to the appropriate name of “Saint John”, as was done for the other place names that experiences similar reporting issues. Table 2 contains the list of all locations identified for the road study, which consists of both origin and destination location names.

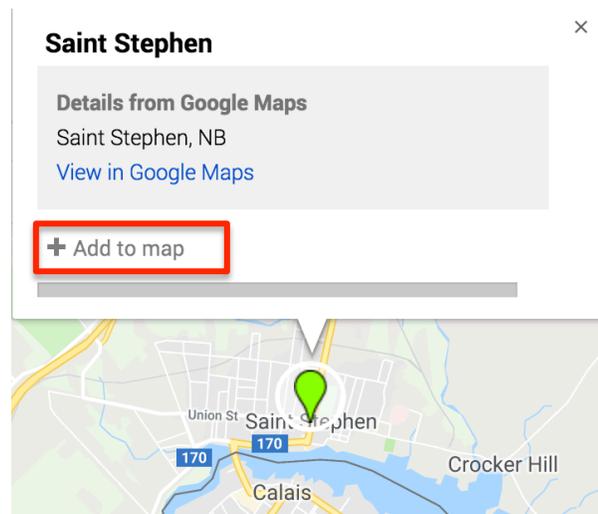
**Table 2 List of reported locations**

Beaver Harbour	L'Etete	Old Ridge	Scotch Ridge
Blacks Harbour	Lake Utopia	Pennfield	St. Andrews
Canal	Lawerence Station	Pleasant Ridge	St. George
Chamcook	Mayfield	Pocalogan	St. Stephen
Chance Harbour	Milltown	Quispamsis	Tower Hill
Grand Manan	Moores Mills	Rothesay	Upper Mills
Heathland	Oak Bay	Saint John	Waweig

The available precision of each location was a limitation to the study. Rather than entering the exact address of each stop along the drives, the drivers included only the community of the pick up or drop off. Since the exact route of each drive was not reported in the data, and without the pickup/drop off address it was not possible to identify the true travel routes for the VDP. The origin and destination information permitted for an approximation of the routes at a broad community level. To understand the types of roads being used to support travel of VDPs, Google Maps was used to make the connection between locations and routes. Since only the community names were provided by the VDP, Google Maps was able to provide an acceptable level of precision given the limited information about the origins/destinations. If GPS travel data between the O/Ds was used, the accuracy and quantity of the data points would be much higher,

suggesting an automated GIS program would be more appropriate for the analysis in such a case.

Each origin and destination pair was entered into “Google My Maps”, an online map tool from Google that allows the user to input and save locations on a traditional “Google Map”, and to trace routes between locals in different layers of information. This was done by creating a new map, followed by adding each location in the origin and destination list to the map, as shown in Figure 1.

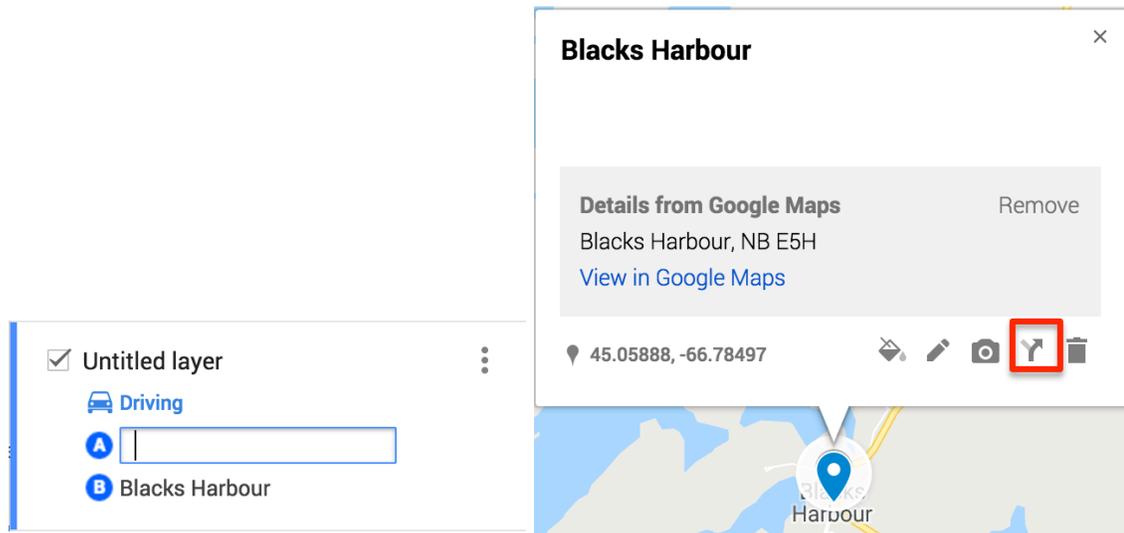


**Figure 1 Location tab and information box with option to add map layer**

To add each area to the map, each location in question was entered into the search bar, which placed a tab at that geographic location, and the option was provided to save and that place into the map. Clicking the “Add to map” would then save that location into the specified layer of the map. This process was repeated for each location, until all 28 were saved into the map. If using a GIS, the centroid of the census subdivision layer would be used for this analysis. Due to the large size of many rural census subdivisions, this centroid would not necessarily correspond to the location of the small communities,

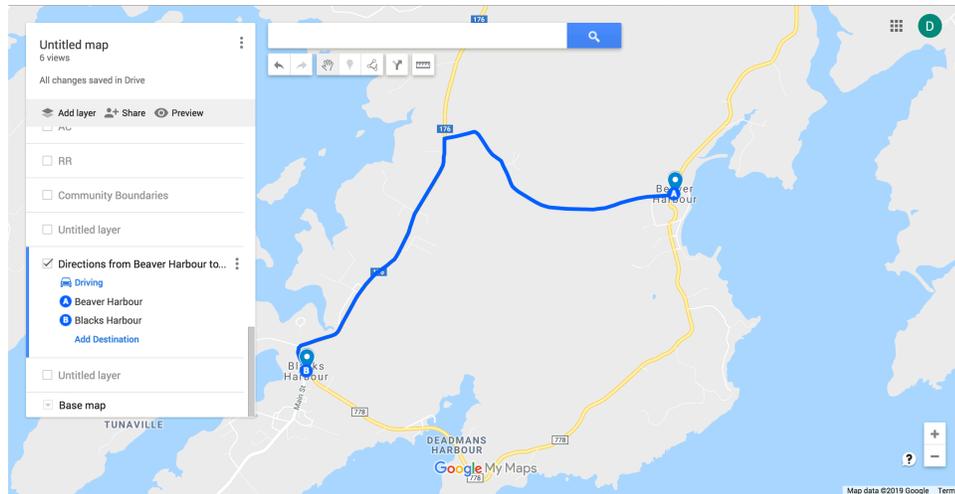
which exist as civil addresses. The Google Maps method permits better approximations for locating small communities using the available O/D information.

Next, for each O/D pair, the driving directions were identified by clicking on the “Direction to here” icon within the town/city’s information box, which prompted the user to select a starting and end point from the list of saved locations, as shown in Figure 2.

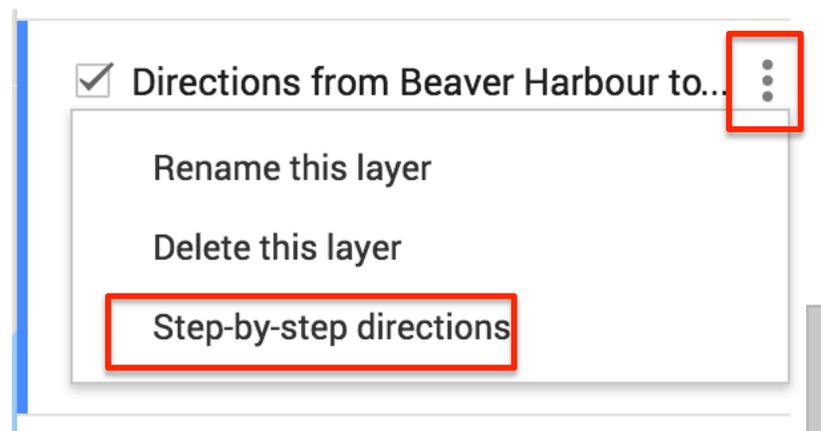


**Figure 2 Input start and end locations for driving directions**

With the origin and destinations input into the program, the route was highlighted on the map, as shown in Figure 3. Clicking on the drop down menu beside the “Directions” layer, and selecting the “Step-by-step directions” option provided a detailed breakdown identified route for further information. This is shown in Figure 4.

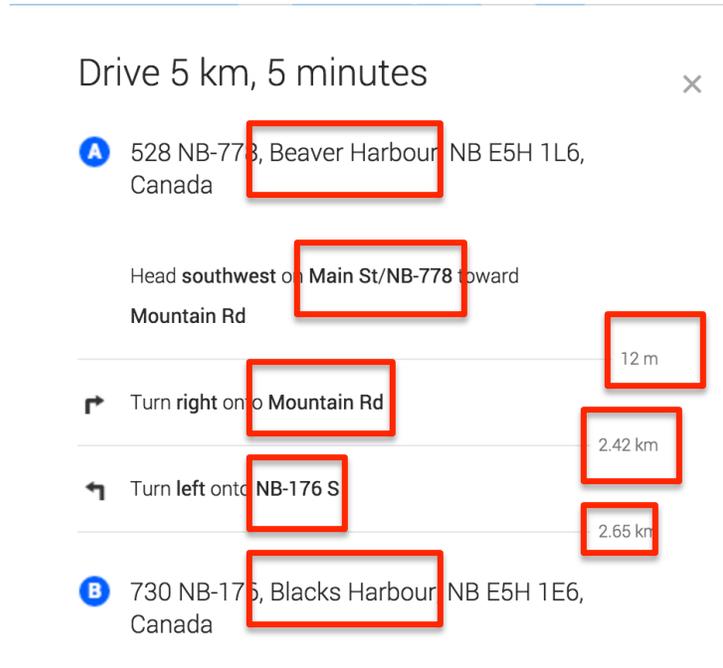


**Figure 3 Route highlighted between origin and destination**



**Figure 4 Drop down menu to access step-by-step directions**

The “Step-by-step directions” of the highlighted route contained information regarding the total travel time and distance, as well as the specific roads and their respective lengths between the beginning and end location. There is a sample of “Step-by-step directions” are shown in Figure 5.



**Figure 5 Step-by-step directions**

This procedure was repeated for each O/D pair, and the road names and segment lengths were recorded into an Excel spreadsheet for analysis. The limitation of imprecise location reporting lead to the use of city/town/village names for general origins or destinations, as identified by Google. This was typically downtown area in the urban locations, while small rural community coordinates fell along a stretch of rural road. This method remained more accurate for estimating between rural communities compared to using GIS, as GIS would require the use of census subdivision centroids rather than the exact communities.

### **3.3 Travel Purposes by Road Class**

The data from the VDPs can also be taken into consideration with the road classification breakdowns to better understand what the main purposes of travel are on each major class

of roadway. This information permits the prospective operational environment of AVs to be determined. The VDP purposes of travel were required to be distributed across the road segments of each O/D pair.

The raw VDP travel data included the purpose for each recorded trip between the origin and destination locations, as shown in Figure 6. The total number of trips between each set of location was already identified in the road segment analysis; however, this section required each individual trip purpose to be catalogued.

Trip Type	Origin	Destination
Column8	Column12	Column13
health	Old Ridge	St. Stephen
health	St. Stephen	St. Stephen
work	Tower Hill	St. Stephen
work	St. Stephen	Tower Hill
work	Milltown	St. Stephen

Figure 6 Raw data sample of purpose, origins and destinations from VDPs

Within the raw VDP data set, the desired origin and destination location were selected and the data were sorted to display only information regarding those trips, as shown in Figure 7.

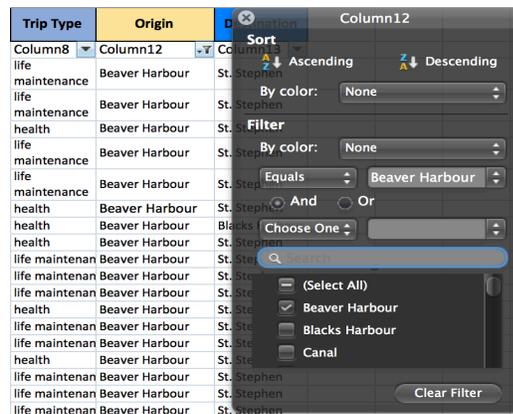


Figure 7 Sorting of locations for desired pairings

For O/D pairings like Beaver Harbour / Blacks Harbour, there was only one recorded drive between locations, with one trip type of Health. This is shown in Figure 8. Most pairings contained more than just one trip, so for each trip the different purposes were recorded. In order to ensure no drives were misplaced in the procedure, after obtaining the purposes for each pairing, the total number were added together and cross referenced with the total number of drives for each pair as used in the road segment analysis.

Trip Type	Origin	Destination
Column8 ▼	Column12 ▼	Column13 ▼
health	Beaver Harbour	Blacks Harbour

**Figure 8 Displayed pairing with one reported trip and one purpose**

With the purposes assigned to each O/D pair, those counts were applied to the road segment breakdown. In the case of Beaver Harbour / Blacks Harbour, the expected kilometres driven on each road class were directly assigned as Health purpose kilometres due to having only one trip purpose.

For those with multiple drives and multiple purposes, the kilometres were distributed. In the case of Beaver Harbour / St. Stephen, there was a total of 19 reported drives between the locations. Of the 19 drives, 6 were assigned Health purpose, and 13 were Life Maintenance. The original road segment lengths identified from Google were then multiplied by the according number of drives (6 Health, 13 Life Maintenance). Table 3 below contains a sample of this step.

**Table 3 Distribution of Beaver Harbour / St. Stephen kilometres to purpose-KM**

Road	Length	Health	Life Maintenance	Quality of Life	Work/Ed.
		6	13	0	0
Main St/ NB-778	5.09	30.54	66.17	0	0
NB-176 N	0.072	0.432	0.936	0	0
NB-785 N	0.178	1.068	2.314	0	0
Ramp	0.432	2.592	5.616	0	0
NB-1 W	47.5	285	617.5	0	0
Ramp	0.439	2.634	5.707	0	0
NB-3 S	0.673	4.038	8.749	0	0
NB-170	1.31	7.86	17.03	0	0
Union St	0.006	0.036	0.078	0	0

Next, the Purpose-Kilometres were applied to the road segment classifications for each piece of roadway. This was done separately for each trip purpose, resulting in four kilometre estimates for each class of road, for a total of 24 total estimates. Table 4 shows this step for the Beaver Harbour / St. Stephen pair, for Health purpose kilometres.

**Table 4 Beaver Harbour / St. Stephen health purpose-KM assignment to road class**

Road	Health-km	Divided Multi-Lane	Ramp	Collector Highway	Local Highway	Named Roads/ Streets	Undivided Highway
Main St/ NB-778	30.54	0	0	0	1	0	0
NB-176 N	0.432	0	0	1	0	0	0
NB-785 N	1.068	0	0	0	1	0	0
Ramp	2.592	0	1	0	0	0	0
NB-1 W	285	1	0	0	0	0	0
Ramp	2.634	0	1	0	0	0	0
NB-3 S	4.038	0	0	0	0	0	1
NB-170	7.86	0	0	1	0	0	0
Union St	0.036	0	0	0	0	1	0
<b>Total</b>	<b>334.2</b>	<b>285</b>	<b>5.226</b>	<b>8.292</b>	<b>31.608</b>	<b>0.036</b>	<b>4.038</b>

This method was repeated for each of the 92 O/D pairs, and the values were totalled for each purpose and road classification. With the total kilometre estimates for each type of roadway by trip purpose, the distances were then compared to identify the most common purpose of travel for each road class. The limitation of this approach was having only the four drive purposes considered separately, with no combination purpose trips reported within the data set that could be applied.

### **3.4 Preliminary Stated Choice Experiment Development**

The stated choice experiment was used to develop a tool for evaluating the perspectives of rural seniors with respect to AVs, as well as putting them into context with other available modes of transportation. This can be helpful for answering questions about different modes of transportation for rural communities, by determining what factors are considered most valuable for people when making a modal choice. As AVs are not yet available for the public to use and assess, methods like stated choice experiments offer a means to compare future transportation options with existing alternatives, and to highlight what attributes are most important for users. The preliminary stated choice experiment was developed for future implementation with regards to mode choices of rural seniors. This pre-pilot survey development exercise sought to incorporate the mode options of VDPs along with AVs and other traditional options like a weekly transit service or riding as a passenger in the vehicle of a friend or family member (as this research is focused on the non-driving rural older adult, the option of driving oneself was omitted).

### 3.4.1 Model Specification

The first step of specifying the model for the stated choice experiment was identifying the alternatives to be used in the model. The alternatives in this context refer to the different mode choices that the survey participants will have to select from. Four modes of transportation were selected for the stated choice model:

1. Automobile (passenger)
2. Weekly transit bus
3. AV service (considered a driverless taxi)
4. VDP

Next the attributes to be associated with each alternative in the model were identified. Not all attributes were applicable to each mode alternative, and only those related attributes were used in the utility functions. Each attribute was labelled as either generic or specific. Generic attributes are those that are applied to all presented alternatives, meaning that within the model there is more than one variable sharing a parameter estimate  $\beta$ . Alternative specific attributes are when the parameters associated with an attribute are specific to one of the presented alternatives (Choice Metrics, 2018). Another benefit to using generic attributes is that it reduces the number of parameters in the model, thus reducing the required sample size needed for the survey.

Only main effects were considered in this design to reduce the number of necessary scenarios. Main effects are the major influences that the attributes and their levels have on the choice making of the participants. These will allow the effects of each attribute to

be tested separately for their main impacts on the choice being modelled. Interaction effects reflect the connection between different variables and the combined influence they have on a choice. While some studies focus heavily on interaction effects, at this stage only the major impacts of the attributes are of interest and interactions are not considered (Hauber et al. 2016). There were a total of eight attributes selected, which are listed below with an indicator in brackets to show whether it is a generic (G) or specific (S) attribute.

1. Drive Time (G)
2. Cost (G)
3. Trip Purpose (G)
4. Weather Conditions (S)
5. Presence of Companion (G)
6. Conversation Provided (G)
7. Availability of Driver (G)
8. Bus Wait Time (S)

This model that was used for the development of this survey was a Multinomial Logit Model (MNL), which provides a simple discrete choice model with fixed parameters with alternatives that are uncorrelated. In discrete choice models, the total utility is given by Equation 1:

$$U_{jsn}(X, \beta) = V_{jsn}(X, \beta) + \varepsilon_{jsn} \quad [E.1]$$

Where:

$V_{jsn}(X, \beta)$  represents the systematic utility, and  $\varepsilon_{jsn}$  represents the random component associated with an individual  $n$  selecting alternative  $j$  in a given scenario  $s$  (Habib, 2013).

$$V_{jsn}(X, \beta) = \sum_{k=1}^{K_j} \beta_k x_{jksn} \quad [E.2]$$

The systematic utility (Equation 2 above) describes the choice of alternative  $j$  during scenario  $s$  by individual  $n$  and the variable  $k$ . Since it is assumed in these models that the random component ( $\varepsilon_{jsn}$ ) is Independent and Identically Distributed (IID) Extreme Value Type I (Hasnine, 2015), the random component can be neglected to develop the choice probability model shown in Equation 3:

$$P_{jsn}(X, \beta) = \frac{\exp(V_{jsn}(X, \beta))}{\sum_{i=1}^J \exp(V_{isn}(X, \beta))} \quad [E.3]$$

This is the choice probability for MNL models, which represents the probability of choosing alternative  $j$  in a scenario  $s$  by individual  $n$ , where  $X$  is the matrix of variables and  $\beta$  is the parameter matrix (Habib, 2013).

In general terms, the initial models took the form shown in Figure 9 below:

---


$$V_{car} = \beta_1(\text{DriveTime}) + \beta_2(\text{Cost}) + \beta_3(\text{Purpose}) + \beta_4(\text{Weather}) + \beta_6(\text{Companion})$$

$$+ \beta_7(\text{Conversation}) + \beta_8(\text{DriverAvailability})$$

$$V_{bus} = \beta_1(\text{DriveTime}) + \beta_2(\text{Cost}) + \beta_3(\text{Purpose}) + \beta_5(\text{Weather}) + \beta_6(\text{Companion}) + \beta_9(\text{BusWait})$$

$$V_{VDP} = \beta_1(\text{DriveTime}) + \beta_2(\text{Cost}) + \beta_3(\text{Purpose}) + \beta_4(\text{Weather}) + \beta_6(\text{Companion})$$

$$+ \beta_7(\text{Conversation})$$

$$V_{AV} = \beta_1(\text{DriveTime}) + \beta_2(\text{Cost}) + \beta_3(\text{Purpose}) + \beta_4(\text{Weather}) + \beta_6(\text{Companion})$$


---

**Figure 9 Initial utility models**

### **3.4.2 Generation of Experimental Design**

The following sections contain the steps followed to complete the generation of the experimental design. These include determining initial parameter estimates, as well as how many attribute levels were to be included and what ranges of values were to be assigned to each.

#### **3.4.2.1 Parameter Estimates**

Preliminary beta coefficients for each attribute were selected from existing values found in literature, where available. The topic of the studies that the parameter values were taken from did not need to be directly related to the overall research being conducted in this study (senior mode choice between VDP, AVs, bus, car passenger), as at the survey development stage they are simply for determining the initial scenarios for a pilot test. The significant factor in this process is that the associated attribute with the coefficient is similar to that being used in the current research, when published values are available.

Previous values were available for more than half of the parameters, but not for Driver Availability, Presence of Companion, having Conversation Provided, as well as Trip Purpose. This is likely due to the specific nature of these attributes in this study; however, the values were not left blank. While it would be possible to use a value of zero for these preliminary estimates, it can be argued that at least the expected sign of the parameter can be predicted, using a small positive or negative coefficient depending on the expected impact. The Driver Availability, Presence of Companion, and having Conversation Provided attributes were assigned a preliminary value of 0.01 each, as these services can be expected to encourage the selection of modes that depend on these attributes.

The limitation with the Trip Purpose attribute is that the only values from the literature in the transportation context were all associated with AVs only, as found in Krueger *et al.* (2016). They suggested a positive value with respect to Work travel ( $\beta= 0.4$ ), but negative for all other purposes ( $\beta= -0.36, -0.48, \text{ and } -0.7$ ). With the wide range of possible values that could result from different trip purposes across the mode choices, and taking into consideration the majority of negative values from Krueger *et al.* (2016), a conservative generic coefficient value of -0.01 was applied for the attribute. Table 5 contains a summary of the preliminary coefficients used to develop the pre-pilot scenarios, as well as the corresponding literature sources (where available).

**Table 5 Preliminary parameter coefficients**

<b>Attribute</b>	<b>Preliminary Coefficient</b>	<b>Source</b>
Drive Time	-0.0031	Hasnine <i>et al.</i> , 2018
Cost	-0.075	Hasnine <i>et al.</i> , 2018
Bus Wait Time	-0.094	dell’Olio <i>et al.</i> , 2011
Trip Purpose	-0.01 (Assumed)	None Available
Weather Conditions (car/AV/VDP))	0.0392	Sabir, M., 2011
Weather Conditions (bus)	0.002	Sabir, M., 2011
Availability of Driver	0.01 (Assumed)	None Available
Presence of Companion	0.01 (Assumed)	None Available
Conversation Provided	0.01 (Assumed)	None Available

Drive time and travel cost parameters coefficient of -0.0031 and -0.075 were taken from the study done at the University of Toronto in 2018, titled *Determinants of travel mode choices of post-secondary students in a large metropolitan area: The case of the city of Toronto* (Hasnine *et al.* 2018). It looked into the mode choices of students attending post-secondary institutions at four major Toronto schools. While the focus of the study was on students in one of Canada’s urban hubs, this is not a concern when applying these values

to the pre-pilot development of a survey for rural older adults. The coefficient used for bus wait time was -0.094, and was found in a study by dell'Olio *et al.* (2011) that focused on the quality of service desired by public transit users. Wait times, cleanliness and comfort were three major factors identified in the study associated with what public transit users look for most when deciding to use a system. The preliminary coefficients for weather conditions were taken from Sabir (2011), a study titled Weather and Travel Behavior. The value used for buses was 0.0392, and for cars, VDPs, and AVs was 0.002.

#### **3.4.2.2 Attribute Levels**

The attributes in the stated choice experiments are used to describe each presented alternative, and allow survey participants to differentiate between the options based on specific parameters. Those include qualities like travel time, costs and wait times, which can vary between different modes of transportation. Each attribute category contains different levels, which are the specific numeric or descriptive values that are selected for each mode alternative (e.g. taxi cost with three levels of \$5, \$10, and \$15). Descriptive levels (e.g. weather conditions like snow or rain) can be assigned by discretion of the researcher, but numerical levels such as costs and wait times should be based on realistic values for the scenarios, which can be identified from literature or other reliable sources. According to a recent review of one year's worth of VDP travel data of seven VDPs operating in New Brunswick, the partner VDP groups averaged approximately 30 km per drive. This was the distance figure used for lesser length of drive, with 60 km used as the greater value to capture longer distance trips. Applying a primary speed of 90km/hour for car-based mode alternatives, this delivered the values of 40 minutes and 20 minutes for

the drive time attribute levels. The speed of 90 km/hour was selected because the speed on many major highways in the region is 110 km/hour, while minor rural roads are more likely to be posted at 70 or 80 km/hour. The value of 90 km/hour was determined as an appropriate average speed for the overall travel for this assessment.

The bus drive times of 64 minutes and 32 minutes was determined by applying an adjustment factor of 1.6 to increase the car times to reflect the slow-stop-accelerate pattern at pickups, which extend the amount of time it takes to reach the destination. This value was not taken from literature, rather assessed by comparing different car and bus route times in the Saint John region using Google Maps.

The lower bus price of \$4 was selected from the City of Saint John Transit web page, where it lists fares ranging from \$2.50 to \$4.00 per ride. Since the bus would be making a long route into rural communities for the pickup, the upper value was utilized for the lower bound. Potential pricing increases to service these areas could arise from travelling the long distance, so the upper value of \$8 was selected in case of a doubling of prices (Saint John Transit, 2018).

The value for cost of AVs came from Bosch *et al.* (2018), a paper titled “*Cost-based analysis of autonomous mobility services*”. This report outlines many components that factor into the cost of a vehicle, and presents summarized costs/km for different scenarios. The selected value coordinated with the pricing for a future competitive situation with AVs in a regional setting. That value was \$0.34/km, which equated to \$20.40 for the greater value, and \$10.20 for the lesser (Bosch *et al.*, 2018).

The wait time for transit bus was determined using an online tool called Moovit, which contains a catalogue of statistics pertaining to public transportation in major cities across the globe, with a section containing average transit wait times. While New Brunswick cities were not listed, the four Canadian cities (Montreal, Ottawa, Toronto, and Vancouver) had average wait times near 15 minutes. This was used as the lesser value as rural transit has wider distances between stops, and an upper value of 25 minutes was selected to account for traffic delays along a simple rural route.

Table 6 provides a summary of each of these attribute level prices and durations.

**Table 6 Attribute level numerical value ranges**

<b>Attribute</b>	<b>Values</b>	<b>Source</b>
Drive Time – Auto Passenger/AV/VDP	40 mins / 20 mins	Google maps
Drive Time - Bus	64 mins / 32 mins	Estimated
Cost – Auto Passenger	\$0- free	Estimated
Cost – Weekly Bus	\$4 / \$8	Saint John Transit
Cost – AV	\$20.4 / \$10.2	Bosch et al. (2018)
Cost – VDP	\$8 / \$15	Approximations from NB VDP data
Bus Wait Time	15 mins / 25 mins	Approximations from Moovit

### **3.4.2.3 Coding the Experiment**

The program that was used to generate the choice scenarios was called Ngene, a tool that is used for developing experimental designs for stated choice experiments. These experiments are used to estimate choice models, a useful resource for transportation planners who desire to conduct new research regarding mode preferences (ChoiceMetrics, 2018).

In order to enter the utility equations into the system, all attributes and the levels had to be expressed using variables and numerical codes. Table 7 contains the attributes assigned to each mode of transportation, their levels, and the numerical values assigned to each level for the purpose of coding.

**Table 7 Summary of attributes and levels for coding**

Attribute	Mode			
	Auto Passenger	Weekly Bus	AV	VDP
Drive time	20 mins (0), 40 mins (1)	32 mins (0), 64 mins (1)	20 mins (0), 40 mins (1)	20 mins (0), 40 mins (1)
Cost	\$0 (0)	\$4 (0), \$8 (1)	\$10.2 (0), \$20.4 (1)	\$8 (0), \$15 (1)
Trip purpose	Health (0), Life Maintenance (1), Quality of Life (2), Work/Ed (3)			
Weather conditions	Good (1), Moderate (0), Poor (-1)			
Presence of companion	Yes (0), No (1)			
Conversation provided	Yes (0), No (1)	-----	-----	Yes (0), No (1)
Availability of driver	Readily Available (0), Uncertain Availability (1)	-----	-----	-----
Bus Wait Time	-----	15 mins (0), 25 mins (1)	-----	-----

After starting the Ngene program, a new “Syntax Window” was opened. This is where all coding occurs for experiments. In addition to the preliminary parameter estimates and attribute levels, the number of scenarios and the type of design had to be selected. The minimum number of scenarios is equal to the lowest common multiple of the attribute levels involved in the design. This design contained attributes with one, two, three, and four levels, which resulted in a lowest common multiple of 12. This is the number of different scenarios the program will generate for the given experiment.

Next, the type of design was selected from a variety of possible designs that include full factorial, fractional factorial, orthogonal, efficient, and Bayesian. An efficient design was determined to be the most suitable; it provides the most effective method for the system to present each attribute level equally in the scenarios, a desired quality in these designs called attribute-level balance, while reducing the standard errors associated with the parameter estimates (ChoiceMetrics, 2018).

Within the “Syntax Window”, the code was input for the system to produce a multinomial logit model for mode choice scenarios between Vehicle Passenger, Weekly Bus, AV, and VDP. This utilized an efficient design to sort attribute levels for the optimum combination of attributes that maximized attribute level balance while minimizing errors associated with the parameters. The syntax code was as shown in Figure 10:

---

```

Design
;alts = alt1, alt2, alt3, alt4
;rows = 12
;eff = (mnl,d)
;model:
U(alt1) = b1[-0.0031]*A1[0,1] + b2[-0.075]*A2a[0] + b3[-0.01]*A3[0,1,2,3] + b4[0.0392]*A4[-1,0,1] +
b6[0.01]*A5[0,1] + b7[0.01]*A6a[0] + b8[0.01]*A7[0,1] /
U(alt2) = b1 *A1 + b2 *A2[0,1] + b3 *A3 + b5[0.002] *A4 + b6 *A5 + b9[-
0.094]*A8[0,1] /
U(alt3) = b1 *A1 + b2 *A2 + b3 *A3 + b4 *A4 + b6 *A5 /
U(alt4) = b1 *A1 + b2 *A2 + b3 *A3 + b4 *A4 + b6 *A5 + b7
*A6[0,1]
$

```

---

**Figure 10 Efficient design syntax for stated choice scenarios**

After entering the syntax into the “Syntax Window”, the model was run, and the program began iterating through combinations of attribute levels. It was left to iterate for

approximately 15 minutes until the estimated D-error, a value representing how efficient the design is, remained unchanging. At this point, the run was stopped and the results of the experimental design were displayed within the “Design Window”. The outputs were then inspected to assess the overall quality of the design and to highlight potential drawbacks that may need to be addressed before a full survey deployment takes place.

### 3.4.3 Incorporating Participant Demographic Information

Another component that was included with the survey design was demographic questions to provide descriptive statistics about the respondents. In some stated choice experiments, the demographic information is included as attributes to be coded into the model; however, to maintain simplicity of the model these were not incorporated directly into the experimental design generation. Two major categories of demographic information were selected: Personal Information, and Household Information. The subcategories selected for each are shown in Table 8.

**Table 8 Demographic Information**

Personal Information	Household Information
1. Sex	1. Residence Ownership
2. Age	2. Household Size
3. Employment Status	3. Household Income
4. Driver Status	4. Number of Vehicles
5. Education	

The expanded demographic information categories and be found alongside the results of the experimental design in Chapter 4.

## **4.0 Analysis and Results**

This chapter contains the results for each of the analyses outlined in the methodology. That includes the volunteer driver surveys and the tasks they regularly perform to assist users, the overall VDP origin and destination travel breakdowns, as well as the stated choice experiment scenarios and efficiency measures.

### **4.1 Driver Survey**

The following sections outline the results of the volunteer driver survey, which include volunteer frequencies per week, the purposes for each stop, passenger counts, as well as the activities performed by the driver to support the clientele. The different categories of stop locations are discussed, as well as some lessons learned from VDP drivers for the operation of AVs in rural areas.

#### **4.1.1 Volunteering and Stop Frequencies**

Twenty-four of the 37 respondent volunteer drivers were aged 65 and over, a higher percentage than national figures showing 10%-15% of volunteer drivers were aged 65 and older (Hanson, 2017), but likely a reflection of the local volunteer pool and demographics in rural New Brunswick which have higher average ages than in urban areas. These data show how it is not just younger working adults volunteering their free time to assisting the people of their community with transportation, but older adults that are helping as well. This may reflect the change in lifestyle that many people experience after the age of 65, the age around which many people begin considering retirement. With free time and a need in the community from mobility-disadvantaged peers, those

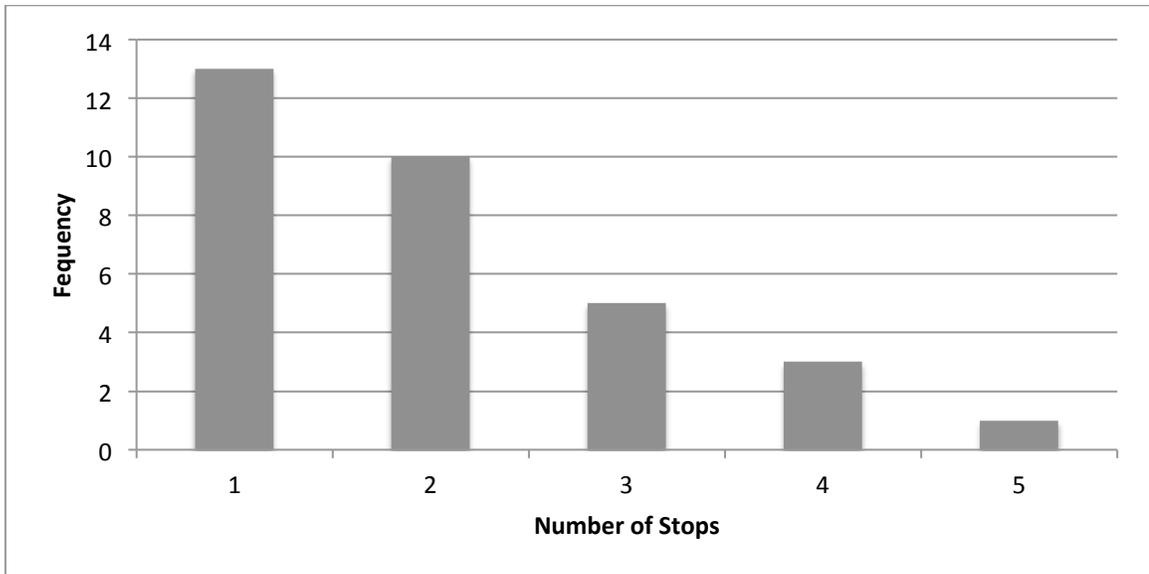
individuals with the time and the ability to help appear to be excellent candidates for a volunteer driver.

The majority of respondents donated approximately 1-2 hours per week (Table 9), which is consistent with national figure reported by Hanson (2017) where those aged 55-64 contributed on average 1.7 hours per week, while those ages 65-74 and 75+ contributed 1.3 hours/week and 1.4 hours/week respectively.

**Table 9 Volunteer frequencies per week**

Hours	Total Count	<65	65+	Total Percentage of respondents
Less than 1 Hour	2	1	1	5%
1-2 Hours	14	6	8	38%
3-4 Hours	9	1	8	24%
5-6 Hours	7	1	6	19%
7-8 Hours	1	1	0	3%
Over 8 Hours	3	2	1	8%
Blank	1		1	3%

Each survey participant was asked to recall their most recent volunteer driving experience, and for that drive to indicate how many stops they made, what the destinations and stop purposes were, what activities they performed in addition to driving, as well as the number of passengers at each stop. The definition of a stop and a drive is outlined in Hanson & Goudreau (2019) as follows: a stop (or trip leg) is defined as the one way travel activity from an origin to a destination during a drive (trip chain) and is associated with a physical stop by the vehicle; a drive consists of all sequential one-way stops to a destination and ends when the commitment to the client ends and the volunteer is free to serve other clients. The number of stops made by the 37 volunteers throughout the trip making is displayed in Figure 11 below.



**Figure 11 Frequency of stops by drivers on most recent drive**

The drivers were instructed to report on their most recent VDP drive only; however, there was a small number of participants (5 of 37) who appear to have neglected to provide information for just the most recent experience and the data suggest the inclusion of multiple drives. This is not to disqualify the provided stop information, as there can be trips with a large number of stops, however by considering the destinations of each stop the likelihood of multiple drives can be inferred. During data analysis, the drives with over five stops were flagged due to the repetitive destination locations (e.g. Hospital stops back-to-back repeatedly) that suggested it held more than just one drive's worth of stops. These flagged stops (those exceeding five stops) were excluded from the stops per drive assessment due to their ambiguity.

#### 4.1.2 Stop Purposes, Volunteer Activities, and Passenger Counts

The drivers indicated the stop purpose based on four categories: Health, Life Maintenance, Quality of Life, and Work/Education. These categories align with the current reporting methods used by the VDPs, and can be used to identify patterns or trends amongst generalized trip making rather than exclusively by destinations. The total number of stops made by the volunteers for each purpose is detailed in Table 10 below. Some stops were assigned to multiple purposes according to the drivers' discretion and knowledge of the users' needs and reasons for the stop. These multi-purpose stop categories are denoted with the initials of the primary stop purposes they involve (H for Health, LM for Life Maintenance, Q for Quality of Life, and W/Ed for Work/Education). Given that the number of total stops recorded was approximately 100, the number of stops is equivalent to a percentage.

**Table 10 Number of stops by purpose**

Purpose	Stops
Health	41
Life Maintenance	21
Quality of Life	21
Work/Education	7
H-LM	5
H-Q	2
H-LM-Q	1
LM-Q	2
Q-W/Ed	1
Total Stops	101

Five different categories of driver activities were presented to the respondents: open/close vehicle door, physically assist client(s) into/out of vehicle, escort client(s) between

vehicle and destination door, escort client(s) into destination to provide further support, and assist with objects (mobility equipment, groceries, etc.). The drivers identified what tasks they performed to assist their clientele during their most recent drive, and the results were divided based on stop purpose. The type and frequency of activities performed in addition to driving by the volunteers is displayed in Table 11.

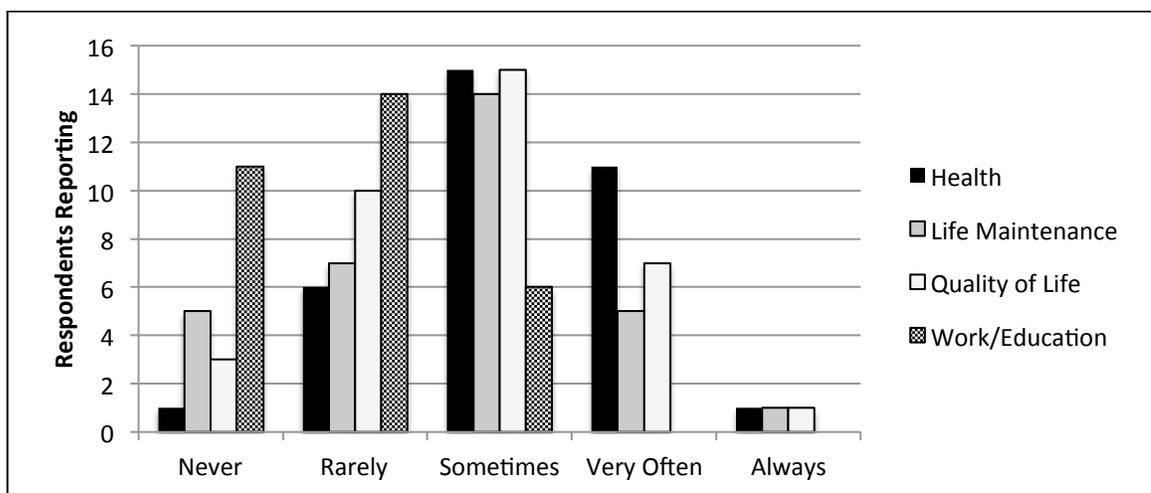
**Table 11 Activities performed by stop purpose**

Activity	Health		Life Maintenance		Quality of Life		Work/Education		Multi-Purpose	
	Assisted	% of Stops	Assisted	% of Stops	Assisted	% of Stops	Assisted	% of Stops	Assisted	% of Stops
Open/close vehicle door	11	27%	5	24%	5	24%	4	57%	7	64%
Assist clients into/out of vehicle	7	17%	3	14%	2	10%	1	14%	4	36%
Escort clients between vehicle and destination door	14	34%	6	29%	2	10%	1	14%	4	36%
Escort clients into destination for further support	15	37%	5	24%	3	14%	0	0%	2	18%
Assist with objects	7	17%	8	38%	10	48%	0	0%	7	64%
Total stops	41		21		21		7		11	
Total activities	54		27		22		6		24	
Stops with no assistance	14		7		8		3		0	
% of stops without assistance	34%		33%		38%		43%		0%	

Health purpose stops were the most frequently reported and had the largest number of driver activities performed overall (54), while Life Maintenance trips were most likely to have driver assistance. When accounting for multi-purpose trips, however, these combined-purpose stops exhibit the highest proportion of stops (100%) with additional assistance from the drivers, having all stops with assistance. Work/Education had the

lowest number (6) of activities performed out of all stop purposes. Out of the total 101 stops, only 32 (32%) did not require any additional assistance from the driver. Across all stop purposes, the percentage of stops that did not require assistance range from 0% to 43%, which shows that approximately 57%-100% of stops encounter some form of assistance, depending on the stop purpose(s).

In addition to identifying what tasks they performed on their recent drives, the volunteers were also asked to indicate on a five-point Likert scale how often they generally provide additional assistance (like the tasks outlined previously) to the VDP users for each stop purpose category (Figure 12). There were several respondents who left items blank in this section, many of which indicating they had not driven for a particular trip purpose yet (e.g. Work/Education) and did not want to give false data representations by selecting the “Never” option. The data in Figure 12 show that Health stops are most likely to require assistance while Work/Education requires the least, consistent with the activities reported by respondents for their previous day of volunteering.



**Figure 12 Assistance frequencies by stop purpose**

Reported by the 37 volunteers, the number of passengers ranged between zero and five people. There was only one instance of zero passengers at a stop made by volunteers, which was the result of a food delivery by the volunteer. The most common number of passengers during the trip making was one passenger, accounting for 83% of the total stops. Table 12 contains the passenger counts for each stop type in the study.

**Table 12 Passenger counts from VDP survey**

Number of Passengers	Health	Life Maintenance	Quality of Life	Work/Education	Multi-purpose
0	0	1	0	0	0
1	36	17	16	6	9
2	4	0	2	0	1
3	0	1	2	0	0
4	1	0	1	1	0
5	0	0	0	0	1
blank	0	2	0	0	0
Total	41	21	21	7	11

Along with each activity reported by volunteers, they were asked to identify whether or not they considered that task to be typical during their volunteering experiences. If the volunteers consider an activity typical, it indicates that they regularly perform the task for similar stop purposes, and that the activity is not out of the ordinary for the services they usually provide. Data regarding what tasks the participants identified as typical is presented in Table 13 below.

**Table 13 Typical activity by volunteers**

Activity	Health			Life Maintenance			Quality of Life			Work/Education			Multi-Purpose		
	Assisted	Typical	% Typical	Assisted	Typical	% Typical	Assisted	Typical	% Typical	Assisted	Typical	% Typical	Assisted	Typical	% Typical
Open/close vehicle door	11	9	82	5	4	80	5	4	80	4	3	75	7	6	86
Physically assist clients into/out of vehicle	7	6	86	3	2	67	2	2	100	1	1	100	4	3	75
Escort clients between vehicle and destination door	14	10	71	6	4	67	2	2	100	1	1	100	4	3	75
Escort clients into destination to provide further support	15	9	60	5	5	100	3	1	33	0	0	N/A	2	2	100
Assist with objects (mobility equipment, groceries, etc.)	7	6	86	8	6	75	10	7	70	0	0	N/A	7	6	86
Total by Purpose	54	40	74	27	21	78	22	16	73	6	5	83	24	20	83

The tasks performed by volunteers were reported to be typical during this study for 77% of stops with extra assistance from volunteers. That represents 102 volunteer tasks out of 133, indicating that a vast majority of the time it is normal for a volunteer driver to provide additional assistance. The stop purpose categories of Work/Education and the Multi-purpose stops had the highest portion of activities considered typical at 83% of tasks, and Quality of Life had the lowest, with 73% of driver activities considered typical. The task of escorting clients into destinations to provide further support was identified as the driver task with the lowest proportion of typical tasks with 17 of the total 25 assists (68%) in this category. Opening/closing the vehicle door and physically assisting clients into/out of the vehicle had very similar proportions considered typical activity at 81% and 82% respectively.

### 4.1.3 Stop Locations

The volunteers indicated for each stop where the destination location was. This included a wide variety of responses, ranging from hospitals, grocery stores, and airports. These destinations were sorted into nine categories, and the stops associated with each category are shown in Table 14. The complete list of destinations and the number of stops for each can be found in the Appendix B: Table B1.

**Table 14 Destination category purposes from volunteers**

Category	No. of Destinations	Health	Life Maintenance	Quality of Life	Work/Education	Multi-purpose	Total Stops
Shopping/Errands	12	1	9	8	0	2	20
Non-Hospital Medical	6	17	3	1	0	3	24
Recreation/Dining out	6	0	4	2	0	0	6
Residence	5	0	1	5	1	1	8
Other	3	0	3	0	0	0	3
Education/Training	2	0	0	0	2	0	2
Hospital	1	23	1	2	2	4	32
Work	1	0	0	0	2	1	3
Transportation	1	0	0	3	0	0	3
Total	37	41	21	21	7	11	101

The most common destination was the Hospital, with 32 of 101 stops, with Health-purpose stops representing 72% (23 stops). Non-Hospital Medical stops (Doctor's appointments, eye appointments, clinics, etc.) were the second most common stop destination, with 24 of 101 stops (24%). Some stops destinations have received multiple purpose classification by the drivers; the most common scenario for this to occur is when a destination is identified for both one specific purpose and for a multi-purpose stop (which often included the primary stop purpose from other stops at that location, i.e. a

doctor's appointment identified as health, as well as Health-Life Maintenance stop by different drivers based on the users' needs).

Specific destinations, however, were labelled with different purposes altogether (neglecting multi-purpose); the five destinations were Eye appointment (Non-Hospital Medical), Grocery Store (Shopping/Errands), Home (Residence), Hospital, and Physiotherapy (Non-Hospital Medical). The volunteers classified Eye appointment as Health and Quality of Life, Groceries was Quality of Life and Life Maintenance, Home was Life Maintenance and Quality of Life, Hospital fell into every purpose classification, and Physiotherapy was Health and Life Maintenance. Eye appointment and Grocery Store received an even split between the two classifications they each received, whereas Hospital was primarily Health, with the remaining classifications accounting for only 28% of the Hospital stops combined. Home Stops received more Quality of Life (3) than Life Maintenance (1), and Physiotherapy was identified as more Life Maintenance (3) compared to Health (1). The volunteers have the best understanding of the needs of the clients and the stop purposes that should be attributed to the destinations are considered true and accurate for that stop.

The volunteer activities were also broken down by the driver tasks performed at each destination. Table 15 contains the number of times each task was performed for the summarized destination categories. Table B2 in the Appendix B contains the task counts for each individual destination location. The tasks are labelled A through E:

Task A - Open/close vehicle door

Task B - Physically assist clients into/out of vehicle

Task C - Escort clients between vehicle and destination door

Task D - Escort clients into destination to provide further support

Task E - Assist with objects (mobility equipment, groceries, etc.)

**Table 15 Volunteer activities by destination category**

Category	No. of Destinations	Total Tasks	Task A	Task B	Task C	Task D	Task E
Hospital	1	54	13	10	14	9	8
Non-Hospital Medical	6	28	7	1	6	9	5
Shopping/Errands	12	19	3	1	2	3	10
Residence	5	15	4	3	3	1	4
Recreation/Dining out	6	8	2	1	2	2	1
Other	3	4	1	0	0	1	2
Transportation	1	3	1	0	0	0	2
Education/Training	2	1	1	0	0	0	0
Work	1	1	0	1	0	0	0
Total	37	133	32	17	27	25	32

The tasks performed at each destination vary, however certain locations have a higher frequency of volunteer intervention than others. Destinations of Hospital, Grocery store (Shopping/Errands), and Doctor's appointments (Non-Hospital Medical) had the highest frequency of volunteer activities. Hospital stops had a total of 54 driver activities, Doctor's appointment stops had 17 driver activities (61% of Non-Hospital Medical activities), and Grocery Store stops (10 tasks) accounted for more than 50% of Shopping/Errands driver activities. The stops at hospitals had relatively high quantities of all driver activities, ranging from 8 to 13 across the different driver activities, but the most common were Escorting clients between vehicle and destination (14 stops) and Opening/closing vehicle door (13 stops).

#### **4.1.4 Preliminary Lessons from VDP drivers for rural AV operation**

This distribution of tasks the drivers perform to support the VDP users introduces uncertainty into the concept of AVs as a useful service for non-drivers in rural areas. Respondents indicated they provided assistance in 68% of overall stops. If the percentage of stops requiring driver assistance are applied to the travel data (excluding home) of the seven groups studied by Hanson & Goudreau (2019), 65% of the Small & Medium groups stops and 64% of the Large group stops would involve driver assistance. It may be possible to automate some tasks, like opening a door, but the majority of tasks still require human interaction.

The data in Table 10 are consistent with some of the findings of Hanson & Goudreau (2019) across seven VDPs operating in New Brunswick, where Health stops were the predominant stop type, accounting for 49% of overall stops, ranging from 34% to 52% depending on group size (Small & Medium (fewer than 100 riders), or Large (101 – 300 riders)). The ranges of stop purposes by group size suggests that each group may be responding to different transportation needs, meaning that the introduction of AV may not be uniformly effective. There are some stop purposes that require relatively little assistance on behalf of the volunteer (Work/Education), while there are stops that consistently show driver involvement with the clients (e.g. Health purpose trips). The data suggest that for trips that are not medically focused, nor to facilitate the transportation of large quantities of household goods (e.g. Life Maintenance tasks like grocery shopping), that AVs would be capable to replicate the trip making.

The fact that nearly one third of stops did not require additional assistance suggests that AV's may still have utility in a limited capacity. If a program were to be interested in adopting AVs in the future despite the poor fit with certain stops, the volunteers might consider transitioning from driver to companion rider in the AVs on trips where their presence is requested. This way, those clients who do not want/need any assistance can use the AV for their travel but those individuals who depend on the additional services will still have them available upon request. This format would remove the wear and tear on the volunteers' personal vehicles, as well as increase the socialization between clients and volunteers, which is a highly valued component of VDPs. The time spent by respondents providing transportation services to users is relatively small on a weekly basis, suggesting that theoretically, existing needs may be satisfied with fewer AVs rather than having multiple drivers volunteering for small periods. However, one potential drawback for the AVs would be if the system implemented a very small fleet, but there was a large demand for particular days/times that the supply might not meet the demand. This issue would fall to whoever is designing the scheduling system to ensure the user schedules are suited by the availability of the AVs.

#### **4.1.5 Driver Survey Conclusions**

The results of the volunteer driver survey indicate a dependence on the additional services provided by the drivers for trips related to a user's health, as well as instances associated with transporting large quantities of household goods like getting groceries. Stops for the purpose of Work and Education show the least dependency on the driver for anything other than driving. The volunteer driving participants in this survey reported a

total of 133 assistance tasks across the 101 stops included in the study, the largest portion of which (41%) are attributed to Health-only purpose stops. Two-thirds of the volunteers surveyed are aged 65 years and older, and 38% of respondents indicated typically volunteering between one and two hours per week. Over half (62%) of respondents reported stopping only once or twice on their most recent volunteer drive, which suggests these programs are not being used for long stop-and-go trips. One limitation of this study is that it was not possible to distinguish from the survey whether the individual VDP users were actually over the age of 65 or not, nor whether they had a condition or disability that required the additional assistance from the drivers. The surveys were distributed to the volunteers, and obtaining this information would have been speculation on the part of the volunteers, as well as potentially facing some barriers in terms of disclosure of private client information. Since the types of stops were associated with destinations that older adults could be expected to have assistance with, like health and shopping, the results have value for rural older adults, even if the ages cannot be directly distinguished from these data.

AVs appear to be capable of meeting the needs of users for approximately one third of stop purposes; however, the mixed dependence on the drivers would require some careful planning. One solution to this issue would be to have volunteers available if needed to accompany clients in a companion capacity rather than as a driver in an AV. This would reduce the demand on volunteers' time since they would only be present by request, and increase the level of assistance they could provide to users. The major benefit of AVs is that no driver is needed; however, to facilitate the additional assistance the users appear

to rely upon, a human presence would still be necessary, ultimately defeating the purpose of an AV. The results of this study suggest that AVs may have limited utility in meeting the needs of rural users dependent on others for transportation, as drivers play important roles in the majority of observed stops. Further research is recommended from the perspective of the VDP users that would focus on the value they place on assistance being provided by volunteers. Ranking of client assistance activities, as well as rating the importance each task has on the user's ability and comfort to use these programs would provide additional insight into the potential of AVs to replicate VDP trips.

#### **4.2 VDP Travel Data**

This component of the study was a preliminary travel assessment using travel data as reported by a VDP in New Brunswick for the purposes of estimating the percentage of kilometres driven on different classes of roadway. The data collected by the program included only the origins, destinations, overall distance travelled on the drive; therefore it is not possible to determine the precise routing that would allow an exact determination of travel by road class. Nevertheless, the presence of origin and destination name permitted the development of travel distance estimates by road class. To determine the kinds of roads being used between the origin and destination (O/D) pairs, the reported kilometres of each drive were neglected, and only the O/D information was used (beginning and end locations, and the number of times that O/D appeared in the year of VDP travel data). The reported kilometres of each drive were not used for the travel data analysis as the travelled routes were not provided, and did not contain any additional information to assist in the road assessment.

#### **4.2.1 O/D Pairs**

The origins and destinations were entered into Google to determine the distance of each drive, using the “shortest distance” as assigned by Google Maps. There was a total of 92 O/D pairs, each considered individually (e.g. St. Stephen to Saint John and Saint John to St. Stephen considered as unique pairs, since the pairs were reported to have different frequencies of drives). The total kilometres were determined from the individual kilometres/drive as reported by Google, multiplied by the number of times the VDP was used for transportation between that origin and destination. This simplification of travel patterns would have some implications on the assessment predictions. This method applies the shortest travel time between locations from the community centre points, while the true origins or destinations are likely located farther away from the approximated locations. This was confirmed by comparing the total estimated distance based upon O/D pairs to total distances reported on a per drive basis by the VDP. The total combined distance travelled between all O/D pairs as reported by the VDP was 137288 km over 3145 total drives. The total kilometres estimated from reviewing travel data based on O/D alone was 62342 km, or 45% of overall reported kilometres. This is a difference of approximately 24 km/drive between reported and O/D based values. Possible sources for this difference between the VDP reported and O/D based values are the accumulation of differences between true origin and destination locations that are away from community centre points used within the analysis, as well as any approximations in driver reporting. GPS data from VDPs would improve the precision of origin and destination travel assessments for these purposes.

The rationale for identifying what proportion of roadway was dedicated to urban travel and rural travel was to determine VDP operating environment; however, without knowing the true location of drop off/pickup, any identification of urban/rural would add additional simplifying assumptions based on the already approximated road segment estimates. The subject of rural versus urban road was also omitted as the definition of “urban” and “rural” tend to vary from region to region, meaning that what might be considered an urban community by some, to others could be considered rural.

The total kilometres for each pair were combined for a total travel distance of 62342 km. The contribution of each O/D pair to the total travel distance was determined by dividing the O/D kilometres by the total travel distance, and displayed as a percentage of the total travel distance. The 92 O/D pairs each contributed to the total kilometres, however, 52% (33263 km) of the total travel distance resulted from only eight O/D pairs, as summarized by the O/D information in Table 16. The complete list of O/D pairs, and the associated drive counts, and distances are catalogued in Appendix C, Table C1.

**Table 16 O/D pairs with the largest travel contribution**

<b>Rank</b>	<b>Origin</b>	<b>Destination</b>	<b>Number of Drives</b>	<b>Total KM</b>	<b>% of Overall KMs</b>
1	St. Andrews	St. Stephen	274	8494	13%
2	St. Stephen	St. Andrews	200	6200	10%
3	St. Stephen	Tower Hill	229	3893	6%
4	Tower Hill	St. Stephen	225	3825	6%
5	St. Andrews	Saint John	34	3502	6%
6	Milltown	Saint John	22	2596	4%
7	Lake Utopia	Saint John	34	2380	4%
8	St. Stephen	Saint John	21	2373	4%

The St. Andrews to St. Stephen O/D pair represents the largest portion of total kilometres, at 13% of the overall kilometres. The second largest contribution of kilometres was the reverse pairing of St. Stephen to St. Andrews with 10% of the total; the combined travel between these two areas accounts for nearly one quarter of the overall distance travelled, indicating a high frequency of movement between these larger rural communities within the region.

Coincidentally, the next two largest shares of distance traveled resulted from St. Stephen to Tower Hill (6%) and Tower Hill to St. Stephen (6%). The remaining 84 O/D pairs provided only 0%-2% of the kilometres each, accounting for 48% of the total travel distance.

The route between St. Stephen and St. Andrews is only 31 km in length, and only 17 km between St. Stephen and Tower Hill, which shows that VDP users are travelling smaller lengths at much higher frequencies to meet their needs, and long distance trips (e.g. to Saint John) are demanded less often. The use of AVs to replicate this travel would require the ability to operate primarily within rural areas, as the majority of the travel is concentrated between the rural communities. The system of AVs could be operated out of the regional “hubs” of the rural travel, which would allow for shorter wait times and less wear-and-tear on vehicles. Although major urban centres would likely be considered first for the placement of an AV program, if they seek to service the rural regions effectively, then the vehicles should be where the demand for service is.

#### 4.2.2 Road Segments

Each road segment on the route between each O/D pair was identified, and the length of travel on that span was recorded from Google Maps. Table 17 contains a sample of one O/D pair with the accompanying road segment information.

**Table 17 Example of O/D road segments**

<b>Origin</b>	<b>Destination</b>	<b>Drives</b>	<b>Distance (km)</b>	<b>Road Segments</b>	<b>Lengths (km)</b>
Beaver Harbour	Blacks Harbour	1	5	Main St/ NB-778	0.012
				Mountain Rd	2.42
				NB-176 S	2.65

Each road segment was classified according to the available provincial road designation information; the six classification categories were Divided Multi-Lane, Undivided Highway, Collector Highways, Local Highways, Named Roads/Streets, and Ramps. There was only one four-lane divided highway in the region to be used, which was NB-1, the lengths of which are identified with east and west directionalities in Table 18.

**Table 18 Estimated VDP travel on divided multi-lane highways (NB-1)**

<b>Roads</b>	<b>Length of Travel (km)</b>
NB-1 E	16762
NB-1 W	8561
<b>Total</b>	<b>25323</b>

Similar to Route 1, there was only one undivided highway along the O/D routes, NB-3, divided into north and south travel in Table 19 below.

**Table 19 Estimated VDP travel on undivided highways (NB-3)**

Roads	Length of Travel (km)
NB-3 N	1399
NB-3 S	1551
Total	2950

There were 17 different collector highways identified in the study between the identified O/D pairs. There are several segments that appear more than once, as they are cross-labeled with a local road name in the region as the road passes through a community. The top five collector highways and the lengths of each are presented in Table 20, along with a combined value for the remaining road segments.

**Table 20 Estimated VDP travel on collector highways (NB-100's)**

Roads	Length of Travel (km)
NB-170	7555
NB-127 N	4675
NB-127 S	4032
King St / NB-170	413
Main St/ NB-176 N	408
Remaining roads	580
Total	17663

There were 21 local highways used between origins and destinations, many identified separately based on the travel directions north (N), south (S), east (E), or west (W). While these directional splits on roads may not be an essential distinction, they are a useful piece of information when considering road wearing and maintenance. The summary of local highways (class NB-700 roads) on the VDP travel routes is displayed in Table 21 below.

**Table 21 Estimated VDP travel on local highways (NB-700's)**

Roads	Length of Travel (km)
NB-755 N	1968
NB-755 S	1961
NB-735 N	1285
NB-735 S	757
NB-760	242
Remaining roads	1041
Total	7254

There were 44 local named roads/streets in this section of the analysis. The segments contributing the highest amount of travel were in St. Stephen. The full list of local named roads/streets used in this assessment and their lengths is presented in Table C2, which can be found in Appendix C. Table 22 contains the data for counts of local roads/streets and the total combined length of travel for this road class.

**Table 22 Estimated VDP travel on named local roads/streets**

Number of Roads	Length of Travel (km)
44	8851

When entering or exiting the divided highway Route 1 (NB-1 E/W), drivers must take an on or off ramp to complete their movements. Since Route 1 (NB-1 E/W) represents a significant portion of travel between the reported destinations, it is important to acknowledge the amount of driving the ramps would need to accommodate, which is why a separate road class category “Ramp” was included in the analysis. Table 23 contains a summary of the road segment lengths by class, and displays the length of travel on each of the six types of roadway, including the highway ramps.

**Table 23 Estimated road travel summary**

Class	Length of Travel (km)	Percentage
Divided Multi-lane (NB-1)	25323	41%
Undivided Highway (NB-3)	2950	5%
Collector Highways (NB-100's)	1766	28%
Local Highways (NB-700's)	7254	12%
Named Roads/Streets	8851	14%
Ramp	300	<1%
Total	62342	100%

The divided multi-lane highway accounted for 41% of the total estimated distanced travelled with over 25000 km of the total 62342 km. The next most frequented road class was collector highways with 28% of the total estimated kilometres. These data suggest that if AVs were to be implemented for these travel purposes, they must be well suited to rural travel on and off major highways.

Roadway lighting, striping, and pavement surface conditions can vary dramatically throughout different regions of the province, meaning that proper maintenance in these areas will be essential for the successful operation of AVs. The American Planning Association published a paper titled *Preparing Communities for Autonomous Vehicles* (Henaghan, 2018), in which a variety of topics were discussed including mobility access, transportation network impacts, and infrastructure and land use. The paper presents a vision for the future infrastructure developments that should be put in place to support autonomous driving from the short term into long term planning. Short-term items include increasing the volume of electric vehicle charging stations to support and encourage the deployment of AVs on public roads. In addition, during early deployment there will be a lack of connectivity available from roadside infrastructure, especially in

rural regions. With rural regions likely lacking the funding to implement connective roadside infrastructure (at least in the short term), the report suggests a simpler approach to assist AVs is to improve the quality of road striping to provide a clear delineation of the roadway (Henaghan, 2018). In extension of this recommendation, replacing damaged or low quality signage would also aid the vehicles sensors to properly identify the information.

When budgeting for improvements to support AVs (resurfacing, striping, signage, lighting, etc.) and for new V2X infrastructure, priority should be given to the lower class rural roads and streets. Although the Multi-lane Divided Highways account for the largest amount of kilometres (41%), these road segments are often maintained to a higher standard. The lower class roads can be neglected and fall into varying states of disrepair, meaning they would need to have improvements to the signage, lane line striping, and asphalt surface to be consistent with the major highway conditions. This would encourage ease of operation of the AVs when transitioning between different road classifications.

### **4.3 Road Segments and Trip Purposes**

These sections present an analysis of the common user needs in combination with the expected roadways to be used by AVs to service the VDP clientele, and operational scenarios of the AVs attempting to meet the user needs in this context.

### 4.3.1 Main Trip Purposes by Road Classification

To determine the main purposes of travel for each road class, the results of the driver activity surveys was combined with the data from the road segment analysis. The combination of the VDP road classification breakdown, and the VDP trip purpose data resulted in 24 separate kilometre estimates. These estimates are broken down by roadway classification and purpose of travel by the VDP. Table 24 contains the road class trip purpose estimate values, rounded to the nearest kilometre.

**Table 24 Trip purpose kilometre estimates**

Road Class	Health	Life Maintenance	Quality of Life	Work/ Education
Divided Multi-lane (NB-1)	22909	1353	1036	25
Undivided Highway (NB-3)	1740	59	6	1146
Collector Highways (NB-100's)	6571	1176	87	9829
Local Highways (NB-700's)	835	176	46	6197
Named Roads/Streets	2270	491	91	5999
Ramp	237	45	16	2

Travel on Divided Multi-lane highways (NB-1) contributed the highest amount of kilometres overall, which was expected as NB-1 is the largest highway that is routed through the region where the VDP operates. This major class of road had the largest portion of kilometres (90%) contributed by Health purpose trips, with an estimate of over 22900 km. The class of Undivided Highways (NB-3's) represented very few of the overall kilometres, but of those spent on this classification, 59% were dedicated to Health trips. The Collector Highways (NB-100's) made up nearly one third of the overall travel from this study, and contrast with the previous two categories by showing the most common purpose (56%) of Work/Education. The primary trip purpose for the Local

Highways (NB-700's) as well as Named Roads/Streets was also Work/Education, with 85% and 68% of the estimated kilometres for each road class, respectively. The final road class category accounted for very little of the overall estimated kilometres (less than 1%), but the strong majority (79%) of that distance was associated with Health travel.

#### **4.3.2 AV Operational Scenarios and Limitations**

In an operation scenario with AVs, the need for advanced user assistance features would be essential to meet the user needs. Automatic vehicle doors, combined with a lift system to aid users into and out of the vehicle would ensure the comfort and ease of access to the vehicle. Accompanied with the lift system, the necessary safety infrastructure would need to be put in place so that there is no risk of a fall when a lift is requested. This could be in the form of rails that retract to and from the lifting mechanism or the vehicle cab, and safely enclose the user while using the system. These would need to compactly fit within the vehicle frame and must not inhibit user mobility within the cab to operate any necessary controls, nor to pose any additional safety threats in the case of a collision. A similar system would need to be available for any large burdensome objects the users might be carrying. These would include items such as walkers, grocery bags, portable oxygen tanks, etc. Specifically related to the mobility equipment, without the aid of another person to assist entering or exiting the vehicle, that equipment would need storage directly with the users. This space must be considered for AV usage in this context.

AVs cannot, however, provide an escort between the vehicle and pickup/destination doors. For this reason, in the many cases that need the additional support outside of the

vehicle that someone would need to be arranged on either end of the trip. While some establishments may be willing and capable to arrange for an employee to meet the vehicle rider upon arrival for that assistance, it is not always available on the home end of the trip making.

The users that maintain a higher level of mobility, and are physically capable of entering and exiting the vehicle without assistance would be well suited for an AV system of transport. AVs in their initial stages, without added accessibility technology, do not appear to have the capabilities to meet the needs of those rural older adults whose physical mobility is at a diminished level. Since many of the target users for this group of rural adults are in need of additional services, the overall likelihood for the “basic” AVs to service VDP users is low. Autonomous Shuttle Busses present a more viable option for these uses, but they must be properly equipped for long journeys rather than shorter urban travel routes they are initially designed for.

#### **4.4 Stated Choice Experiment Development**

The following sections contain the results of the experimental design generation, in the form of choice scenarios and the accompanying efficiency measures for the design. The demographic information to be collected along with the stated choice survey is detailed further, and recommendations are made regarding potential alterations to the model in the future.

#### 4.4.1 Demographic Questions

Demographic questions permit further connections to be made between stated choice responses and the people who participate, by providing descriptive statistics about the factors outside of the experiment that might display trends among the mode choices. The information to be collected about the individual respondents is outlined in Table 25.

**Table 25 Individual demographic information**

<b>Sex</b>	Male Female Other
<b>Age</b>	65-74 75-84 85+
<b>Employment Status</b>	Fulltime Part-time Retired Student Unemployed
<b>Driver Status</b>	Licensed Active Driver Licensed Non-Driver Unlicensed Non-Driver
<b>Education</b>	< High School Diploma High School Diploma College Certification Bachelor's Degree Post-Graduate Degree

The household information to be collected about respondents included the home ownership status, number of people living in the household, the income, and the number of vehicles. The selection options for survey participants about the household information are shown in Table 26.

**Table 26 Respondent household information**

<b>Residence Ownership</b>	Own Rent Alternative arrangement
<b>Household Size</b>	1 person 2 persons 3 persons 4 persons 5 or more persons
<b>Household Income</b>	<\$15000 \$15000 to \$30000 \$30000 to \$45000 \$45000 to \$60000 \$60000 to \$75000 >\$75000
<b>Vehicles</b>	0 1 2 3 or more

#### **4.4.2 Choice Scenarios**

Ngene was used to generate an experimental design resulting in 12 different scenarios with varying attribute levels across the mode choice alternatives. The program provides the scenarios in the form of variables that needed to be replaced with the values the code was used to represent. Table 27 contains a sample scenario provided from the experimental design.

**Table 27 Choice scenario 1 from Ngene**

<b>Attribute</b>	<b>Car Passenger</b>	<b>Weekly Bus</b>	<b>AV</b>	<b>VDP</b>
<b>Drive Time</b>	1	0	0	1
<b>Cost (car passenger)</b>	0			
<b>Trip Purpose</b>	0	2	3	1
<b>Weather Conditions</b>	0	1	1	-1
<b>Presence of Companion</b>	1	0	0	1
<b>Conversation Provided (car passenger)</b>	0			
<b>Availability of Driver</b>	1			
<b>Cost (bus, AV, VDP)</b>		1	0	0
<b>Bus Wait Time</b>		0		
<b>Conversation Provided (VDP)</b>				0

The information associated with each value in the generated scenarios was manually added in for a result with all attributes and the appropriate levels displayed. Table 28 shows the same scenario as above, formatted with attribute level content. All 12 formatted scenarios are available in the Appendix D.

**Table 28 Formatted scenario 1**

<b>Attribute</b>	<b>Alternative</b>			
	<b>Car Passenger</b>	<b>Weekly Bus</b>	<b>AV</b>	<b>VDP</b>
Drive Time	40 mins	32 mins	20 mins	40 mins
Cost	\$0	\$8	\$10.20	\$8
Trip Purpose	Health	Quality of Life	Work/Ed	Life Maintenance
Weather Conditions	Moderate	Good	Good	Poor
Presence of Escort	No	Yes	Yes	No
Conversation Provided	Yes	---	---	Yes
Availability of Driver	Uncertain Availability	---	---	---
Bus Wait Time	---	15 mins	---	---

In the stated choice survey, a participant would be presented with each of the 12 scenarios with the varying attribute levels for the alternative mode options. Based on the assigned attribute levels, the user would then select which mode alternative they most prefer. This would result in 12 choice decisions for each survey that is distributed, and can indicate which attributes are the most influential on the mode choices of the respondents.

#### 4.4.3 Multinomial Logit Model Efficiency Measures and Probabilities

Table 29 contains the efficiency measures associated with the multinomial logit model used to generate the choice scenarios, from the Ngene design output.

**Table 29 MNL efficiency measures**

D error	0.40
A error	0.54
B estimate	99.43
S estimate	660169.17

D-error and A-error are measures of how efficient the experimental design is at determining choice information from the experiment participants. The values should be low, and since every experiment is different, that level of acceptable D and A-errors falls to the researcher (ChoiceMetrics, 2018). In this case, the errors both had values of less than one, which is sufficiently low and considered very efficient.

The B-estimate represents the level of utility balance in the design, and is represented as a percentage. The B-estimate for this experimental design received a value of 99.4, which suggests that the alternatives are very evenly balanced. While this might appear to be a

positive finding given the importance of utility-balance, there is a threshold of 70% to 90% for the utility to be considered well balanced (ChoiceMetrics, 2018). When the value rises above 90%, and especially at 99%, the possibility of identifying any trends between the mode choices is nearly impossible as each alternative is so closely balanced. This means that the alternatives generated in the scenarios for this experiment are too evenly balanced, and it will be difficult to identify what attributes are the most valuable to respondents.

One method to investigate the high B-estimate is to examine the MNL Probabilities for each alternative and choice scenario. Table 30 contains the probabilities for each situation, and it can be observed that the values are extremely evenly distributed, each with a value of nearly 0.25, or an equal 25% chance of that alternative being selected in each scenario. A low B-value would suggest that one alternative has a dominant probability across the situations, which would also have been an issue. When there is one dominant alternative across all scenarios, this means the combination of attribute levels has resulted in favouring one mode over the others. This means it can be expected that most respondents will select the same mode for every scenario, which also does not provide any insight into what attributes were most influential to the mode selection.

**Table 30 MNL probabilities**

Choice situation	Car Passenger	Weekly Bus	AV	VDP
1	0.261	0.233	0.259	0.246
2	0.251	0.233	0.276	0.239
3	0.268	0.237	0.238	0.257
4	0.251	0.252	0.246	0.250
5	0.263	0.258	0.243	0.235
6	0.258	0.241	0.259	0.242
7	0.270	0.238	0.249	0.243
8	0.252	0.245	0.228	0.275
9	0.249	0.221	0.255	0.275
10	0.258	0.236	0.245	0.261
11	0.275	0.226	0.245	0.254
12	0.264	0.238	0.258	0.239

The S estimate is an approximation of the number of times the experiment will need to be repeated in order for all parameter estimates to be statistically significant at 95% (ChoiceMetrics, 2018). It can be used as an estimate of the required sample size for an experiment, which in this initial design is over 660000. By including every attribute and attribute level originally identified for the experiment, it is impossible at this stage to receive a realistic sample size, given the small population that is available for survey participation in New Brunswick.

This value is unrealistically large, indicating that adjustments will be required to the design, perhaps simplifying the model by removing some attribute levels or focusing on fewer alternatives. This value is likely to shrink after a pilot test, as more reliable priors are obtained the necessary sample size will reduce. Even with a potential reduction with pilot-test priors, it seems unlikely to reduce to a sample size achievable in a small region like New Brunswick. It is recommended that the overall scope of the stated choice

experiment be reduced to focus on only the attributes the researcher deploying the survey deems essential, and minimizing the number of attribute levels.

The attributes were divided in to four priority categories, with Priority 1 being the highest level (i.e. essential attribute), and Priority 4 the lowest. This can be used by future researchers to improve the experimental design by incrementally adjusting attributes with the goal of maintaining acceptable efficiency measures. Table 31 contains the attributes and the recommended priority level categories.

**Table 31 Attribute priority groups**

<b>Attribute</b>	<b>Priority Group</b>
Cost	1
Drive Time	1
Bus Wait Time	1
Trip Purpose	2
Weather Conditions	3
Presence of Companion	4
Conversation Provided	4
Availability of Driver	4

The Priority 1 attributes are related to level of service quality like travel time, wait times, and costs. These are common amongst stated choice experiments and should be applied in the future models. After those, Priority 2 should be incorporated, followed by Priorities 3 and 4 if possible. Reducing the number of available attribute levels would reduce the required sample size, and should be considered for some attributes like Trip Purpose and Weather Conditions.

## 5.0 Conclusions and Recommendations

This research aimed to gain an understanding of how rural VDPs help meet the needs of their clients beyond the task of driving, for various purposes, and in different roadway environments. The lessons from this study have practical applications for VDP operations, policy development, and the development of transportation alternatives, particularly AVs. Given that AVs remain primarily a conceptual technology with only limited deployment, there is a need to understand how they could conceivably address mobility issues, in particular in rural areas where alternatives are limited. This requires an understanding of travel demands, practical use of vehicles by users, and the geographic operating environment for vehicles. In absence of this information, this research studied VDP as a proxy. This offers the benefit of both adding to the scientific literature surrounding VDP operation, while also contributing to the broader debate of AV adoption. The uptake of AVs by non-drivers will be contingent on the following conditions:

1. The ability of the AVs to physically meet the needs of prospective users
2. The AV can be accommodated on existing and future road networks
3. The AV will be a preferred choice among prospective users

Surveys were distributed to the volunteer drivers at VDPs in New Brunswick to determine what tasks they perform in addition to driving to support the users. Existing data containing one-year worth of travel data from a New Brunswick VDP was able to provide origins and destinations and trip purposes, which were combined using road data from Google for the purposes of understanding the prospective roadway operating

environment. AV operational scenarios were discussed, and limitations were identified for the use of the self-driving vehicles in this context. A stated choice experiment was developed using four mode choice alternatives and eight attributes, which can be built upon by future researchers to assess the mode choices of rural seniors. The following sections outline the major conclusions from the study, as well as recommendations for future work.

## **5.1 Conclusions**

Several conclusions were drawn from the results of this study, related to VDP driver information, the route between pickup and drop off, the influence on how AVs would function in the same environment, and future steps for deployment of a stated choice experiment.

The volunteer driver surveys were deployed to local VDPs to determine the tasks performed by the volunteer in addition to driving to support the clients. The total number of distributed surveys was 60, and 37 were completed and returned. The types of stops reported by the drivers suggest a heavy dependence on the driving services for health related purposes. The largest percentage of stops (41%) was associated with Health trips, and was followed by Life Maintenance and Quality of Life trips (21% each, respectively).

The activities reported by the drivers showed that Health stops were not only the most frequent trip purpose, but also had the highest count of additional assistance provided by the volunteer, while Life Maintenance stops had the largest proportion of additional tasks

with the smaller overall number of stops. Nearly 70% of the 101 stops reported providing additional assistance to the users, and Work/Education stops showing the least dependency on the driver with 43% of stops having no assistance. The tasks done by the volunteers were identified as typical in 77% of situations, which suggests that it is common for users to rely on additional support from their drivers. The higher user dependency on additional driver assistance suggests that AVs may not be suitable, as many of these tasks require a human to provide that service.

This study provided valuable insights into the operational services provided by VDPs, an area of literature that is currently limited. The tasks performed by volunteers indicate a high level of dependency on additional services from the drivers, which suggests that AVs would not suit many user needs in these rural communities. Transportation planners would be advised to investigate alternative options to AVs (e.g. VDPs) to fill the demand for rural transportation from older populations, rather than to plan for a mode that would not satisfy the needs of many prospective users.

The available data for one year of travel of a local VDP was used as a case study to determine the operating environments of the VDP, and the expected environments of AVs should they be used for similar purposes. The origins and destinations were reported, and using Google Maps the road segment information between each pair was identified (road segment name and length) and were sorted into different road classification categories. This analysis identified that approximately 41% of the estimated kilometres were contributed by Divided Multi-lane Highways, 28% by Collector Highways, 14% by Named Roads/Streets, with the remaining distances from Undivided

Highways and On/Off Ramps. Over 50% of the expected travel distance was spent between 8 of the 92 O/D pairs. Since the most frequent locations are centred around one part of the region, this suggests that a shared AV central “hub” could be established in one of the central communities to allow quick response times and reduce unnecessary mileage on the AVs compared to if they were centred out of major cities further away.

This suggests that if AVs are to be implemented, priority should be given to smaller rural roadways with respect to infrastructure upgrades, to ensure a cohesive transition for AVs with well-maintained major highways. Transportation planners and government officials would need to consider the options to best support autonomous driving by preparing for a variety of different operating environments, from small rural roads to major divided highways, increasing overall access to charging services and maintaining line painting and signage quality.

The stated choice experiment was developed using software called Ngene, incorporating eight attributes and four mode choice alternatives into an efficient-type design with 12 different choice scenarios. After some alterations, the stated choice experiment can be deployed in the future to assess the mode choices of rural older adults between transportation alternatives including being a vehicle passenger, bus services, VDP, and AV. While there is a wide range of AV-related stated choice experiments available in the literature, they are limited in terms of rural applications and offering alternatives like VDPs. The information to be gathered from the survey will provide transportation planners with an understanding of the potential mode split that AVs will have, and whether or not they will be a desirable alternative for these rural populations. The design

resulted in poor efficiency measures, however, and future work will need to be done to ensure the right combination of attributes and levels for the best possible design. The attributes were ranked by level of importance, to ensure the next researcher will have a guideline to iteratively improve the design.

## **5.2 Recommendations**

This study explored the role of the volunteer driver, as well as use of VDPs as a proxy for AVs to understand the operational demands of users. The operational environment of VDPs was determined, and considered for AV operation as well. Finally, a stated choice experiment was developed to be deployed in the future to understand the mode choices of rural older adults, with current and future transportation options available. Since this is a limited area of focus within the AV literature, and there is a general lack of literature regarding VDPs, several recommendations for future research and development are presented below:

- The driver surveys reflected only the most recent volunteer driving experience of the respondents and did not include the age of users. It is recommended that a long-term study be conducted, focused specifically on VDP drivers and the additional services the drivers provide to users, with user ages collected. This would provide a much larger sample and a more detailed understanding of the scope and frequency of volunteer tasks. This would permit common patterns among users needs to be observed over time, and identify trends for services among age groups. In the long term, this would demonstrate how user dependency might increase or decrease as younger age cohorts begin to transition into the

older phase of their lives. An electronic system for the drivers to input this information would reduce the demand on program coordinators for data maintenance, and streamline the process of entering and analysing the reported data.

- A future survey of VDP clients should be conducted to understand the user perspective of additional services provided by drivers. By understanding what services the programs provide, in addition to driving, that are most highly valued by their users, it will permit VDPs to enhance the quality of their services. In addition, this will highlight the extra features that should be incorporated into autonomous travel in the future to accommodate older passengers.
- The VDP travel values represented a baseline value and an effective estimate of road classes, which simplified the travel routes and resulted in under representation of rural road travel and urban street travel. This difference in reported versus expected equates to approximately 24 km/drive, and is likely a result of the O/D simplifications. To further understand the travel behaviour of rural VDPs, it is suggested that researchers collect more precise origin and destination information. This could be done using GPS data, which would permit more accurate estimations of inter-community travel and the road networks frequented by the drivers.
- The deployment of a stated choice experiment focused exclusively on the mode choice of rural seniors in small regions like New Brunswick, providing mode choice options that include AVs and VDPs, in combination with traditional modes of transportation. This would provide a baseline framework for planners to

understand what parameters associated with AVs would lead to successful programs and the modal shift that can be expected when deployed.

- It is recommended that the developers of AVs take into consideration the limitations of the understanding of technology amongst many older adults, and to design their vehicles in a way that they are operable for all levels of vision, auditory, and physical ability.
- Exploring the economic perspective associated with preparing New Brunswick roads for AVs would allow government officials to effectively plan and budget for future infrastructure upgrades to include V2X cohesively throughout the road networks.

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## Appendix A1: Volunteer Driver Survey

### Volunteer Driver Role Survey

The goal of this survey is to develop a better understanding of tasks a volunteer driver performs to assist clients in addition to driving. This project has been approved by the Research Ethics Board of UNB, and is being conducted by David Copp. Please email david.copp@unb.ca with any questions or concerns you may have.

**Q1. What is your age (in years)? Please check the most appropriate category:**

- Less than 65 years       65 years and older

**Q2. How often do you volunteer as a driver? (Please check one)**

- 1-2 hours per week       3-4 hours per week       5-6 hours per week       7-8 hours per week       Over 8 hours per week

**Q3. Consider your most recent volunteer driving experience. For that drive, please indicate in the following table: the destination for each stop, the stop purpose, the tasks you performed to assist clients in addition to driving, if this was typical activity, and how many passengers you assisted on that trip**

Stop Number	Destination (i.e. Hospital, Pharmacy, Grocery Store, etc.)	STOP PURPOSE				TASKS OTHER THAN DRIVING						
		Health	Life Maintenance	Quality of Life	Work/Education	A) Open/close vehicle door	B) Physically assist clients in/out of vehicle	C) Escort clients between vehicle and destination door	D) Escort clients into destination to provide further support	E) Assist with objects (mobility equipment, groceries, etc.)	Is this a typical activity?	Number of passengers assisted?
<i>Example</i>	<i>Hospital</i>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<i>2</i>
1		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
2		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
3		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
4		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
5		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
6		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
7		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
8		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	

Survey continues on page 2

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Figure A1: Volunteer Driver Survey Page 1

**Q4. For the following stop purposes, how often do you perform activities in addition to driving to assist a passenger? Please check the most appropriate answer for each category.**

**a. When you drive as a volunteer, at stops for Health purposes how often do you provide assistance to users in addition to driving? (Please check one)**

Never                       Rarely                       Sometimes                       Very Often                       Always

**b. When you drive as a volunteer, at stops for Life Maintenance purposes how often do you provide assistance to users in addition to driving? (Please check one)**

Never                       Rarely                       Sometimes                       Very Often                       Always

**c. When you drive as a volunteer, at stops for Quality of Life purposes how often do you provide assistance to users in addition to driving? (Please check one)**

Never                       Rarely                       Sometimes                       Very Often                       Always

**d. When you drive as a volunteer, at stops for Work/Education purposes how often do you provide assistance to users in addition to driving? (Please check one)**

Never                       Rarely                       Sometimes                       Very Often                       Always

**End of Survey**

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Thank you for completing the survey. Please place this form into the return envelope addressed to David Copp at the University of New Brunswick, and deposit it into a mailbox at your earliest convenience.

**Figure A2: Volunteer Driver Survey Page 2**

## **Appendix A2: Ethics Review and Informed Consent Letter**

This component of the research did not pose more than minimal risk to the participants or volunteers as (as defined by the Tri-Council Policy), and as such there was no need for strenuous safety procedures. Another major component of the review was ensuring study participants were properly informed about the research and give consent for the researcher to collect and analyse the data they provide; this was done by including an explanatory letter with the questionnaires. The REB outlined strict guidelines for informed consent forms/letters, and it was required to include the following information:

- A statement to identify who the researcher is, their contact information, as well as how they are associated with the University of New Brunswick;
- The name and contact information for the faculty supervisor overseeing the research;
- The name and contact information of an individual not directly involved with the research project, who in this case was the Director of Graduate Studies for the Department of Civil Engineering;
- A clear statement that formally invites the reader to participate in the research project;
- An explanation of the research project objectives, as well as the procedures that participants are being asked to follow for the data collection, and what specific information is being gathered;
- An outline of the desired timeline for which participants have to complete and return questionnaires;
- A statement that explains to readers that participation is voluntary, and that they are permitted to withdraw from participation at any time during the research project without penalty. In the case of surveys or questionnaires this means that participants may decline to answer certain questions if they so desire;
- Information that tells participants how to receive the results of the study;
- An outline of any risks involved with the research, or in this case an acknowledgement of the lack of risk to participants.

This letter contained contact information for researchers, outlined the purpose of the research, and the explained scope of what was being asked of participants. In many cases, consent forms must be administered to participants and kept on file by the researchers. In this study, however, with the minimal risks involved it was permitted that by completing and returning the questionnaires, the drivers were indicating consent to participate. A copy of this letter can be found on the following page.

Dear Participants,

My name is David Copp and I am a graduate student at the University of New Brunswick, working under the supervision of Dr. Trevor Hanson of the Civil Engineering Department. As part of my research, I am examining Volunteer Driver Programs (VDPs), particularly the role in which the volunteer driver plays throughout the rides. Because you are a volunteer driver for one of these programs, I am inviting you to participate in this research study by completing a brief survey about your most recent volunteer driving experience. The following questionnaire will require approximately 5 minutes to complete.

This project has been reviewed by the Research Ethics Board of the University of New Brunswick and is on file as REB 2018-133. There is no compensation for responding nor is there any known risk. In order to ensure that all information will remain confidential, please do not include your name. If you choose to participate in this project, please answer all questions as honestly as possible and return the completed questionnaires promptly in the included envelopes to UNB. We hope to have all surveys returned by November 26, 2018. Participation is strictly voluntary and you may refuse to participate at any time.

Thank you for taking the time to assist me in my study. The data collected will provide useful information regarding the level of involvement of volunteer drivers during trips and the tasks they perform in addition to driving (i.e. assisting clientele to/from vehicle, handling wheelchairs, etc.). Completion and return of the questionnaire will indicate your willingness to participate in this study, as well as permit me to use the data to complete my thesis work. If you require additional information or have questions, please contact my supervisor or myself at the numbers listed below. If you would like a summary copy of this study please feel free to contact us.

If you are not satisfied with the manner in which this study is being conducted, you may report (anonymously if you so choose) any complaints to myself, Dr. Hanson, or the Civil Engineering Director of Graduate Studies Dr. Peter Bischoff at the numbers or emails listed below.

Sincerely,

David Copp

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## Appendix B: Volunteer Driver Survey Tables

**Table B1 Destination Purpose Classification by Volunteers**

Destination	Health	Life Maintenance	Quality of Life	Work/ Education	Multi-purpose	Total
Activity Centre	0	0	1	0	0	1
Airport	0	0	3	0	0	3
Appointment	1	0	0	0	0	1
blank	0	1	0	0	0	1
Café	0	1	0	0	0	1
Clinic	1	0	0	0	1	2
Community Living Centre	0	0	1	0	0	1
Convenience store	0	0	1	0	0	1
Doctor's appointment	11	0	0	0	2	13
Drug Store	0	2	0	0	1	3
Errands	0	2	0	0	0	2
<b>Eye appointment</b>	<b>1</b>	<b>0</b>	<b>1</b>	<b>0</b>	<b>0</b>	<b>2</b>
Farmer Brown's Nursery	0	0	1	0	0	1
Food bank	0	1	0	0	0	1
Food Delivery	0	1	0	0	0	1
GED course	0	0	0	1	0	1
Grocery Store	0	3	3	0	0	6
Hair appointment	0	1	0	0	0	1
Hardware Store	0	0	1	0	0	1
Health Centre	1	0	0	0	0	1
Help move client	0	0	0	0	1	1
Home	0	1	3	0	0	4
Home from workshop	0	0	0	1	0	1
Hospital	23	1	2	2	4	32
Hotel	0	0	1	0	0	1
Laundry outlet	0	0	0	0	1	1
Pharmacy	2	0	0	0	0	2
Physiotherapy	1	3	0	0	0	4
Princess Auto	0	0	1	0	0	1
Restaurant	0	1	0	0	0	1
Robins Donuts	0	1	0	0	0	1
Senior facility	0	0	1	0	0	1
Shopping	0	0	1	0	0	1
Store	0	1	0	0	0	1
Visit family	0	1	0	0	0	1
Vocational centre	0	0	0	1	0	1

Work	0	0	0	2	1	3
Total	41	21	21	7	11	101

**Table B2 Volunteer activities by Destination**

Destination	Task A	Task B	Task C	Task D	Task E
Activity Centre	1	0	0	0	0
Airport	1	0	0	0	2
Appointment	0	0	0	1	0
blank	1	0	0	1	0
Café	0	0	1	1	0
Clinic	2	0	1	0	1
Community Living Centre	0	0	0	0	0
Convenience store	0	0	0	0	0
Doctor's appointment	4	1	4	5	3
Drug Store	1	0	0	0	0
Errands	0	0	0	0	2
Eye appointment	0	0	0	1	1
Farmer Brown's Nursery	0	0	0	0	0
Food bank	0	0	0	0	1
Food Delivery	0	0	0	0	1
GED course	0	0	0	0	0
Grocery Store	1	1	1	1	6
Hair appointment	0	0	1	1	0
Hardware Store	0	0	0	0	1
Health Centre	1	0	0	1	0
Help move client	0	1	1	1	1
Home	2	0	1	0	2
Home from workshop	1	1	0	0	0
Hospital	13	10	14	9	8
Hotel	0	0	0	1	1
Laundry outlet	1	0	0	0	1
Pharmacy	0	0	1	2	0
Physiotherapy	0	0	0	0	0
Princess Auto	0	0	0	0	0
Restaurant	1	0	0	0	0
Robins Donuts	0	0	0	0	0
Senior facility	1	1	1	0	1
Shopping	0	0	0	0	0
Store	0	0	0	0	0

Visit family	0	1	1	0	0
Vocational Centre	1	0	0	0	0
Work	0	1	0	0	0
Totals	32	17	27	25	32

## Appendix C: VDP Origin/Destination Data

**Table C1 Origin/Destination Pairs, Drive Counts, and Total KMs**

Origin	Destination	Drives	Km/drive	Total O/D km	Percentage of Total Travel
Beaver Harbour	Blacks Harbour	1	5	5	0%
	St. Stephen	19	56	1064	2%
Blacks Harbour	Milltown	2	63	126	0%
	Saint John	17	70	1190	2%
	St. George	2	16	32	0%
	St. Stephen	10	58	580	1%
Canal	Saint John	1	73	73	0%
Chamcook	St. Andrews	1	6	6	0%
Chance Harbour	Blacks Harbour	1	48	48	0%
	St. George	7	49	343	1%
Grand Manan	Saint John	10	118	1180	2%
	St. Stephen	13	106	1378	2%
Heathland	Saint John	3	117	351	1%
	St. Stephen	6	6	36	0%
L'Etete	St. Stephen	1	57	57	0%
Lake Utopia	Saint John	34	70	2380	4%
	St. George	4	9	36	0%
	St. Stephen	5	51	255	0%
Lawrence Station	St. Stephen	2	33	66	0%
Mayfield	St. Andrews	2	36	72	0%
	St. Stephen	99	5	495	1%
Milltown	Blacks Harbour	3	63	189	0%
	Milltown	3	N/A	N/A	N/A
	Pennfield	4	55	220	0%
	Saint John	22	118	2596	4%
	St. Stephen	468	3	1404	2%
	Waweig	1	21	21	0%
Moore's Mills	St. Stephen	31	12	372	1%
Oak Bay	Saint John	4	103	412	1%
	St. George	11	34	374	1%

	St. Stephen	10	9	90	0%
Old Ridge	Saint John	1	116	116	0%
	St. Stephen	203	7	1421	2%
Pennfield	Blacks Harbour	6	8	48	0%
	Milltown	4	55	220	0%
	Saint John	8	63	504	1%
	St. George	21	9	189	0%
	St. Stephen	11	50	550	1%
Pleasant Ridge	Saint John	1	110	110	0%
Pocalogan	St. Stephen	1	64	64	0%
Rothesay	St. Stephen	2	128	256	0%
Saint John	Blacks Harbour	2	70	140	0%
	Grand Manan	12	118	1416	2%
	Heathland	3	115	345	1%
	Lake Utopia	5	69	345	1%
	Milltown	5	118	590	1%
	Oak Bay	2	104	208	0%
	Old Ridge	1	116	116	0%
	Pennfield	2	63	126	0%
	Pleasant Ridge	1	110	110	0%
	St. Andrews	10	103	1030	2%
	St. Stephen	7	113	791	1%
	Upper Mills	3	125	375	1%
Scotch Ridge	St. Stephen	91	16	1456	2%
St. Andrews	Chamcook	4	6	24	0%
	Mayfield	6	36	216	0%
	Saint John	34	103	3502	6%
	St. Andrews	17	N/A	N/A	N/A
	St. George	16	33	528	1%
	St. Stephen	274	31	8494	13%
St. George	Blacks Harbour	1	15	15	0%
	L'Etete	3	14	42	0%
	Oak Bay	2	34	68	0%
	Pennfield	6	8	48	0%

	St. Andrews	4	33	132	0%
	St. George	7	N/A	N/A	N/A
	St. Stephen	3	43	129	0%
St. Stephen	Beaver Harbour	5	55	275	0%
	Blacks Harbour	12	58	696	1%
	Grand Manan	6	105	630	1%
	Lake Utopia	4	51	204	0%
	Lawerence Station	2	33	66	0%
	Milltown	325	3	975	2%
	Moores Mills	17	12	204	0%
	Oak Bay	6	9	54	0%
	Old Ridge	203	7	1421	2%
	Pennfield	5	50	250	0%
	Pocalogan	1	63	63	0%
	Quispamsis	1	133	133	0%
	Rothestay	3	129	387	1%
	Saint John	21	113	2373	4%
	Scotch Ridge	59	16	944	1%
	St. Andrews	200	31	6200	10%
	St. George	8	43	344	1%
	St. Stephen	183	N/A	N/A	N/A
	Tower Hill	229	17	3893	6%
	Waweig	41	15	615	1%
Tower Hill	Milltown	2	23	46	0%
	Saint John	1	111	111	0%
	St. Stephen	225	17	3825	6%
Upper Mills	Saint John	5	124	620	1%
Waweig	St. Stephen	1	15	15	0%
Total Distance Travelled				63519	100%

**Table C2 Full List of Named Local Roads/Streets**

<u>Roads</u>	<u>Length of Travel (km)</u>
Bancroft Rd	52.5
Boyd Rd	1.3
Brunswick St	69.4
Campbell Dr	1.5
Canal Rd	1.0
Carleton St	1.7
Chipman Hill	27.5
Church St	223.8
Civic Dr	0.1
Clarence Ridge Rd	15.0
Cranberry Head Rd	0.1
Flume Ridge Rd	1.7
Grove Ave	7.4
Hall Rd	0.0
Harkness Rd	5.4
Harriet St	119.0
Hayman Avenue	163.7
Hill Rd	86.1
King St	78.5
L'Etete Rd	4.5
Main St	133.1
Market Square	9.2
Milltown Blvd	2314.5
Montague St	239.1
Mountain Rd	2.4
Municipal Dr	0.1
New Airport Access Rd	30.5
North St	7.7
Old Bay Rd	2521.6
Pleasant St	13.8
Portage St	3.5
Prince William St	1536.6
Pump House Rd	16.3
Pumphouse Leftbranch Rd	33.3
Reed St	321.2
Rose Bay Rd	0.3
Spring St	4.3
St Andrews North Rd	0.0

St David Ridge Rd	1.5
St Patrick St	88.0
Union St	524.0
Upper Mills Rd	37.2
Wallace St	0.1
Water St	152.8
<hr/>	
Total	8851.3

## Appendix D: Stated Choice Scenarios

**Table D1 Scenario 1**

Attribute	Alternative			
	Car Passenger	Weekly Bus	AV	VDP
Drive Time	40 mins	32 mins	20 mins	40 mins
Cost	\$0	\$8	\$10.20	\$8
Trip Purpose	Health	Quality of Life	Work/Ed	Life Maintenance
Weather Conditions	Moderate	Good	Good	Poor
Presence of Escort	No	Yes	Yes	No
Conversation Provided	Yes	---	---	Yes
Availability of Driver	Uncertain Availability	---	---	---
Bus Wait Time	---	15 mins	---	---

**Table D2 Scenario 2**

Attribute	Alternative			
	Car Passenger	Weekly Bus	AV	VDP
Drive Time	40 mins	64 mins	20 mins	20 mins
Cost	\$0	\$4	\$10.20	\$15
Trip Purpose	Life Maintenance	Work/Ed.	Health	Quality of Life
Weather Conditions	Poor	Good	Good	Moderate
Presence of Escort	Yes	No	No	Yes
Conversation Provided	Yes	---	---	Yes
Availability of Driver	Uncertain Availability	---	---	---
Bus Wait Time	---	25 mins	---	---

**Table D3 Scenario 3**

Attribute	Alternative			
	Car Passenger	Weekly Bus	AV	VDP
Drive Time	40 mins	64 mins	20 mins	20 mins
Cost	\$0	\$8	\$20.40	\$8
Trip Purpose	Quality of Life	Quality of Life	Quality of Life	Health
Weather Conditions	Good	Moderate	Moderate	Poor
Presence of Escort	No	Yes	Yes	No

Conversation Provided	Yes	---	---	No
Availability of Driver	Readily Available	---	---	---
Bus Wait Time	---	15 mins	---	---

**Table D4 Scenario 4**

Attribute	Alternative			
	Car Passenger	Weekly Bus	AV	VDP
Drive Time	20 mins	64 mins	20 mins	40 mins
Cost	\$0	\$4	\$20.40	\$15
Trip Purpose	Health	Work/Ed.	Health	Work/Ed.
Weather Conditions	Poor	Poor	Moderate	Good
Presence of Escort	Yes	Yes	No	No
Conversation Provided	Yes	---	---	No
Availability of Driver	Readily Available	---	---	---
Bus Wait Time	---	15 mins	---	---

**Table D5 Scenario 5**

Attribute	Alternative			
	Car Passenger	Weekly Bus	AV	VDP
Drive Time	20 mins	64 mins	40 mins	20 mins
Cost	\$0	\$4	\$10.20	\$15
Trip Purpose	Work/Ed	Health	Life Maintenance	Quality of Life
Weather Conditions	Good	Good	Poor	Moderate
Presence of Escort	No	No	Yes	Yes
Conversation Provided	Yes	---	---	No
Availability of Driver	Uncertain Availability	---	---	---
Bus Wait Time	---	15 mins	---	---

**Table D6 Scenario 6**

Attribute	Alternative			
	Car Passenger	Weekly Bus	AV	VDP
Drive Time	20 mins	64 mins	40 mins	20 mins
Cost	\$0	\$4	\$20.40	\$15
Trip Purpose	Life Maintenance	Life Maintenance	Life Maintenance	Work/Ed.

Weather Conditions	Poor	Poor	Good	Moderate
Presence of Escort	No	Yes	No	Yes
Conversation Provided	Yes	---	---	Yes
Availability of Driver	Readily Available	---	---	---
Bus Wait Time	---	25 mins	---	---

**Table D7 Scenario 7**

Attribute	Alternative			
	Car Passenger	Weekly Bus	AV	VDP
Drive Time	20 mins	32 mins	40 mins	40 mins
Cost	\$0	\$4	\$10.20	\$15
Trip Purpose	Work/Ed.	Life Maintenance	Life Maintenance	Life Maintenance
Weather Conditions	Good	Poor	Poor	Moderate
Presence of Escort	No	No	Yes	Yes
Conversation Provided	Yes	---	---	No
Availability of Driver	Uncertain Availability	---	---	---
Bus Wait Time	---	25 mins	---	---

**Table D8 Scenario 8**

Attribute	Alternative			
	Car Passenger	Weekly Bus	AV	VDP
Drive Time	40 mins	32 mins	40 mins	20 mins
Cost	\$0	\$8	\$20.40	\$8
Trip Purpose	Work/Ed.	Health	Work/Ed.	Health
Weather Conditions	Moderate	Moderate	Poor	Good
Presence of Escort	Yes	No	No	Yes
Conversation Provided	Yes	---	---	No
Availability of Driver	Readily Available	---	---	---
Bus Wait Time	---	15 mins	---	---

**Table D9 Scenario 9**

Attribute	Alternative			
	Car Passenger	Weekly Bus	AV	VDP
Drive Time	20 mins	64 mins	20 mins	40 mins

Cost	\$0	\$8	\$10.20	\$8
Trip Purpose	Quality of Life	Life Maintenance	Work/Ed.	Health
Weather Conditions	Poor	Moderate	Moderate	Good
Presence of Escort	Yes	No	Yes	No
Conversation Provided	Yes	---	---	Yes
Availability of Driver	Uncertain Availability	---	---	---
Bus Wait Time	---	25 mins	---	---

**Table D10 Scenario 10**

Attribute	Alternative			
	Car Passenger	Weekly Bus	AV	VDP
Drive Time	40 mins	32 mins	20 mins	40 mins
Cost	\$0	\$8	\$10.20	\$8
Trip Purpose	Health	Quality of Life	Quality of Life	Quality of Life
Weather Conditions	Moderate	Poor	Poor	Good
Presence of Escort	Yes	No	No	Yes
Conversation Provided	Yes	---	---	Yes
Availability of Driver	Uncertain Availability	---	---	---
Bus Wait Time	---	15 mins	---	---

**Table D11 Scenario 11**

Attribute	Alternative			
	Car Passenger	Weekly Bus	AV	VDP
Drive Time	20 mins	32 mins	40 mins	40 mins
Cost	\$0	\$8	\$20.40	\$8
Trip Purpose	Life Maintenance	Health	Quality of Life	Work/Ed.
Weather Conditions	Good	Moderate	Moderate	Poor
Presence of Escort	Yes	Yes	No	No
Conversation Provided	Yes	---	---	No
Availability of Driver	Readily Available	---	---	---
Bus Wait Time	---	25 mins	---	---

**Table D12 Scenario 12**

Attribute	Alternative			
	Car Passenger	Weekly Bus	AV	VDP
Drive Time	40 mins	32 mins	40 mins	20 mins
Cost	\$0	\$4	\$20.40	\$15
Trip Purpose	Quality of Life	Work/Ed.	Health	Life Maintenance
Weather Conditions	Moderate	Good	Good	Poor
Presence of Escort	No	Yes	Yes	No
Conversation Provided	Yes	---	---	Yes
Availability of Driver	Readily Available	---	---	---
Bus Wait Time	---	25 mins	---	---

## **Curriculum Vitae**

Candidate's full name: David Kenneth Copp

Universities attended: University of New Brunswick (2013-2017); BScE

Conference Presentations:

1. Copp, D., Hanson, T.R. 2019. Learning from rural innovation: what can volunteer driver programs teach us about planning for autonomous vehicles? Canadian Transportation Research Forum 54th Annual Conference, May 26-29, 2019, Vancouver, BC
2. Hanson, T.R., Goudreau, M., Copp, D. 2018. A Community-Based Approach to Addressing Transportation Needs for Rural Older Adults in Canada: Progress in Research. TRANSED International Conference for Older Adults and Persons with a Disability, Nov 12-15, Taipei, Taiwan