The Impact of COVID-19 on Public Transit and Micromobility Ridership

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Thesis submitted to the faculty of the Virginia Polytechnic Institute and State University in partial fulfillment of the requirements for the degree of

Master of Science
In
Civil Engineering

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December 7, 2020
Blacksburg, VA

Keywords:
COVID-19, Mobility Ridership

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ABSTRACT

The Coronavirus pandemic changed the normal lives across the country as strategies for mitigating the spread of the virus were put in place. Daily life was moved to a virtual setting as much as possible and typical mobility purposes changed or were eliminated. Shared transportation ridership declined dramatically in response to the pandemic, with reported drops of up to 90% across the United States. Mobility providers were tasked with determining strategies to encourage ridership during the risky time.

The main research question that was explored in this study was, “What is the impact of the Coronavirus pandemic on public transit and micromobility ridership?” The study aimed to determine important factors that potential riders consider and emphasize in their decision making. The research approach was to use a custom-developed stated preference survey. The survey collected opinions about public transit and micromobility ridership during and emerging from the Coronavirus pandemic. The study focused on Blacksburg, VA as it has both public transit and micromobility services. Personal characteristics and stated important factors that influenced potential rider decisions were determined to understand what is most important to potential riders. Mobility providers can use these findings to better address rider concerns and make informed decisions on provided service. Therefore, encouraging an increase in shared transportation ridership.

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GENERAL AUDIENCE ABSTRACT

The Coronavirus pandemic changed normal life across the country as the government tried to reduce the spreading of the virus. Businesses were closed, events cancelled, and daily life was moved to a virtual setting as much as possible. The typical purposes for taking a transportation trip, like commuting, changed or were eliminated. In addition, transportation types that are shared across many users like busses and bikeshares presented higher risks for contracting the virus. Therefore, these types of shared transportation services experienced a dramatic decline in people riding them, with reported ridership decreases of up to 90% across the United States. Transportation providers and decision makers were tasked with identifying ways to encourage people to ride shared transportation options.

The main research question that was explored in this study was, “What is the impact of the Coronavirus pandemic on public transit and micromobility ridership?” The study aimed to determine important factors that potential riders consider and emphasize when they decide what type of transportation to use. The factors considered were both traditionally used factors, like convenience and on-time reliability, and pandemic specific factors, like disinfectant and fresh air. The approach used to conduct this research was a custom developed survey based on the respondent’s personal transportation preferences. The survey collected opinions about public transit and shared transportation device usage during and emerging from the Coronavirus pandemic. The study focused on Blacksburg, VA as it has both public transit and shared transportation device services. Factors that influenced potential rider’s decisions were determined. Transportation providers and decision makers can use these factors to better address concerns that potential riders might have and make informed decisions on how to best provide transportation services to increase the number of riders.

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Chapter 1: Introduction

The novel Coronavirus (SARS-CoV-2) was a new type of coronavirus that was first reported to the World Health Organization (WHO) in late December 2019. SARS-CoV-2. The virus was first discovered in Wuhan City in the Hubei Province of China (World Health Organization, 2020a). A report to the WHO detailed several detected cases of pneumonia with an unknown cause. On January 5th, 2020, WHO first published the news about the new virus (World Health Organization, 2020b). Since the discovery of SARS-CoV-2, the virus has spread globally, with the number of cases increasing worldwide. By November 2020, over 50 million people have been infected with SARS-Cov-2, and over 1.3 million people have died from Coronavirus Disease 2019 (COVID-19).

Human coronaviruses are a family of viruses that can infect people and cause them to become ill. Seven known types of coronavirus can infect humans, four of which are common, usually causing cold-like symptoms. The other three can cause severe illness. The Novel Coronavirus is one of the three types considered extremely dangerous. It causes COVID-19, which is an acute upper respiratory illness that leads to pneumonia. COVID-19 has proven challenging to trace and contain because, while some of the infected experience severe symptoms, other infected people have mild symptoms (cold or allergy type symptoms) to no symptoms (asymptomatic). Therefore, tracing and mitigating the spread can be challenging primarily because of the wide variance in symptoms. Checking for a specific symptom, such as a fever, was used as a mitigation tool, however with such wide variance symptom tracking was a less than optimal solution.

The virus traveled quickly around the world; precautions like washing hands frequently, avoiding crowds and not getting too close to others, and staying home when one felt sick were suggested. Countries around the world took different approaches in attempting to slow the spread. As the situation got more severe throughout early 2020, businesses began to close or move to an online platform in the United States. In mid to late March, U.S. states began to mandate stay-at-home orders. Since essential workers were the only people going to work and unnecessary trips were discouraged, there was little demand for transportation. The primary trip purposes were to get food and supplies or to go to the doctor. These conditions significantly impacted the ridership of shared transportation since fewer people were moving around than before COVID-19.

Throughout the summer months states began to implement multiple-phase plans to reopen businesses and begin to restart the economy. This began to generate more demand for transportation because people were beginning to move about. However, most entities that were able to be remote (online based) were encouraged to continue. This research aims to determine what factors influenced potential rider's mobility decisions as the country began to reopen during the Coronavirus pandemic.

1.1 IMPACT ON TRANSPORT

Transportation has been significantly impacted since the beginning of the pandemic. Travel bans were put in place by many countries to slow/limit the spread of the virus in most countries. On March 31, 2020, the United States Center for Disease Control and Prevention (CDC) issued a Global Level 4 travel advisory for all U.S. citizens, strongly advising all citizens to avoid international travel (Bureau of Consular Affairs, 2020)(Bureau of Consular Affairs, 2020). The United States closed the borders to incoming travelers. Following these precautions, stay-at-home orders were put in place by most governors. The advisement to stay at home, in addition to the risk shared transportation posed for contracting the virus, resulted in a significant decrease in the ridership of shared transportation.

1.1.1 Public Transit

Riding public transit increased the risk of contracting the virus because of the recirculating air, the close proximity to other riders, and the prevalence of high-contact surfaces. Many authorities discouraged use decreasing ridership, and therefore agencies reduced service in response. Additionally, with stay-at-home orders in place, only essential workers were traveling to work. Public transit revenue and ridership decreased significantly since the Coronavirus escalated to a global pandemic. Metro Magazine estimated that public transit ridership had decreased by between 60% to 90% of the pre-virus ridership numbers (Comfort, 2020). New York City, one of the world's hardest-hit areas early on, experienced a 90% decline in ridership on its subway system. San Francisco's rapid transit system ridership declined by 97%. City bus systems had taken a lesser hit on ridership, although still significant, with Richmond, VA bus system declining by almost 40% and Washington, D.C. dropping by 60% (Hughes, 2020). Between encouraging safe pandemic practices and dramatic cuts in ridership, many agencies reduced public transit service. Washington, D.C. heavy rail Metro system experienced 95% ridership reduction and closed 19 stations (George, 2020). Some smaller transit agencies suspended all service to reduce the economic impact while working to reduce the spread. The Blacksburg Transit, the bus system in Blacksburg, VA, reduced service, suspended fares, limited buses to 9 passengers per bus, and implemented rear door boarding (Blacksburg Transit, 2020). As the situation progressed, ridership fell for Blacksburg Transit to the point they had to suspend additional service lines.

1.1.2 Micromobility

As micromobility proliferated in the U.S. in 2017 and 2018, they have been used primarily for short-distance trips or complete the last mile of a multimodal trip. Micromobility devices provide a safer isolated mode for workers to commute on, rather than riders' proximity on public transportation. Since decently small, the shared devices can be quickly disinfected by each user by using a disinfecting wipe. Many riders chose to use micromobility instead of public transit. Shared micromobility companies had varying responses to the pandemic. In some areas, service was reduced or suspended indefinitely, while other places saw increases in service. Revel, a shared electric moped company, reduced service in Oakland, CA but expanded service in parts of New York City to provide a transport mode for essential health care workers (Descant, 2020). Many companies offered free riders for essential workers in large cities. In China, as the first wave restrictions were being lifted, Beijing bikeshare companies saw an increase in rides of up to 187% (Naka, 2020).

1.1.3 Other Modes of Transportation

In May 2020, the NY Times reported that air travel traffic decreased by 94%, with 6,215 planes fully grounded (Chokshi, 2020). With mandatory stay-at-home orders in place, few people traveled long-distance, so air and rail travel ridership plummeted. Similar to public transit, the recycled air and proximity to other people also deterred riders from taking flights at the beginning of the pandemic. As more avenues for proper and timely disinfecting and social distancing were put in place, air travel passenger numbers slowly increased.

1.2 RESEARCH QUESTION

The main research question was, “What is the impact of the Coronavirus pandemic on public transit and micromobility ridership?” The study focused on Blacksburg, VA, a college town with both residents and students heavily relying on shared transportation (primarily bus or E-scooter) options as their access to mobility. Traditional shared transportation planning models were not designed to accommodate pandemic circumstances, so this research will be essential in moving forward to provide effective service during and after this pandemic. The key factors that riders consider when deciding a transportation mode during the pandemic and moving forward were examined.

The pandemic of 2020 has shaken lives across the globe. The new normal includes 6 feet of physical distance between people, disinfecting as much as possible, and wearing masks whenever exposed to other people. However, people still need to go to the grocery store, pharmacy, and live their lives. The way transportation fits into this new normal is currently unknown because of the novelty of the situation. The most recent pandemic of similar magnitude to the Coronavirus was the 1918 Influenza Pandemic there is not much knowledge applicable from that previous experience to inform the current transportation system.

1.3 RESEARCH PROBLEM AND APPROACH

Since Coronavirus’s lasting impacts are still unknown, and the pandemic was less than six months in duration, there is almost no published data to be used. This research was conducted through a ridership stated preference survey distributed to Blacksburg residents and Virginia Tech students in Blacksburg to address this problem. Through the survey, data was accrued from potential riders of shared transportation that represent their opinions on riding shared transportation during and beyond COVID-19.

This online distributed survey was conducted to collect quantitative and categorical data based on the stated ridership preferences of the respondents. The data used in this study was collected from people who live, work, or go to school in Blacksburg, VA. The survey's geographic distribution was essential to ensure that respondents were people who can use the available shared transportation in the Blacksburg area. Quantitative research was conducted because it “defines a structured cause-and-effect relationship between the problem and factors” (SIS International Research, 2020). The survey results show the relationship between COVID-19 and mode decision-making and what factors are essential in the decision-making process. The categorical variables, such as resident type and age, were collected to group the quantitative data for better analysis.

A statistical analysis approach of the collected data was used to develop results for research. The data was broken down into groups using the categorical variables and compared based on groups. Based on personal characteristics, trends were concluded to be extrapolated onto the broader population, using these categories.

1.4 RESEARCH OBJECTIVE

This research aims to determine the important factors that riders consider during elevated risk, like a pandemic, when needing mobility. Further than the impact directly related to Coronavirus, this research could better understand what riders consider important in decision making. This research can be a steppingstone to determining a more resilient planning model and structure that can increase industry resilience to unexpected and rare events.

1.5 ANTICIPATED CONTRIBUTIONS

This research has contributions to transportation agencies, micromobility companies, and the industry at large. This study is a preliminary investigation into the impacts that the Coronavirus pandemic had on shared transportation ridership. This preliminary research can help launch larger investigations into the Coronavirus impacts in urban areas with more robust shared transportation systems. Transit agencies and shared mobility companies should use findings from this research to understand the rider's decision making as the country emerges from COVID-19. A new normal is emerging from this pandemic, and the results of this analysis can help decision-makers make important choices to move shared transportation forward by addressing potential rider's concerns and providing safe, reliable service.

This study can also have lasting impacts on shared transportation progression as the common mode of transportation. This research contributes to knowledge of the traveler's decision-making process and the criteria that potential riders weigh the most when making choices. Finally, it should help change how the profession looks at shared transportation systems' resilience when rare events occur. The increase in resilience and service quality occurs by shedding light on potential factors that can be quickly adjusted to provide excellent service while accommodating unplanned circumstances.

1.6 DOCUMENT ORGANIZATION

The subsequent sections of this report are organized as follows. A review of published literature related to pandemics, micromobility, public transportation is presented. Conclusions about what is not currently understood are made. This is followed by a discussion of the methodology used to collect and analyze the primary data. A discussion about the findings from the data analysis, supported by visual aids, is then given. Finally, conclusions and recommendations from the study are stated, and potential future work is suggested.

Chapter 2: Literature Review

2.1 PURPOSE

The purpose of this chapter is to summarize findings from a review of relevant literature. It presents the current state of knowledge on topics that are complementary to the research study. It also illuminates knowledge that is currently missing. This research investigation contributes to these missing gaps. To best understand this research project's full scope, this literature review was conducted with three main themes in mind. These themes are pandemics, micromobility, and public transit. The review will discuss previous pandemics and epidemics that had similar effects as the Coronavirus and how transportation ridership was impacted. An investigation into micromobility and public transit will be included, specifically looking at ridership, standard practices, and implementation on college campuses.

2.2 PANDEMICS

Current knowledge suggests that the Coronavirus, like most human viruses, is transmitted between humans by three modes. Those modes are direct contact, indirect contact through contaminated surfaces, or close contact with someone infected via nose or mouth droplets. These droplets are commonly released when the infected person coughs, sneezes, talks, or sings. The virus spreads when the infected droplets enter another person's mouth, nose, or eyes (World Health Organization, 2020c). Other transmission sources can cause potential infection, but there are many things not presently understood about Coronavirus, so transmission characteristics of the disease have the potential to change. At this time, advised precautions include avoiding close contact with people ("social distancing"), washing hands, and avoiding touching possible entry points into the body like the nose, mouth, and eyes. If social distancing cannot be adhered to, a fabric facial covering is suggested to reduce the potential of the transmission of droplets from one person to the other.

The world has experienced many epidemics and even some pandemics throughout the 20th and beginning of the 21st century. The last pandemic with a similar severity level to the Coronavirus was the 1918 Influenza Pandemic, sometimes referred to as the Spanish Flu. This pandemic caused 50 million deaths across the world, 675,000 of which were in the United States. The Flu Pandemic had severe effects on the public. However, since it happened over 100 years ago, the similarities to transportation impacts are few because of how different the 1918 transportation offerings and public perspectives were. Severe Acute Respiratory Syndrome (SARS) and Middle East Respiratory Syndrome (MERS) have been the most recent pandemics like the Coronavirus. These were all types of pandemics that spread through close contact and cause severe respiratory issues. SARS and MERS had a much smaller impact than Coronavirus. These two pandemics impacted life in the same way as the Coronavirus has and will. They can help understand what was learned from these past experiences and figure out what is still unknown. MERS was much more deadly to those infected, killing 17 people for every 50 people infected (Graphics, 2020). However, it spread much slower than Coronavirus, so it was easier to contain. SARS was more widespread than the MERS epidemic, yet the Coronavirus still surpassed the infected numbers within weeks of the initial outbreak. Even so, the SARS epidemic significantly interrupted daily life for many countries and had similar characteristics to the Coronavirus pandemic. Therefore, an in-depth investigation of the impacts on transportation was conducted.

2.2.1 SARS

Some of the current understanding and infection prevention strategies for Coronavirus were developed from the global experience with the SARS epidemic in 2003. It was a human epidemic that originated in Hong Kong. This epidemic is the most similar global disease crisis compared to the current Coronavirus pandemic because of its nature and how it can spread. The impacts were much less widespread and the number of infected and deaths were vastly smaller than those of the Coronavirus pandemic. SARS spread to 37 countries, infecting 8,098 people, and killing 774 of those infected (Olsson et al., 2011). Asia, especially China, where the SARS virus originated, was hit hardest, followed by Canada. The infected places and citizens of these places had varying responses to the outbreaks regarding travel and mobility.

(a) Transport Responses

The infected countries and cities addressed the outbreaks differently from each other regarding travel and mobility. In Taiwan, if someone was determined to have SARS or was known to have or suspected of having close contact with someone who was diagnosed with it, they were put into quarantine. By quarantine laws, use of public transit was forbidden by those with a SARS diagnosis (Tyshenko & Paterson, 2010). In Canada, health care workers were put on “Work Quarantine,” which meant they could only go to work and home without using any public transit, for fear of spreading the virus to other people through shared mobility (Ries, 2006). Some governments mandated lower usage of shared transportation by people that could potentially spread the virus. However, what proved to influence shared transportation ridership the most during the SARS pandemic was the perception of risk or the fear of encountering the virus. Risk has two perceived causes, natural and human, and the human-caused risk tends to cause more of people's reaction (Tyshenko & Paterson, 2010). This perception of the high risk of contracting a virus alters people’s activities and can scare people away from using public transportation because it was advised to avoid close contact areas (Wang, 2014).

For example, in Toronto, the SARS outbreak was perceived by most of the citizens to be a human-caused risk because humans brought the virus to Toronto, and humans are the ones who can spread it (Tyshenko & Paterson, 2010). Therefore, in Toronto, even though no data was supporting the notion that SARS was overrunning the city, people perceived it as a huge risk and therefore acted with fear and extreme caution. Residual fear, which is defined as the fear that persists when a new SARS case was reported, affected ridership too (Wang, 2014). The persistence of the residual fear made the timing of the peak of lost ridership later than the cases' peak. Singapore was more transparent with information than many other infected places, which helped reduce the fear reaction. They taught transit professionals how to look out for the potential signs of SARS and how to conduct daily wellness checks. The results of these checks were published to public transit riders, which gave them more confidence in their safety. As with Singapore, “there would have been little fear and panic if the real prevalence of SARS had been made transparent (through monitoring) and communicated effectively” (Tyshenko & Paterson, 2010). The risk communication efforts proved very important in affecting the ridership of public transit during the SARS pandemic. This communication should come from the authorities directly and not through the news media. As seen during SARS, the news media presented the events accurately. However, they only reported cumulative numbers and had gaps in the information, all of which added to people’s feeling of uncertainty (Tyshenko & Paterson, 2010). Confidence from the leaders of the transit providers spreads people’s confidence in safety.

At the time SARS broke out, the concept of micromobility had not yet been integrated into society. Therefore, there is no known micromobility data or even small understandings about the ridership impact on micromobility from SARS. Studying the SARS and Influenza pandemics can give useful insights into previous experiences and impacts of global health crises on human actions. However, neither of these align very closely with the type and effects of Coronavirus. The differing ridership impacts of public transit will be investigated in this study. Understanding the ridership impact will help to reveal people's decision-making during a pandemic and how to better address choices in the future.

2.2.2 Micromobility

Micromobility includes a variety of "fully or partially human-powered vehicles" (NACTO, 2019b) that are traditionally small in size. These devices can include bikes, E-bikes, E-scooters, and mopeds. Micromobility incorporates both personally-owned and shared-use. For purposes of this study, the term micromobility shall include E-bikes, E-scooters, and E-skateboards and will focus on shared-use. There are limited numbers of studies and published data on micromobility since it is an entirely new transportation mode. Therefore, this literature review will consider multiple types of micromobility in both personal and shared micromobility applications.

(a) Description and History

Micromobility provides a need-based, short-term mobility option that is convenient and generally hassle-free, especially in a well-developed urban area. The devices are typically linked through GPS connectivity that enables monitoring and tracking of the vehicle's position and utilization. Generally, these mobility options are accessible through an Internet-enabled smartphone or device application platform. The user first links a credit card to the application and may use it to unlock and use that company's micromobility devices. There are several forms of unlocking, but that is one of the most common, especially for E-scooters. Some studies have concluded that convenience can be a crucial motivator for using micromobility over other mode options (Shaheen & Cohen, 2019). Especially in urban settings, it can be much easier for a rider to walk outside and grab an E-scooter or shared bike and instantly ride to where they need to go, instead of walking or using public transportation. Or ever more so, avoid having to find and pay for parking. Additionally, the micromobility option can solve the first/last mile problem by getting the rider to and from major public transit stations in a cost-effective manner. A survey of over 4,500 transportation users conducted by the Transit Cooperative Research Program (TCRP) found that shared mobility, including bike sharing, "largely complements public transit," which boosts mobility throughout an urban area (Shared-Use Mobility Center & Feigon, 2016). However, the same study also found that micromobility and public transit competed for ridership during certain times. A study of micromobility conducted in Chicago found that people taking trips that are long distance (more than 3 miles) and are on transit routes, generally do not choose micromobility over public transit because micromobility is costly on longer distance trips (C. Scott Smith & Schwieterman, 2018). Bike sharing competes the most, out of micromobility modes, with public transit during peak hours as people use it to commute to and from work (McKenzie, 2019; Shared-Use Mobility Center & Feigon, 2016).

Micromobility has the potential to provide services to passengers traveling 5 miles or less. This accounts for about 50%-60% of total passenger miles traveled. Although micromobility poses an excellent opportunity for riders, it is estimated that shared micromobility will only end up being used by about 8%-15% of the trips that people take within a 5-mile radius (Heineke et al., 2019). There could be many reasons for people not to choose micromobility, including their lack of comfort with riding the devices, safety concerns, or devices availability.

E-scooters specifically have had limited in-depth studies done across locations because of how new the mode is. Due to this, the results of the studies conducted differ from each other. Surveys conducted for micromobility suggest that E-scooters play an important role in commuting. However, travel pattern data suggests otherwise. This discrepancy can be attributed to the difference in land use and the service size in different locations. The surveys conducted in Denver, Portland, and Baltimore suggest E-scooters are used equally between commuting and recreation, followed by transit connect and social purposes (NACTO, 2018). However, in Austin, Texas, E-scooter usage data showed higher usage on weekends and holidays, suggesting commuting is not the most common trip purpose (Caspi et al., 2020). This study also found the trip ends were less often at recreational areas, which concludes that recreation may not be the most important purpose. Data analyzed from Indianapolis, Indiana, showed E-scooters were used less for the last mile commuting trips, but more so for midday errand runs, campus travel, and leisure trips (Mathew et al., 2019). Different locations display a range of study results examining trip generation use of micromobility, especially E-scooters. It can be difficult to generalize results from trip data studies. Understanding trip purpose across geographic regions with such variable results requires additional factor attribute studies.

The city council or local governing body has the authority and responsibility to regulate and restrict micromobility use in their area. The local authorities are charged with holding the public's health, welfare, and safety to the highest degree. Therefore, this responsibility can significantly impact the availability and usage of micromobility devices in a specific region. Many cities and localities use short-term permits or pilot programs to regulate the usage of micromobility services (NACTO, 2019b). Permits and pilot programs give local authorities quick and effective management of the implementation of shared micromobility companies. The popularity and integration of micromobility, especially shared micromobility services, are expected to rise in the coming years. With this in mind, a study of shared mobility and public transit encourages the collaboration of public transit agencies and alternative mobility agencies, like bikeshare and E-scooter companies, to enhance the riders experience by providing connected and adjacent services from the beginning to the end of a customer's trip (Shared-Use Mobility Center & Feigon, 2016). The future of micromobility will primarily rely on the response of city officials to the provided service. In Indianapolis, only 15% of deployed E-scooters were found to be used for longer than an hour a day (Mathew et al., 2019). The utilization ratio is vital for E-scooter service providers and city officials to understand. This ratio can provide important data to understand where scooters are needed and where they are overrunning the streets and where they are underutilized. This can help officials adjust their decision-making, policies and fees associated with E-scooters.

(b) Different Modes and Growth

The Society for Automotive Engineers (SAE) classifies micromobility into two categories of powered (including fully and partially powered) and nonpowered. Within the powered category, there are six micromobility vehicles, as seen in Figure 1, that are:

- Bicycle
- Standing scooter
- Seated scooter, also called "moped"
- Self-balancing board, also called "hover board"
- Non-self-balancing board, also called "skateboard"
- Skates

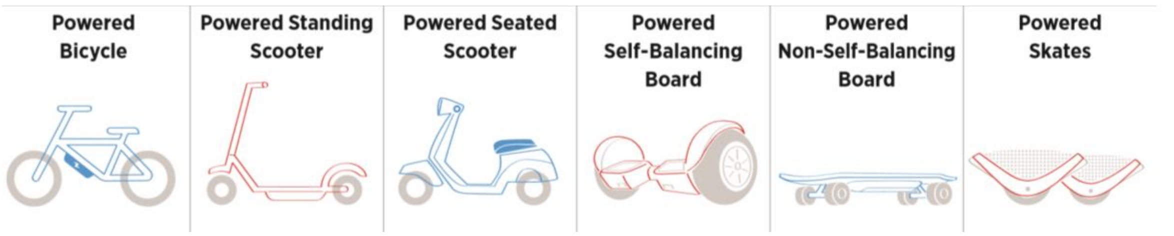

Figure 1: Micromobility Vehicle Types (SAE International, 2019)

All six vehicles provide power for the riders. Within micromobility, the bicycle can be traditional with no power or can provide pedal-assistance.

Micromobility encapsulates both privately-owned and shared devices. However, privately-owned bicycles are not considered to be part of the micromobility family. This literature review will focus mostly on shared micromobility as it has the most research completed, and it is the focus of this research survey. The most common shared micromobility devices are bicycles and electric scooters. These vehicle types will be the focus of this research as they are the two accessible micromobility in the study area of Blacksburg, VA.

Bike sharing companies can supply either traditional pedal bikes or electric bikes, E-bikes. E-bikes range in power supplied, from some providing enough power to make the bike pedal-less, to others that require assisted-pedaling to boost the power on upward climbs. Some of the pedal-assist E-bikes can go up to 18 mph (Capital Bikeshare, 2020). Standing scooters are fully powered electric scooters, equipped with a throttle, brakes, speedometer, and a light. These E-scooters are provided through sharing service companies. Most cities with shared E-scooter service have 15 mph as the maximum speed limit (Lime, 2020). Seated scooters are fully powered electric mopeds, generally accompanied by two helmets and a phone mount for easy navigation. At the time of this writing, these devices are less common than bike-sharing and E-scooters but are being increasingly implemented in cities. Revel is one of the leading domestic electric moped companies with service in four major cities across the country. Self-balancing and non-self-balancing boards and skates are all micromobility that is almost solely privately owned and operated.

Pedal bikes, considered a mode characterized as micromobility, have been in use for over two centuries. However, the modern era micromobility is a relatively new mode of mobility. The first station bikeshare began to increase in popularity in 2010. Bikeshare programs experienced exponential growth in the mid-2010s growing by 300,000 bikes from 2013 to 2015 and growing by 1 million bikes from 2015 to 2016 (DuPuis et al., 2019). Bikeshare trips taken also grew exponentially, as shown in Figure 2. Dockless bikeshares grew popular in 2017; however, this mode did not persist long as they disappeared from most North American cities in 2018. The first

E-scooter sharing service companies, Lime and Spin, launched in 2017 and exploded in popularity throughout 2018, accumulating 38.5 million trips in North American cities in that first year (Ajao, 2019; Caspi et al., 2020; NACTO, 2018). The E-scooter proved valuable to the mobility market because it gave flexibility to riders since there are not specific docks that they must be delivered to at the end of the rider.

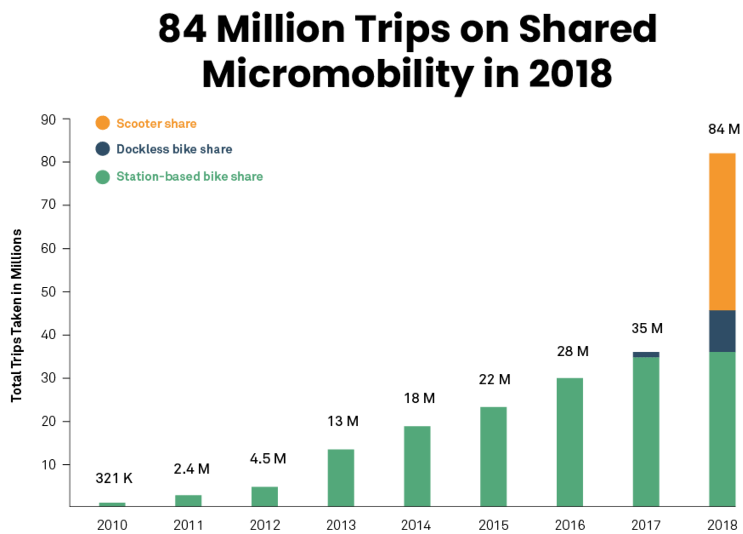

Figure 2: Micromobility Trips Taken in 2018 (NACTO, 2018)

A study of the spatial association of E-scooter usage, conducted in Austin, Texas, found that higher employment density shows a positive relationship with generating E-scooter trips. This study also found that bicycle infrastructure increases E-scooter usage. This can be attributed to the increased safety comfort level that riders experience when there is designated space for them. E-scooters also have found success in the short distance trips markets. In Chicago and the surrounding areas, on trips between 0.5 and 2 miles, E-scooters increased the number of trips of "non-auto options competitive with driving" to 75% (C. Scott Smith & Schwieterman, 2018). E-scooters provide a great alternative to driving when the rider is going to a location with parking constraints.

The public perception of E-scooters is very positive. Populus Insights conducted a study of 7,000 people with E-scooters available to them in major cities, which found that 70% of these people have a positive perception of E-scooters. Broken down by major cities, San Francisco shows a much lower positive public perception, claiming only 52% of the public view (Fong et al., 2019). This lower perception (Fong et al., 2019). This can be attributed to San Francisco being the first city to implement the new mode and therefore was a testing center that experienced operational glitches. These issues could have negatively impacted the perception of the public on E-scooters. Figure 3 shows the public perceptions by major city. San Francisco is an outlier in the data set, as it is 15% lower than the second-lowest.

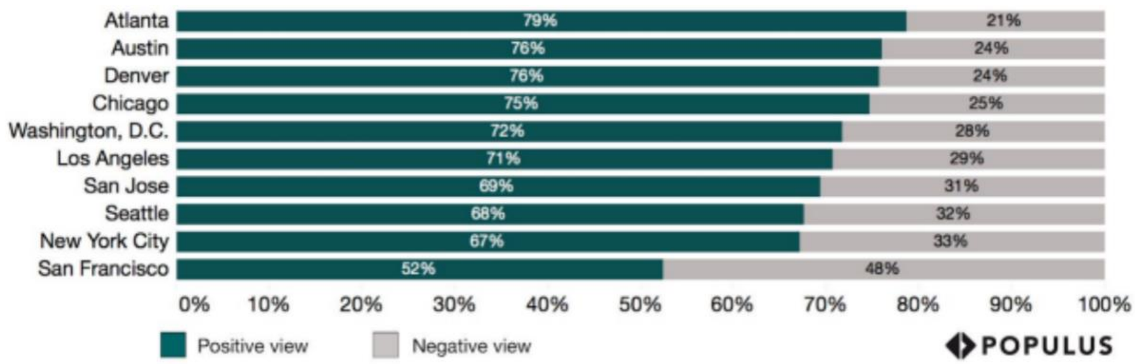

Figure 3: E-scooter Public Perception (Fong et al., 2019)

(c) Cost

Shared micromobility proves to be economically-favorable over other shared or mass transportation for those that are funding the service. Micromobility devices generally require much fewer upfront costs than other modes such as ridesharing or public transit. It costs about $400 to purchase an electric scooter like the ones used by shared E-scooter companies. Compared to the upfront per-rider cost of purchasing an automobile or buses for public transit is significantly less. Also, scooters are estimated to break even on the cost within four months of use (Heineke et al., 2019). For riders, E-scooter trips average about 19 minutes and cost about $3.50-$3.85 per trip (NACTO, 2019a; Portland Bureau of Transportation, 2018). However for riders, E-scooter trips average about 19 minutes and cost about $3.50-$3.85 per trip (NACTO, 2019a; Portland Bureau of Transportation, 2018). this varies significantly between trip length and the host company of the scooter. In Arlington, VA, Bird scooters cost $0.39 per minute (plus tax) with a $1 start fee, while Lime scooters cost only $0.24 per minute with a $1 start fee. Many micromobility devices follow a similar cost structure, with an initial start-up fee and a fee per minute afterward. Depending on the location and the device, the cost per minute can differ.

(d) Competitive Companies

E-scooters in the U.S. are provided to the public through private companies that establish relationships with local authorities who grant access to the area. The emergence of E-scooters was established by two primary companies, Lime and Bird, in the United States. Since the E-scooter rose in popularity so quickly, Lime and Bird became some of the fastest-growing companies in the US, reaching a billion-dollar valuation within the first year of the companies' launch (Ajao, 2019). Countless companies are(Ajao, 2019). emerging with micromobility devices, and the available services depend on the location. Some of the most notable companies in the United States are Bird, Skip, Zapp, Lime, and Spin. Bird and Spin are both implemented in about 40 US cities and urban settings (Shaheen et al., 2020). The market seems to be changing as companies move in and out of cities due to city permit regulations and vendor decisions. In 2019, Washington D.C., not including the surrounding Virginia and Maryland areas, had eight shared E-scooter companies offering service. These companies were Bird, Bolt, Razor, Lime, Spin, Skip, Lyft, and Jump by Uber (Cremente, 2019). However, DDOT (D.C. Department of Transportation) did not renew four of these permits, for Bird, Bolt, Lime, and Razor for 2020, leaving just four companies left. Amongst these four, Lyft, Jump, Skip, and Spin, there are 10,000 provided E-scooters (Calbaugh, 2020).

Unlike the E-scooter model, bike sharing programs in the United States are predominantly public or public-private initiatives through the specific cities and university areas. The top five bike sharing programs that have proven extremely successful are Citi Bike in New York City, Capital Bikeshare in Washington D.C., Citi Bike in Miami, Divvy in Chicago, and Blue Bikes in Boston (Walker, 2019). The sharing programs are mostly operated by a third-party company. Motivate is one of the leading operating companies that run the systems for bike-sharing, operating in four of the top five programs. This company provides operations, rebalancing, maintenance and repairs, and customer service for the bike sharing programs (Motivate, 2020). These programs have different offerings and pricing determined by the initiative officials based on the program's scale and the locations being served. Blue Bikes in Boston has a fleet of over 3000 traditional pedal bikes with no power assistance, while Capital Bikeshare in Washington D.C. offers 4,300 bikes, including traditional and pedal-assist bikes (Bluebikes, 2020; Capital Bikeshare, 2020).

(e) College Towns

Micromobility has increasingly been implemented on college campuses across the US in the past couple of years. They provide a great mobility option for affordable and on-demand short trips around campus. Additionally, the solution to limited parking it provides makes it a thriving mode for college campuses. In Austin, Texas, home to UT Austin, spatial lag models suggest students are using E-scooters. For this research, it was concluded that college campuses and towns are "ready markets" for shared E-scooter services (Caspi et al., 2020). Many college campus infrastructure systems have some of the most desirable E-scooter usage traits, like bike lanes, low-speed roads, and ahigh intersection density (Archer et al., 2019). E-scooter mobility can provide a unique and attractive market sector with these types of traits. Many college campuses have local/regional public transit systems, and E-scooters can provide the last mile mobility option for students using these transit systems. Spin scooter company, a subsidiary of Ford, in partnership with Virginia Tech Transportation Institute, launched 300 E-scooters on the Virginia Tech campus in the Fall 2019 (Spin, 2019). This deployment of scooters is a part of a research study to help understand the usage of scooters on a college campus. While these devices are feasible and a great option for college campuses, they have been receiving some backlash in the past year from colleges. San Diego State University banned all use of micromobility devices on campus because of the safety issues they were causing (SDSU News Team, 2019). However, the university did encourage their use to and from campus, recognizing their benefits as an alternative mobility option.

2.2.3 Public Transit

Public transit has had a much longer history than micromobility in the United States. In the 1800s, there were mass transit ferries and horse-drawn omnibuses. Public buses were some of the first introduced transit systems. In the early 1900s, the first heavy rail train systems were established, starting with the Boston T and New York City's Subway. From then on, public transit has become increasingly essential to the mobility of people. There are integrated public transit systems in large cities that can include heavy rail, light rail, bus, and paratransit. In the modern-day, public transit is proving to play an important role in congestion reduction and environmental activism. Many cities and towns have directed resources to fund a public transit system that can benefit the citizens.

(a) Mode Types

Public transportation incorporates a collection of modes. It is defined as a mobility service that can move a mass of people in one trip. It can include both intra and intercity movement. For this study, public transportation will refer to intracity movement. Within this designation of public transportation, there are nine types of mass transit. These modes are:

- Heavy rail, also called “subways”
- Light rail
- Bus
- Streetcar
- Paratransit services
- Cable cars

Less common modes are:

- Vanpool services
- Water taxis and ferries
- Monorails and trams

(APTAAdmin, 2020)

Public transportation modes are on a continuum, with fuzzy lines between the name groupings. Heavy rail is composed of both subways and rapid rail. Like the NYC Subway, subways generally service central municipalities and not regional surroundings, while rapid rail, like the D.C. Metro, service the entire metropolitan area, including surrounding jurisdictions. Subway systems typically move slower than rapid rail (Johnson, 2019). Light rail systems are typically implemented when the more expensive heavy rail system is not economically-feasible or practical. These systems service areas that are not included in the bigger metropolitan served by heavy rail. Currently-operated light rails include the Charlotte Lynx and San Francisco Muni Metro. Buses are a more versatile public transportation option for many land uses. Bus systems can be implemented in urban, suburban, and rural areas and have success. This literature review will focus on heavy rail and buses as they are the most common public transportation modes. The survey and study will focus on busses because Blacksburg’s public transportation is a bus system.

(b) Ridership, Growth and Decline

Throughout the last two decades, public transit has increased in popularity and ridership by 21% (APTAAdmin, 2020). The technology, safety, and reliability of many systems have dramatically increased service quality for many systems, increasing the ridership for many years. Recently, public transit ridership has plateaued or even decreased in some major cities. The heavy rail systems in some of the largest US cities showed a significant decline in ridership between 2016 and 2018 (Graehler et al., 2018). Many studies have found that the decline in ridership can be attributed to increased car ownership, the service's unreliability, and the transit service reductions that some systems have done (Graehler et al., 2018). A study conducted in NYC found that implementation of micromobility, like bikeshare, can decrease public transit ridership (Campbell & Brakewood, 2017).

While there has been an overarching plateau and a decrease in ridership for public transit, the ridership trends vary by mode and locality. In the fourth quarter of 2019, heavy rail had a 5.49% increase in unlinked passenger trips across the United States, while total bus unlinked passenger trips were down by 2.05% from the previous year (Dickens, 2020). Looking at large bus agencies, the Washington DC Metro Area system had a decrease of 4.22% in ridership, while Atlanta’s Metro Rapid Transit experienced an increase of 6.53% in ridership (Dickens, 2020). There is significant variability in ridership for public transit with the mode and location, amongst other factors.

There have been many studies conducted on the ridership of public transit systems. Intuitively, ridership increases in denser-populated metropolitan locations. Similarly, it has been seen that an increase in employment positively increases ridership (Graehler et al., 2018). These characteristics can be compared to Blacksburg because the ridership of the Blacksburg Transit (BT) increases during the semester months. After all, the population dramatically increases with students that need to go to work, class, and activities. For example, in July 2018, BT had 92,240 passengers, and in October 2018, BT had a total of 653,663 passengers (Blacksburg Transit, 2018). A study conducted in NYC found that transit ridership is influenced by supply and displays a lag (Chen et al., 2011). This means that people create demand for transit services after there is a predetermined supply. Many studies have seen that transit fares dramatically impact the ridership (Chen et al., 2011; Graehler et al., 2018). This factor will have little impact on this study because 1) most survey respondents are Virginia Tech students who do not have transit fares because that cost is included in their student fees, and 2) Blacksburg Transit has eliminated all fares during the pandemic.

(c) Cost

Fare collection can be very versatile, depending on the mode and size of the system. For most heavy rail, tickets and or passes must be purchased before entering the train platform. Depending on the agency and cost structure, a second scan may be required as the passenger is leaving the destination station. The Subway is a flat rate cost in New York City, meaning passengers pay $2.75 no matter how far they travel. In contrast, the Washington D.C. Metro has a cost structure that depends on the number of stops the passenger's rides for and the time of day. Metro stops require passengers to scan into the origin station and again when leaving the destination station to track and enforce this cost structure.

Bus pricing and fare collection can have a significant impact on ridership. As stated previously, a fare increase can decrease ridership. The implementation of fare collection can impact ridership because it can significantly slow down the system. This can make the service unreliable, which negatively impacts ridership. Blacksburg Transit collects minimal fares because most of the riders are Virginia Tech students that pre-pay their fares through student fees. The BT system only accepts exact fares if paying on the spot. There are one month and six month passes that may be purchased. The adult fare is $0.50 per ride and is collected when passengers board the bus. Virginia Tech students are required to show their student ID to board all BT buses.

(d) College Towns

The University of North Dakota surveyed students to understand the factors that they consider when choosing to take a campus bus or not. The number one factor was convenience, followed by (in no particular order) weather, time, accessibility, parking availability and cost, and vehicle cost (Scott et al., 2011). During this study, students expressed that the shuttle service provides convenient mobility that is a warmer option during the winter. This can be extrapolated onto other campuses with poor weather conditions. Public transit also poses an important public safety service for the university campus.

According to a U.S. PIRG report, 101 colleges and universities in the country provide a free-of-fare transit system to all students, employees, and staff of the university (Hanover Research, 2014). Depending on the university, the system could be university-owned, university-operated, or have a relationship with the local government to operate service where the university is the primary revenue source.

A study conducted on Qatar University's campus found that safety followed by "ease of use" are the two most important factors that college students consider when deciding to take public transport. Travel time was found to be a priority for the students for improvements. A structural equation model (SEM) found that choosing public transport as a student's mode of choice is positively impacted by service at the bus stops, service of busses, and the service of drivers (Shaaban & Kim, 2016).

(e) Blacksburg Transit

The BT is a department of the Town of Blacksburg that runs transit service and has a close relationship with Virginia Tech. For the 2020-2021 academic year, full-time students pay $96 per semester in Transportation Service fees (Virginia Tech, 2020b). This money goes to BT to fund the transit service for all the students. Although BT is Blacksburg owned and operated, it strongly depends on the Virginia Tech student population for ridership and, therefore, schedules based on students. The BT adjusts service levels based on the academic calendar of VT. Reduced service for BT provides each route about every 30 minutes to an hour, where full service during the school year provides each route every 10-15 minutes (Blacksburg Transit, n.d.). Blacksburg transit earned the American Public Transportation Association's (APTA) small urban transit system award for outstanding service. The system has seen an increase in revenue over the past several years, growing ridership by 22% since 2016.

2.3 CONCLUSIONS

The conclusions from the literature review are as follows:

- The last pandemic of similar severity and impact was in 1918. Its study might yield very limited insight into the impacts of modern public transit and micromobility ridership.
- During the SARS and MERS pandemics, the public perception of public and shared transportation proved to be one of the most important reasons why there was a decline in ridership in many cities.
- Micromobility, although a new class of mobility, has experienced exponential growth and public acceptance in the past three years.
- The trip purposes for taking micromobility, specifically E-scooters, is not yet well understood and varies by location.
- Public transit in the past decade has had overall increase in ridership.
- Public transportation on college campuses has a mostly positive public perception by students.

Chapter 3: Methodology

3.1 INTRODUCTION

This chapter will discuss the methodology used to collect and analyze the data for this study. The survey's details, including the platform used, sample size determination, coding, and marketing will be discussed. The methods used to partition the data into groups and analyze the data are also presented. The methodology used meets this study's goals by determining the impact of COVID-19 on public transit and micromobility ridership. Five key hypotheses will be discussed to scope the findings into manageable categories.

3.2 SURVEY

A custom survey was used as the data collection tool to capture the opinions of the respondents. This survey was designed to capture respondent's stated preferences for mode choice and factors that influence this choice during the Coronavirus pandemic. This survey was targeted to generate both Virginia Tech student and Blacksburg resident responses to gather a full picture of mode usage and ridership. Defining characteristics of the respondents were collected as categorical variables to be used in partitioning, however the respondent's identities were kept anonymous. The survey comprised 23 questions, including two open-ended discussion questions and one textbox question to collect email addresses for entry into the raffle. Skip and display logic were used to present the desired questions depending on previous answers, so most of the respondents were shown fewer questions than the total 23. All but two of the questions on the survey were designed to collect quantitative data. This kind of data made it manageable to use statistical analysis on which to draw conclusions.

During May 2020, the survey was developed and tested to ensure the anticipated response data was collected. Edits were made based on test respondents' comments, and the survey was finalized in early June. On June 5, 2020, the first announcement of the survey was sent out. The survey was published to respondents to complete within two months, concluding on August 5, 2020. This two-month timeframe was chosen because it gave enough time to capture the desired sample size while giving a duration of responses that could change opinion over time. The survey was also conducted over the summer months because it was a very influential part of the Coronavirus pandemic. This timing allowed the respondents to think about what they would do in the fall when students return to Blacksburg and the population increases significantly. Published data and advice from authorities about proper pandemic protocols were changing sporadically during the data collection period. This could have influence on the variability of the collected data.

3.2.1 Platform

Qualtrics XM was the survey platform used to create, administer, and conduct a simple survey analysis. Qualtrics XM was chosen because of it's easy to use and because of the total package interface. This platform provided a tool to create the survey, edit the survey in real-time, and analyze and manage the response data. On the user end, Qualtrics XM's respondent interface made it easy to maneuver through the survey allowing both forward and backward movement. The survey also included an orange progress bar across the top, showing the respondents how much of the survey they had completed. All these features can be seen in Figure 4, a snapshot of the respondent interface.

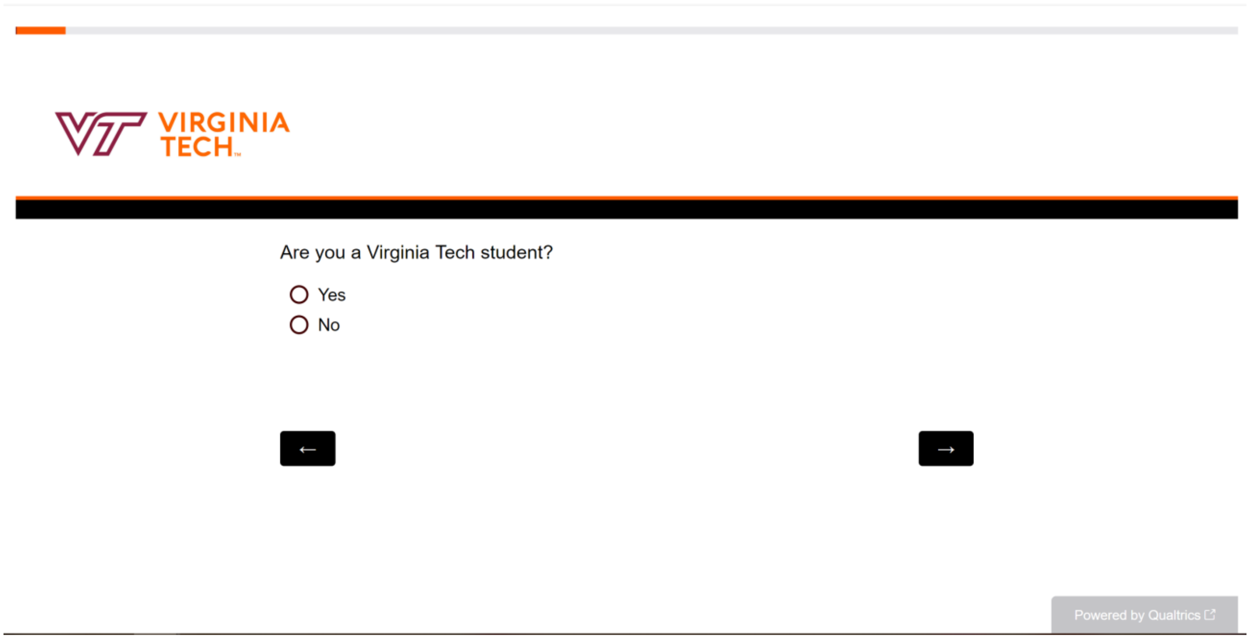

Figure 4: Qualtrics XM User Interface

In addition to the program's ease, Qualtrics XM was chosen because Virginia Tech students have free access to the platform. Qualtrics XM also made it easy to distribute the survey via an anonymous link sent out to potential respondents. Bitly, an online resource that creates compressed links, was used to create a shortened link for a more approachable looking access link used in the marketing strategies. Qualtrics XM also provided quick proportional response data by question. It offered other analysis tools like cross-tabulation that were useful in the analysis of the data as well.

3.2.2 Determination of Sample Size

The anticipated sample size was determined based on a preferred 95% confidence level with a margin of error of 5%. Blacksburg has a total population of 44,223 as of July 2019, so the desired sample size was determined to be 381 respondents (U.S. Census Bureau, 2019). The following(U.S. Census Bureau, 2019) formula was used to calculate the desired sample size.

$$Sample\ Size = \frac{\frac{z^2 \times p(1-p)}{e^2}}{1 + \left(\frac{z^2 \times p(1-p)}{e^2 \times N}\right)}$$

(Survey Monkey, 1999)

Where: N is the population size

e is the margin of error

z is the z-score, determined by the confidence level

p is the likely sample proportion (Survey Monkey, 1999)

The z-score is the number of standard deviations away from the mean of the data. For a confidence level of 95%, a z-score of 1.96 was used. Since the sample proportion was unknown, a value of 50% was used to be equal. This sample size, confidence level, and margin of error reflect that the results of a survey conducted of the entire applicable population (in this case the 44,223 people of

Blacksburg), with 95% certainty, would fall within ±5% of the results that were determined by the conducted survey of the 381 sample size.

After the two-month collection period, a total of 400 people responded to the survey. There is a slightly better than anticipated margin of error, of ±4.88%, for the collected data set with this sample size.

The survey was distributed in a manner to attain both Virginia Tech student and Blacksburg resident responses. In Fall 2019, Virginia Tech had 34,131 students living on and off-campus at the Blacksburg campus (Virginia Tech, 2020a). With a total Blacksburg population of 44,223, Virginia Tech students account for about 77% of the total Blacksburg population. As seen in Figure 5, this distribution is reflected in the sample sizes between students and residents collected during the survey. A deliberate approach to marketing the survey was used to achieve this desired distribution between survey respondents.

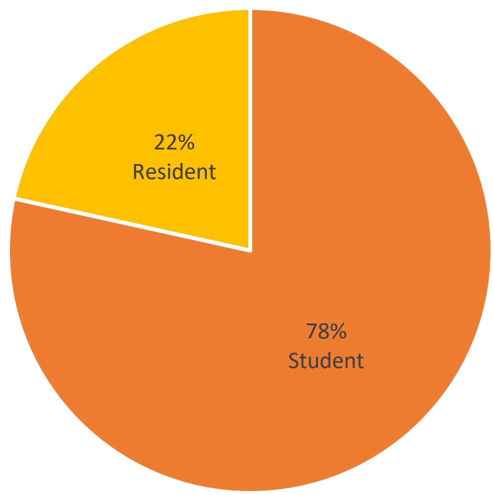

Figure 5: Student vs. Resident Distribution of the Collected Data

3.2.3 Survey Coding

Survey coding was used to produce concise results that were straightforward to analyze. Each question was carefully designed to ask for the specific desired data. Pre-determined multiple-choice answers were concise and easy to compare with each other while painting a holistic picture for the respondents. Some answer selections were developed in conjunction with established data and factors. For example, the age buckets used as answer selections were chosen because they were the same as the Coronavirus data's buckets. This helped to understand how age, a risk factor for the Coronavirus, influenced ridership decisions.

Questions that were designed to be compared between public transit and micromobility were split into two questions. Both had the same wording and answer options, so the preference between modes could be easily compared between the two questions. This was especially important for the two main stated preference questions 15 and 16 that asked how comfortable the respondent would be with taking public transit (Q15) and micromobility (Q16) during and coming out of the pandemic. These two questions were used heavily in the analysis of the data to determine factors that could influence this stated preference.

3.2.4 Marketing

The survey was marketed through social media platforms and direct group communication networks. Facebook was the most used platform for marketing. The survey was pushed out through periodic postings on many Facebook groups that targeted both Virginia Tech students and Blacksburg residents. These groups were Virginia Tech Class of 2021, 2022, and 2023, and Everything Blacksburg. These groups had well-developed followings with many active users, shown through multiple posts per day and users' engagement with these posts. Table 1 shows the membership numbers for the Facebook groups used in the survey advertisement. These groups totaled about 30,000 potential views of the survey announcement and link.

Table 1: Group Membership

Group	Members
Everything Blacksburg	8,249
Class of 2023	7,853
Class of 2022	7,588
Class of 2021	6,316
Total	30,003

These Facebook groups provided sufficient outlets to contacting potential respondents with varying schedules and daily patterns. The initial marketing of the survey was posted on Friday, June 5, 2020. This initial push was intense, with three posts across the first week. The same marketing flyer was posted periodically, with about 7-14 days in between posts. On June 29th, it was announced that two $25 Amazon gift cards were being offered for a raffle to incentivize completing the survey. The winners were chosen by a random number generator and contacted by email. The winners were contacted on July 13th and July 31st and were sent an electronic copy of an Amazon gift card.

In addition to Facebook groups, accessible listservs, other social media avenues, and group communication networks, like GroupMe, were used to spread the survey. The Civil Engineering Department at Virginia Tech posted a promotional piece about the survey on their Twitter feed. The group communication networks were student-only groups. The groups included students with different majors and daily movements during college, providing well-balanced samples of various students. It was intentional to advertise to diverse groups to make sure the respondents had varying shared transportation usage and needs. Ensuring variety in this way was crucial to collect as much of a holistic shared transportation usage picture as possible.

3.3 ANALYSIS

A statistical analysis of the data and reviewing the two open-ended discussion questions were done to develop this study's results. The t-test for statistical independence and descriptive statistics were the primary analysis used. These tests were conducted to address the developed hypotheses and research questions. Using the test results, conclusions were made about micromobility and public transit ridership and how the Coronavirus has impacted it. These conclusions and results will be discussed in Chapter 4 of this paper.

3.3.1 Hypotheses

This study determined several hypotheses about the impact different characteristics had on the ridership during the Coronavirus pandemic. These were developed in conjunction with the survey, and the survey questions were designed to collect data that directly related to them. The hypotheses are as follows.

1. Those who are older and those with underlying conditions, both characteristics that put people at higher risk for complications with the Coronavirus, will have a lower percentage of people willing to ride shared transportation.
2. During and coming out of the pandemic, students will be significantly more likely to be willing to ride public transit and micromobility.
3. Those originating from urban/suburban, including Northern Virginia, Richmond, and Hampton Roads, will have a lower percentage of people willing to ride public transit than those originating from more rural areas.
4. Disinfecting of the mode and physical distance from others will be the two highest-ranking factors of importance when deciding whether to take shared transportation.
5. There will be a higher percentage of people willing to take micromobility over public transit during the Coronavirus pandemic, especially during an outbreak because it is easy to disinfect, and contaminated air is less of a concern.

3.3.2 Statistical Methods

To begin the analysis, the data was cleaned by removing survey responses that were insufficient for analysis. These tossed surveys included any that were below 50% completed. This percentage was chosen because those that had completed at least 50% had answered through question 11 or further in the survey, providing useful data to the analysis. The survey's final two questions were open-ended, giving the respondent a chance to share their ideas on measures that would make them feel more comfortable in shared transportation. These two questions were the least answered in the survey. Q22 focused on public transit and had 245 responses, and Q23 focused on micromobility and had 175 responses. The micromobility response number was much lower because many respondents discussed both modes in the Q22 answer. These response rates were somewhat anticipated. The final two questions were designed to be experimental and capture new ideas about rider comfortability outside of the factors discussed earlier in the survey. Therefore, lower response rates were not of great concern when collecting data.

Since partially completed surveys were found to be acceptable data sources, the total number of survey responses is not reflected in every partitioned group of data. Pivot tables were used to separate the data by two variables/questions from the survey, and only respondents that had responses to both questions are included in that specific analysis.

The survey was designed to collect both the previous respondent's normal transportation activities before the Coronavirus pandemic, and the respondents intended actions and decisions regarding transportation during and coming out of the pandemic. This gave a baseline to understand what was happening before and how a traumatic event can alter the normal mobility movements.

A series of statistical analyses were used to understand big picture of the data collected. Descriptive and inferential data analyses were used to determine relationships between the population characteristics and ridership during the Coronavirus and to infer differing opinions between population groups. Proportional relations were evaluated to understand what factors or personal characteristics statistically impact shared transportation usage, specifically micromobility and public transit. Cross-tabulation was used to determining relationships between the survey variables and ridership preferences. The t-test and descriptive statistics, like mean, median, and variance, were the statistical tools used to determine the collected data results. These methods define the correlated relationships between the collected data and determine the statistical significance of the results. Qualtrics XM and Excel were used to conduct all analysis tests.

Questions 15 and 16 on the survey were most frequently used in the analysis as the stated preference for taking shared transportation during the pandemic. These questions were compared to many categorical variables to determine what type of person was willing to take shared transportation and what types of person was not. These questions asked the respondents about the affect COVID-19 has on their attitude towards using public transit (Q15) and micromobility (Q16). The three answer choices were using the mode regardless of the situation, using it only with confidence of safety and cleaning precautions being taken, or would not use it at all.

The t-test was used to compare if two groups were different and the significance of the difference. The T score is the "ratio between the difference between two groups and the difference within the groups" (Glen, 2020). The higher the score, the more different the groups are from each other. For example, when comparing Group A and Group B, the T score represents the number of times more different Group B is from Group A than the differences within Group A. The confidence interval range calculated in this analysis was considered. The larger the confidence interval the less certainty there is in the results.

Mean, median, and variance were used to understand the most common opinions and how others range from this. The mean is the average outcome from a data set, while the median is the most middle value outcome. Median helps to determine if there are severe outliers that skew the mean from the true average. Variance is the spread of the outcomes of the data set. These simple statistics were used to compare many of the variables asked about in the survey. Question 19 asked the respondents to rank the factors that they consider most important when considering taking shared transportation.

3.3.3 Partitioning the Data

Through the analysis of the data, the respondents were put into smaller sample groups to understand the way personal characteristics impact riding decisions. Out of the 25 questions that were included in the survey, five questions were demographic characteristic questions. Of these five, only three of them were asked to resident-identifying respondents while all five were asked of students. Defining characteristic questions were included in the survey to understand the demographics of the respondents and how this impacts ridership. These characteristics were also used to break the data into smaller samples. The demographics questions that were asked focused on student/resident status, duration of living in Blacksburg, original home location, on/off campus status, and age. Respondents were also asked how long they have lived in Blacksburg. The survey asked about the respondent's pre-pandemic normal mobility routines including, where they live and the primary mode they would use. All these categorical variables were used to define smaller samples that could be compared to each other to determined what impact they have on ridership during the pandemic.

The respondents were broken up into Virginia Tech students and Blacksburg residents. Since students make up 77% of the population, it was important to reflect this proportion in the respondents. Also, students account for the majority of the Blacksburg Transit ridership, so it was important to gather opinions from students. Blacksburg Transit estimated 95.1% of its passengers in October 2018 were students, and this majority is standard throughout the BT rider reports (Blacksburg Transit, 2018). Therefore, it was important to make sure the respondents were divided between students and residents at this same ratio.

The student's living location was important to determine if there was a need for mobility and, if so, to what extent. The campus of Virginia Tech is easily accessible to those living on campus because it is well connected with sidewalks. Those who are on campus and need to get to the Math Emporium, located about 1 mile from the center of campus, have a need for transportation because it is located off-campus. Of the 314 respondents who identify as students, only about 9% live on campus, so most of the student respondents live off campus and therefore need mobility to get to campus. The distribution of student living locations is shown in Figure 6.

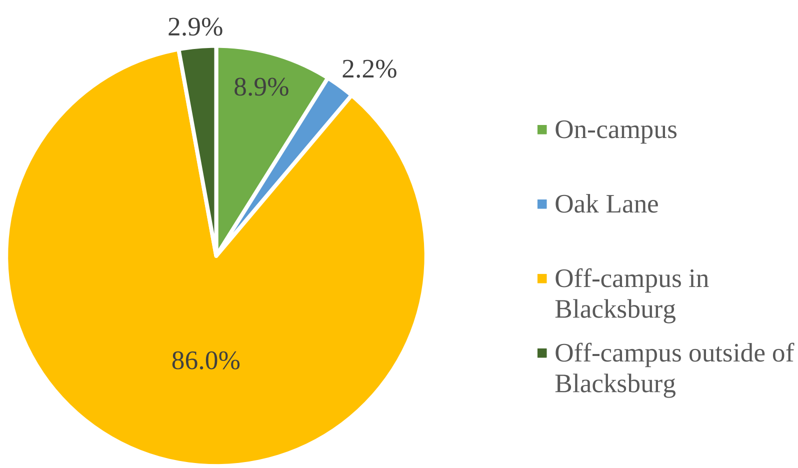

Figure 6: Student Living Locations

For those that need transportation, distance from campus can be an external factor and can affect ridership. Those who live far from campus and must get to class or work. They are pressured to get there somehow. While some may have access to personal automobiles, others may not have a choice and are left to take shared transportation. This could impact their decision-making. While they may not feel completely safe taking shared transportation during the pandemic, they might be pressured to take it anyway, to be able to get to their destination.

This lack of mode choice has a lot of influence on rider's decision-making. The t-test for independence was used to determine the significance of living location on shared transportation ridership preferences, focusing on public transit during the pandemic. Micromobility was not considered because in Blacksburg these devices were only offered on campus and therefore cannot provide full mobility to those that live off campus.

The respondent's age was broken down into six buckets, resembling the similar buckets used by the CDC to categorize the Coronavirus cases and deaths. The current knowledge is that the risk for complications goes up with age. As expected, the most common age range for the survey respondents was between 20-29 years, having about 64% of the total sample. This complements the Blacksburg population, as people's median age is 22 years (Data USA, 2018). The age will be an important characteristic to divide the data into sample buckets. Age is one of the leading risk factors tied to the Coronavirus, so it was used to see if a known risk affects the respondents riding decisions. Figure 7 shows the breakdown of age groups. There were very few survey respondents identified as 65 years or older. This is likely due to two main factors, 1) the marketing strategy used social media, and most people of this age group do not use social media as avidly and 2) many people that age likely do not use public transit or micromobility. With such a small group size for this age bracket, confidence in the results of this group will be less.

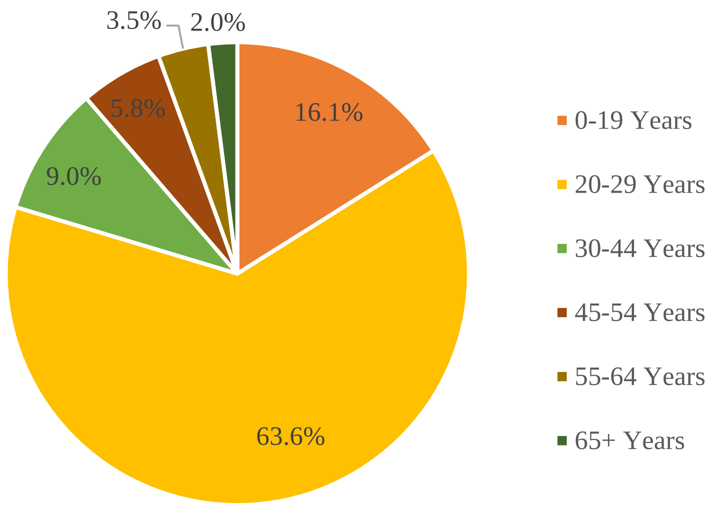

Figure 7: Age Distribution

The t-test was used to test the difference in age bracket groups and their opinion on riding shared transportation during this pandemic. Since age has a known risk associated with it, given by the CDC, it is anticipated that there will be significant differences in ridership intentions between older and younger respondents. Younger respondents have been seen to have less severe complications with the Coronavirus, so it is expected that they will be more willing to ride both public transit and micromobility. The responses from questions 15 and 16 of the survey will be categorized using the age bracket breakdown. The t-test will be run on these groups to compare the response differences, which will show the significance of age on the decision to choose a shared mode during the pandemic.

Similarly to age, the nine pre-existing conditions identified by the CDC as putting someone at a higher risk for complications with the Coronavirus will also be analyzed. These pre-existing conditions are asthma, liver disease, diabetes, lung disease, kidney disease being treated with dialysis, serious heart conditions, immunocompromised, hemoglobin disorders, and severe obesity. The majority of respondents responded that they have no known pre-existing conditions that would put them at risk for complications with the Coronavirus, as shown in Figure 8. Those who identified as having these kinds of pre-existing conditions will be compared to those without the conditions using the t-test and the responses to Q15 and Q16, similar to what was done with age. Of the people who responded with having pre-existing conditions, about 84% responded that this condition makes them more cautious when making transportation commuting decisions.

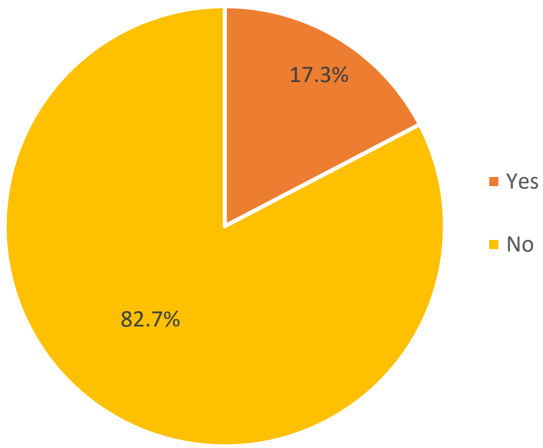

Figure 8: Pre-existing Conditions Distribution

Using display logic, respondents that identified as a student were asked about where they are from when not at school, called hometown. The options given were urban Virginia, other regions of Virginia, other urban/suburban areas, other rural/exurban areas, and international. This data was used to determine if prior or familiar experiences impacts ridership choices. The Coronavirus has had significant large scale and severe impacts on densely-populated urban/suburban areas due to large numbers of transmission vectors. People in these areas are presumed to be more cautious about decisions involving the risk of contracting the Coronavirus because of the experience in a more severe, riskier location. The Metro in Washington, D.C., and the surrounding areas had significant service cuts at the beginning of the pandemic because of its risks with taking it. Therefore, it was thought that people from this area would be less willing to take shared transportation because they have experience/knowledge of the risks compared to someone who has not had this experience. This study aims to determine how people who have experienced situations are affected by the virus in their future transportation decisions, even after relocating to a less densely populated area like Blacksburg. Of the 314 students who responded to the survey, most of them (~57%) are from Virginia's three main urban areas, including Northern Virginia, Richmond area, and Hampton Roads. Over 80% of the students are from urban/suburban areas, as shown in Figure 9. The t-test was used to determine the difference between people from urban/suburban and rural/exurban areas and how they react to shared transportation during the Coronavirus. This investigation is particularly looking at the anticipated public transit usage.

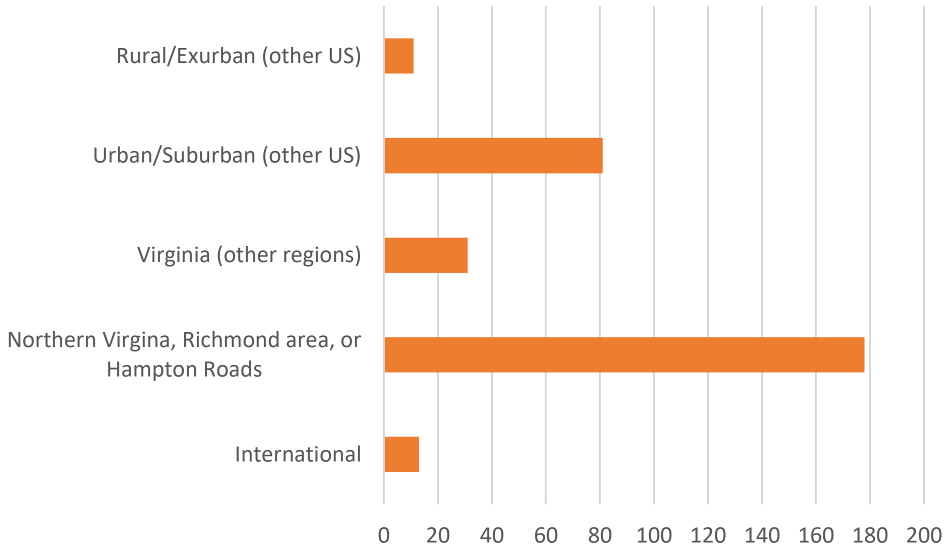

Figure 9: Originating Location for Students

The survey respondents were asked to rank seven defined factors from most important to least important when considering what transportation mode to choose during the pandemic. These defined factors were cleanliness (i.e. disinfection), physical distance, clean air, how long a trip takes, cost, convenience, and ADA compliance. An 'Other' option was also included for respondents that had differing important factors not listed. The mean and variance of these rankings were used to understand the most important factors for people. Overall, cleanliness was most often ranked as number 1, meaning most important, with the physical distance between riders getting the most common number 2 ranking. The factors ranked highest for first and second choices are displayed below in Figure 10.

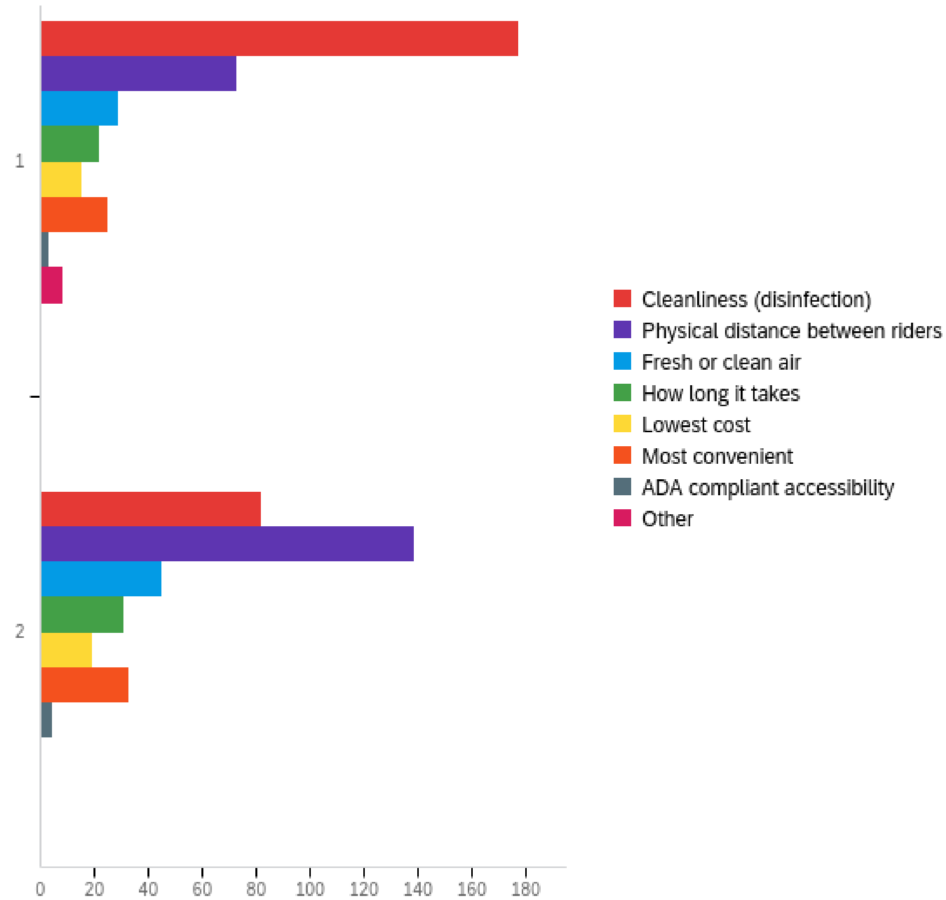

Figure 10: Ranking Distributions for the Top Two Positions (Qualtrics XM, 2020)

As many states in the U.S. did, Virginia deployed a three-phase plan for reopening the state from the stay-at-home orders due to the pandemic. On May 15, Virginia went into Phase 1, the most restrictive phase. On June 12, Virginia entered Phase 2 and on July 1 entered Phase 3. The phases impacted the opening of businesses and reflected the confidence the government had in the ability to stay safe while entering back into typical life activities. This type of confidence could impact a rider's decisions based on how they may regard what authorities say about the pandemic. The survey responses before and after July 1 will be compared to each other to determine if the authority's confidence impacts the rider's decision. The responses were generalized to determine if there is an overall shift in responses towards more willing to ride shared transportation. One hundred and seventy-two respondents answered during the Phase 1, ninety-nine during Phase 2, and one hundred and ten during Phase 3, as shown in Figure 11. The t-test was used to determine if the three phase groups differed in ridership preferences because of this government reopening timeline.

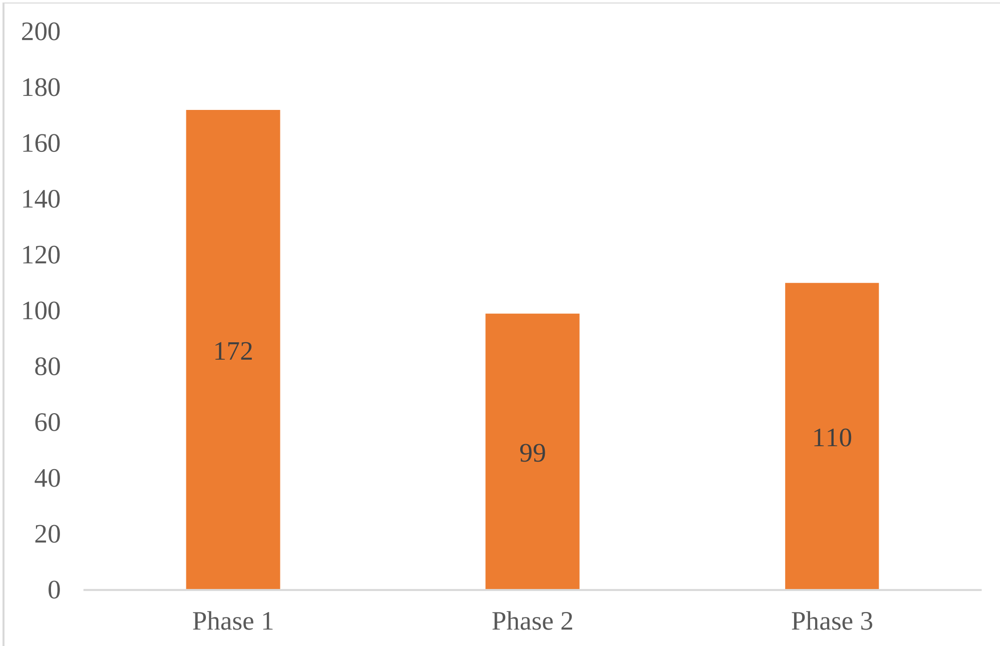

Figure 11: Opening Phases Response Distribution

Chapter 4: Analysis and Discussion

4.1 OVERVIEW

This chapter will examine the analysis that was completed on the collected survey data. Statistical analysis for confidence was used to determine the significance of the data. Conclusions from this analysis will be discussed. The conclusions will address the research question and the accompanying hypotheses outlined in Chapter Three. These conclusions will also help decision-makers better understand rider preferences and therefore have better knowledge and guidance when making service decisions. Also, findings from the free-response section of the survey will be discussed. Unique inputs on the pandemic mobility situation were determined to help decision-makers and agencies best address concerns.

4.2 ANALYSIS

The following analysis will examine the survey's statistical significance to conclude about the entire Blacksburg community and their ridership choices. The analysis will be organized using the same partitioned groups discussed in Chapter Three. A t-test for statistical independence was used in this analysis to understand the significance of the survey result.

4.2.1 Opening Phases

It was anticipated that the opening phases would have influence on the respondent's ridership preferences. The survey was released during the early stages of the Coronavirus pandemic when it was extremely new and not well understood. However, during the survey timeframe the United States was in a period of reopening from the initial lockdown that was put in place. The three phases of reopening had individual requirements and allowances for more businesses to open. For example, in Virginia the first opening phase allowed restaurants to reopen for outdoor seating only at half capacity. These opening decisions showed the progression of understanding of the virus and how to protect people from transmitting it. Therefore, it was anticipated that this would impact the confidence riders would have in taking public transit and micromobility. The timestamps of the survey responses were analyzed to determine if there was a correlation between the phases and ridership preferences. The responses were partitioned by phase number and compared using the t-test for statistical significance. From this analysis, the only notable difference is that a higher percentage of people in Phase 3 were willing to take public transit with safety measures taken as compared to Phase 1 and 2, shown in Table 2. Phase 3 allowed indoor dining, and higher percent capacity in retail and recreational facilities. Table 3 shows the confidence interval of Phase 3 for people willing to take public transit with safety measures taken to be statistically significantly higher than Phase 1 or 2. This difference, while significant, is not extremely large. Therefore, it is concluded that the Phase of reopening may have had some influence as the restrictions on the state of Virginia were loosened and the virus was better understood. However, there is no strong statistical difference across the reopening phases. The confidence intervals of this analysis were larger which shows greater uncertainty in the results.

Table 2: Public Transit Ridership Preferences during Opening Phases

Opening Phase	Phase 1	Phase 2	Phase 3
I would not feel comfortable using public transit	35%	35%	33%
I would only use public transit with safety measures taken	45%	47%	57%
I would use public transit regardless of the health crisis	19%	17%	10%

Table 3: Confidence Interval of Ridership Preferences during Opening Phases

Ridership Preferences	Phase 1		Phase 2		Phase 3	
	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
I would not feel comfortable using public transit	31%	39%	31%	39%	29%	37%
I would only use public transit with safety measures taken	41%	50%	43%	52%	53%	61%
I would use public transit regardless of the health crisis	16%	22%	14%	20%	7%	13%

4.2.2 Student versus Resident using Public Transit

The statistical differences between the responses of students and residents were determined. The student and resident ridership preferences were used along with proportional statistics to determine likely factors that are why there is a difference in actions between these two groups of respondents.

The Virginia Tech students account for about 72% of the total population of Blacksburg. This proportion was reflected in the response ratios between students and residents. It was hypothesized that students would be more likely to ride public transportation and micromobility during the pandemic. This could be attributed to many factors, both Coronavirus-related and everyday mobility trends, but mainly their age bracket being at a lower risk for complications with COVID-19, student-centric mobility systems, and a need for transportation. Table 4 outlines students and residents' response proportions when asked about their ridership choices for public transit during the pandemic.

Table 4: Resident and Student Ridership Preferences

Ridership Preference	Students	Resident
I would not feel comfortable using public transit	31%	46%
I would only use public transit with safety measures taken	52%	42%
I would use public transit regardless of the health crisis	17%	12%

Over 50% of students responded that they would be willing to use public transit if they were confident in the safety measures. Contrarily, the largest proportion of residents, would not feel comfortable taking public transit. A t-test for statistical significance was conducted to determine if these results are significant enough to confidently say that students are more willing to ride public transit than residents. Tables 5 and 6 outlines the confidence intervals for each ridership choice decision for students and residents respectfully.

Table 5: Confidence Interval of Student Ridership Preferences for Public Transit

Student Ridership Preference	Minimum	Maximum
I would not feel comfortable using public transit	28%	35%
I would only use public transit with safety measures taken	48%	55%
I would use public transit regardless of the health crisis	14%	20%

Table 6: Confidence Interval of Resident Ridership Preferences for Public Transit

Resident Ridership Preference	Minimum	Maximum
I would not feel comfortable using public transit	44%	48%
I would only use public transit with safety measures taken	40%	44%
I would use public transit regardless of the health crisis	11%	13%

The confidence intervals for all three ridership choices between students and residents are separate and do not overlap. Therefore, it can be said that these proportions are statistically significantly different. For both choices to ride public transit, residents have a lower proportion regardless of the health crisis, or safety measures are taken. Therefore, it is concluded that residents are less likely than students to ride public transit during the pandemic. Additional support for this conclusion is that the proportion of residents who are not comfortable taking public transit is significantly higher than the proportion of students not comfortable. This supports the claim that residents are less likely to take public transit. The confidence intervals of this analysis remained small which supports the certainty of these results.

This result is reinforced by many factors that likely impact the mode decision differences between students and Blacksburg residents. Some of these factors are directly related to the Coronavirus pandemic, while others reflect differences in daily life that impact ridership between students and residents. Blacksburg Transit surveyed their riders in 2016 and found that the three most influential factors for mode choice are parking, weather, and the time it takes (The Virginia Tech Center for Survey Research, 2016). These factors were considered to determine their influence in this study.

Firstly, the Blacksburg Transit system was designed and implemented as mobility centered around students. While residents are welcomed to use it, the provided service routes do not encompass most residential Blacksburg. Instead, the routes center around going from campus to students off-campus apartments and back on campus. The survey respondents showed a statistically significant difference between students and residents living close to a BT bus stop. Table 7 shows the proportional responses to if they live close to a BT bus stop. 97% of students report having a bus stop close to where they live, while only 42% of residents report this. It is much less likely that a person would choose a mode that is not readily available and convenient for them. This helps explain why residents are much less likely to take public transit.

Table 7: Proximity to BT Bus Stop

Proximity	Resident	Student
Close	42%	97%
Not Close	58%	3%

It should be noted that this response could contain slight bias because of the nature of the word ‘close.’ Students may be willing to walk further to get to a stop, considering that distance still ‘close,’ while a resident may disagree and consider the same distance far. However, this makes an important insight that the age and lifestyle condition of those that are the anticipated users of a public transit system needs to be considered. A pre-set distance of ¼ to ½ mile primarily determines bus stop locations to ½ mile (Nabors et al., 2008). Considering the proximity of potential riders to a bus stop as a variable distance determined based on the age and lifestyle of the population being served could improve ridership.

Since the BT bus system was designed for students, the destinations along the service routes are primarily on-campus or student housing. As shown in Table 8, only 18% of the residents that responded to the survey said their primary commuting purpose was to go to/from the Virginia Tech campus. Even more, 34% of the responding residents commute outside of the Blacksburg town limits. BT has minimal service outside of Blacksburg, so these riders have little option to take public transit to fulfill their daily mobility needs. With such limitation of service, these riders lack factors that would drive them to use public transit like convenience and accessibility to places they need to go. In contrast, 91% of students report their main commuting reason is to go to/from on campus.

Table 8: Commuting Purpose for Residents and Students

Commuting Purpose	Resident	Student
To/from work in Blacksburg (off campus)	48%	7%
Going to/from the Virginia Tech Campus	18%	91%
Other	34%	2%

The student and resident commuting purpose proportions were statistically significant from each other, proving a strong correlation with students going to campus and residents going elsewhere both in Blacksburg and outside of it. This makes the BT system much more useful for students because it provides the mobility service they need.

Ridership can also be influenced by the abundance of other modes available to potential riders. When other modes, like personal vehicles, are readily available, they can be used much more than public transit because of convenience. However, when these other modes become inconvenient, costly, or inefficient and, public transit supplies these factors, the rider is more likely to choose it. Owning and maintaining a personal vehicle can be a costly expense for people, especially students who lack full-time income. Many Virginia Tech students do not have cars because of this. Without access to other modes, students can experience a lack of choice and therefore are reliant on using share transportation, specifically the Blacksburg Transit. Access to parking is also a consideration. At Virginia Tech, student parking is a huge issue. The parking passes are quite costly, and the offered lots do not have excellent access to the campus because they are located on its outskirts. Contrarily, the faculty parking that is offered has much better locations and is more reasonably priced for full-time employment. As summarized in Tables 9 and 10, the statistical difference between the residents and students that used personal car/motorcycle compared to public transit was significant. The stated mode choice prior to COVID-19 was used to determine if this type of factor was influential.

Table 9: Mode Choice for Residents and Students

Mode	Resident	Student
Car	84%	19%
Public Transit	6%	55%
Other	11%	26%

Table 10: Confidence Intervals of Mode Choice

Mode	Resident		Student	
	Minimum	Maximum	Minimum	Maximum
Car	82%	85%	19%	20%
Public Transit	5%	7%	54%	56%

This data concludes that residents are more likely to take personal vehicles than public transit, while students are the opposite and more likely to take public transit. The confidence intervals of this analysis are very small, supporting the certainty of these results. stronger. These mode choice splits could be, in part, attributed to lack of choice and the differing parking availability for the two groups.

4.2.3 Age Distribution and Public Transit

The age distribution of respondents could have an influence on ridership preferences because of the higher risks associated. Many residents are older than students and many have with family members of all different ages. This could make them more cautious when choosing a mode to take, hoping to lower the risk of exposure to the virus. The residents are overall older than the students, with 51% of them being over the age of 45. The CDC has determined that age is a risk factor for having complications with the virus. Therefore, this could also influence residents to minimize the amount of exposure they have to the virus by avoiding public transit.

Table 11 shows the proportions of people willing to take public transit and not willing to take it based on their age bracket. As the age bracket increases, the proportion not willing to use public transit increases. 100% of those respondents that are older than 65 years are not willing to take public transit. The 55-64 age bracket is the only outlier to this trend. The 0-19 years age bracket is the most likely to take public transit regardless of the health crisis, with 26% of the respondents in this age bracket responding with this ridership preference. This response is statistically significantly different from any of the other age brackets as summarized in Table 12. Showing that the 0-19 age bracket is most likely to care less about any potential hazards that public transit could pose during the public health crisis.

Table 11: Ridership Preferences for Public Transit by Age Bracket

Ridership Preferences	I would not feel comfortable using public transit	I would only use public transit with safety measures taken	I would use public transit regardless of the health crisis
0-19 years	21%	53%	26%
20-29 years	33%	51%	16%
30-44 years	37%	49%	14%
45-54 years	57%	39%	4%
55-64 years	43%	50%	7%
65+ years	100%	0%	0%

Table 12 shows the confidence intervals of ridership preferences for public transit broken down by age groups. The group of respondents in the 0-19 age bracket who are not comfortable using public transit during the pandemic is statistically significantly different from those who are unwilling to take public transit. This age bracket has the least proportion of respondents that would not be willing to take public transit. Those who responded that they would only use public transit if specific safety measures were taken were not statistically different between each age bracket. This means that no conclusions can be made that age impacts those willing to take public transit with less risk involved.

Table 12: Confidence Intervals by Age Bracket

Ridership Preferences	I would not feel comfortable using public transit		I would only use public transit with safety measures taken		I would use public transit regardless of the health crisis	
	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
0-19 years	18%	24%	49%	57%	22%	29%
20-29 years	29%	37%	47%	55%	13%	19%
30-44 years	33%	41%	44%	53%	11%	17%
45-54 years	52%	61%	35%	43%	3%	6%
55-64 years	39%	47%	46%	54%	5%	9%
65+ years	100%	100%	0%	0%	0%	0%

The 65 years and older age bracket was determinant with all respondents saying they would not feel comfortable taking public transit during the pandemic. This makes sense because of the escalated risk associated with their age range. The CDC’s data on hospitalizations due to the Coronavirus shows that the risk of complications ending in hospital admittance increases exponentially with age brackets, as shown in Figure 12. This supports the results that people in older age brackets would be less willing to engage in riskier behavior because of the much higher chance of having complications if contracting the virus. Looking at public transit, these results support Hypothesis 1 that older age brackets are less likely to ride public transit. Succeeding analyses will analyze Hypothesis 1 for micromobility.

This age distribution analysis results are cautioned because of the limited response rate by people in the older age brackets. There was only a total of eight respondents within the oldest age bracket (65+). This could be attributed to the survey's online nature and many older people not having access to or an understanding of how to use the platform. The two oldest age groups show smaller confidence intervals which prove more certainty in the results. However, a targeted survey reaching all age groups would need to be conducted to make fully confident conclusions on the influence of age.

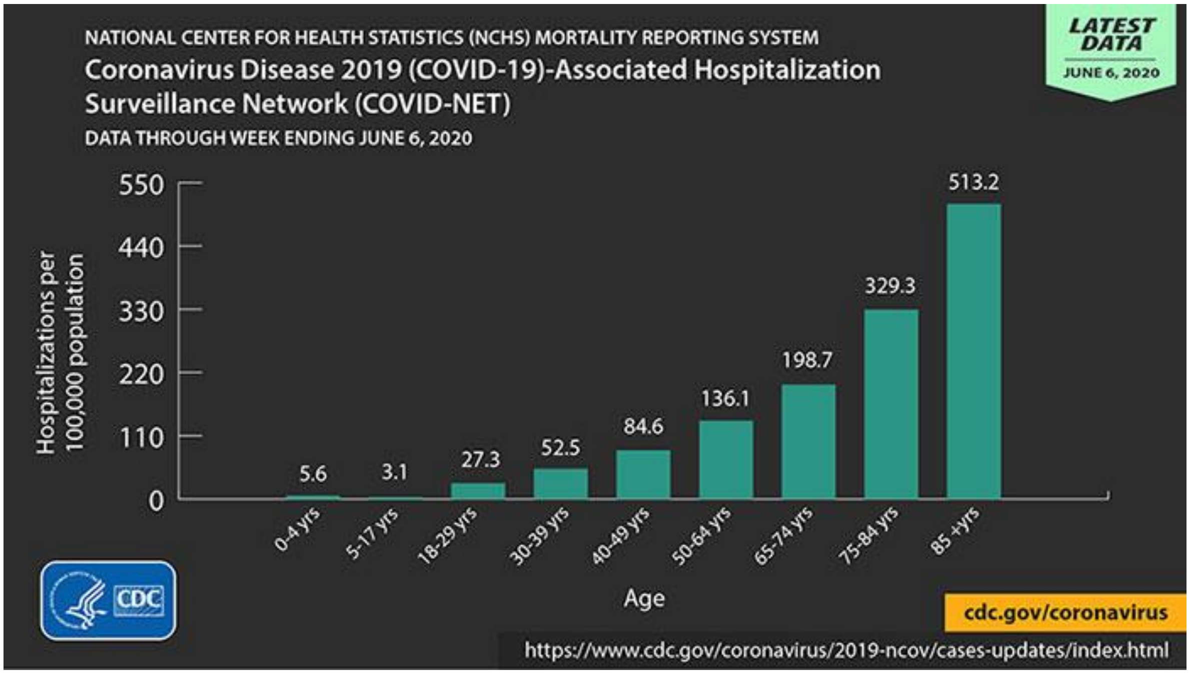

Figure 12: Coronavirus Hospitalizations by Age Group (CDC, 2020)

4.2.4 Pre-existing Conditions and Public Transit

Pre-existing conditions also put a person at higher risk of complications with COVID-19. These pre-existing conditions include asthma, liver disease, diabetes, lung disease, kidney disease being treated by dialysis, serious heart conditions, immunocompromised, hemoglobin disorders, and severe obesity. Having these conditions could impact the willingness of a potential rider to take public transit because it could pose a higher chance of them contracting the virus. Table 13 shows the proportions of people with pre-existing conditions and their ridership preferences for taking public transit. Just under 50% of people with pre-existing conditions would not be willing to take public transit at all, while 43% would be willing with known safety measures being taken.

Table 13: Public Transit Rider Preferences with Pre-existing Conditions

Ridership Preference	Pre-existing Conditions	No Known Conditions
I would not feel comfortable using public transit	49%	32%
I would only use public transit with safety measures taken	43%	51%
I would use public transit regardless of the health crisis	8%	18%

Table 14: Confidence Intervals for Public Transit Riders with Pre-existing Conditions

Ridership Preference	Pre-existing Conditions		No Known Conditions	
	Minimum	Maximum	Minimum	Maximum
I would not feel comfortable using public transit	45%	53%	28%	35%
I would only use public transit with safety measures taken	39%	47%	46%	55%
I would use public transit regardless of the health crisis	5%	10%	15%	21%

Table 14 shows the confidence intervals of potential rider's preferences with pre-existing conditions and those without any known conditions. There is not a statistically significant difference between people that are willing to take public transit with safety measures, with respect to their pre-existing condition status. However, people that do not feel comfortable taking public transit show a statistically significant difference between people with pre-existing conditions and those without known conditions. This means that people with pre-existing conditions, which the CDC confirms puts them at higher risk for COVID-19 complications, are less willing to take public transit compared to those that do not have known conditions. The confidence intervals of this analysis are larger which shows a little less certainty; however, this can be attributed to the small sample size. These results support Hypothesis 1 that people with pre-existing conditions will be less likely to take public transit because they are at higher risk for complications.

4.2.5 Students versus Residents using Micromobility

The same statistical difference analysis was conducted between students and residents for their ridership decision to ride or not ride micromobility. The same hypothesis was made as with public transit, that students would be more willing to take micromobility. It was anticipated that residents would be less likely to take micromobility overall because of their unfamiliarity with the mode, generally older age, and limited access to the mode outside of Virginia Tech's campus. The Roam bikeshare has 12 hubs around the Blacksburg area and provide micromobility options for residents. However, the Spin scooters are geofenced to the Virginia Tech campus and therefore are limited in the use that they can provide for residents living and moving outside of the campus. The results from the survey were more evenly distributed between students and residents than anticipated. Table 15 shows the choice proportions for micromobility ridership between students and residents, and Tables 16 and 17 show the confidence intervals for these questions.

Table 15: Resident and Student Ridership Preferences for Micromobility

Ridership Preference	Students	Resident
I would not feel comfortable using micromobility	46%	41%
I would only use micromobility with safety measures taken	38%	41%
I would use micromobility regardless of the health crisis	16%	19%

There was much less of a defining weight towards one ridership choice over the other between students and residents. Contrarily to the public transit investigation results, students responded more heavily to not being comfortable riding micromobility during the pandemic. This could be attributed to the shared aspect of the mode without the oversight of sanitization. Also, micromobility poses a new mode experience that could come with some unfamiliar navigation of the sidewalk and road and safety concerns without the regular availability of helmets.

Table 16: Confidence Interval of Student Ridership Preferences for Micromobility

Student Ridership Preference	Minimum	Maximum
I would not feel comfortable using micromobility	42%	50%
I would only use micromobility with safety measures taken	34%	41%
I would use micromobility regardless of the health crisis	13%	19%

Table 17: Confidence Interval of Resident Ridership Preferences for Micromobility

Resident Ridership Preference	Minimum	Maximum
I would not feel comfortable using micromobility	38%	42%
I would only use micromobility with safety measures taken	38%	42%
I would use micromobility regardless of the health crisis	17%	21%

The confidence intervals between students and residents show that overall, there is no statistically significant difference between students' and residents' choices and opinions. There is significance in the ridership choice of not feeling comfortable taking micromobility. The statistics show that students are more likely to be uncomfortable riding micromobility; however, it is a small proportion higher than residents. The confidence intervals are small for this analysis and show certainty in the results.

The ridership of micromobility could be influenced by the commuting distance for a potential rider. Micromobility is more useful for shorter length trips. Therefore, people that must travel several miles to get to their destination will be less likely to ride micromobility because it is a less convenient mode for them. In addition, the geofenced E-scooters do not supply mobility for these longer-range trips.

From the analysis, Hypothesis 2 is rejected because it cannot be said that students are more likely to be willing to ride micromobility. However, Hypothesis 2 regarding public transit was accepted because student and resident responses were statistically significantly different from each other, with students showing to be more likely to be willing to ride public transit.

4.2.6 Age Distribution and Micromobility

The willingness to ride micromobility was also analyzed regarding the age brackets determined by the survey. The data were analyzed by age bracket within each of the given ridership preferences, unwilling to take, willing to take with safety measures taken, and willing to take. The proportions of respondents in the determined age bracket that responded with each of the three responses are more evenly spread for micromobility. Most of the age brackets, excluding 30-44 years and 55-64 years, had the highest proportion of respondents saying they are unwilling to take micromobility during the pandemic, as shown in Table 18. The two age brackets that did not follow this trend had the highest proportion of respondents say they would only use micromobility with safety measures taken. This result is surprising because it was anticipated that micromobility would be more heavily considered as an acceptable mode for the younger age brackets. Using micromobility, regardless of the health crisis, was the least likely to be chosen option for every age bracket, except for the 55-64 years age bracket that tied proportions with using micromobility with safety measures.

Table 18: Age Bracket Ridership Preferences for Micromobility

Ridership Preferences	I would not feel comfortable using micromobility	I would only use micromobility with safety measures taken	I would use micromobility regardless of the health crisis
0-19 years	40%	37%	23%
20-29 years	46%	39%	15%
30-44 years	34%	46%	20%
45-54 years	57%	35%	9%
55-64 years	29%	36%	36%
65+ years	75%	25%	0%

Table 19: Confidence Intervals of Age Bracket Ridership Preferences for Micromobility

Ridership Preferences	I would not feel comfortable using micromobility		I would only use micromobility with safety measures taken		I would use micromobility regardless of the health crisis	
	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
0-19 years	36%	44%	33%	41%	19%	26%
20-29 years	42%	51%	35%	43%	12%	18%
30-44 years	30%	38%	42%	50%	17%	23%
45-54 years	52%	61%	31%	39%	6%	11%
55-64 years	25%	32%	32%	40%	32%	40%
65+ years	71%	79%	21%	29%	0%	0%

The results of the ridership preferences by age bracket were mostly statistically insignificant from each other, summarized in the confidence intervals in Table 19. This means that it cannot be said with certainty that any one age bracket has a more significant ridership preference than another age group. As expected, age group 65 years and older is statistically significantly different, most likely to not feel comfortable taking micromobility. The age group sample sizes and confidence intervals of these groups both varied in this analysis showing some limitation to the certainty of the results. Insignificant data does not mean that the data collected is useless. The survey data shows that micromobility is more agreed upon amongst many age brackets, which is different from what was expected because of the young popularity of the mode. For micromobility, the results of this analysis reject Hypothesis 1 that older people will be less likely to ride micromobility.

Micromobility is a new mode of transportation that takes coordination and balance to use. Additionally, there is little legislation that binds them to one riding surface (road versus sidewalk), and therefore, can be confusing for the rider to know where to go. Most of the devices in micromobility are technology-based, requiring a smartphone to use. All these factors can have an impact on the older age bracket not using the mode.

4.2.7 Pre-existing Conditions and Micromobility

The pre-existing conditions of the respondents were compared to their willingness to ride micromobility to determine if it was an influencing factor. Having pre-existing conditions escalates a person's risk for complications with COVID-19. Therefore, as with public transit, it was anticipated that those with these kinds of conditions would be less likely to ride shared micromobility because of the high contact surfaces and uncertainty of disinfectant. Table 20 shows the micromobility ridership preferences for respondents with and without pre-existing health conditions. 61% of those with known conditions would not be willing to take shared micromobility.

Table 20: Micromobility Rider Preferences with Pre-existing Conditions

Ridership Preference	Pre-existing Conditions	No Known Conditions
I would not feel comfortable using shared micromobility	61%	41%
I would only use shared micromobility if safety measures were taken	30%	40%
I would use shared micromobility regardless of the health crisis	9%	18%

Table 21: Confidence Intervals of Micromobility Riders with Pre-existing Conditions

Ridership Preference	Pre-existing Conditions		No Known Conditions	
	Minimum	Maximum	Minimum	Maximum
I would not feel comfortable using shared micromobility	57%	65%	37%	45%
I would only use shared micromobility if safety measures were taken	26%	34%	36%	44%
I would use shared micromobility regardless of the health crisis	7%	11%	15%	22%

Table 21 shows the confidence intervals for people with and without pre-existing conditions and their ridership preferences for taking shared micromobility. People with pre-existing conditions were found to be statistically significantly less likely to feel comfortable taking shared micromobility. This was expected because of the higher risk they take by using shared transportation. A statistically significant difference between people with and without known conditions was also found within people that stated they would only take micromobility if safety measures were taken. This difference showed people without health concerns being more willing to take public transit with safety measures taken. This shows that people with pre-existing conditions are less likely to take micromobility during the pandemic. These findings support Hypothesis 1.

4.2.8 Hometown Type

Students were sent off-campus and back to their hometowns in March of 2020 when the pandemic first hit the United States. Many of the students were in these hometown areas for about five months before coming back to Blacksburg for the Fall 2020 semester. This experience in another area could impact the ridership choices that students make. Urban/Suburban areas, both within Virginia and other parts of the US, were hit harder in the pandemic's earlier months. Hypothesis 2 aims to determine if the type of hometown students originate from impacts the ridership choices. Hypothesis 2 states that students originating from urban/suburban areas will be less likely to take public transit. Micromobility was not considered in this analysis because shared micromobility is too new of a mode and is not implemented widespread enough to have influence by hometown. This analysis was only conducted for student respondents between each hometown type, and the confidence intervals of these were compared to determine if they are statistically significantly different from each other. The international group was omitted from the t-test because there were too few respondents in this category to have significant results. Table 22 shows the proportions of ridership preferences by students in each hometown type. The proportions for each ridership preference were similar between hometown types.

Table 22: Ridership Preference by Hometown Type

Ridership Preference	Urban Virginia	Urban/Suburban (Other US)	Other Virginia	Rural/Exurban (Other US)	International
I would not feel comfortable using public transit	34%	22%	33%	27%	50%
I would only use public transit with safety measures taken	54%	46%	48%	64%	50%
I would use public transit regardless of the health crisis	12%	32%	19%	9%	0%

Using the t-test, confidence intervals were determined for each hometown type as shown in Tables 23 and 24. The confidence intervals show barely any statistically significant difference between the urban/suburban hometown locations and the rural/exurban hometown locations for public transit ridership. There is a difference between urban Virginia and other parts of Virginia's response in using public transit regardless of the pandemic, where other parts of Virginia respondents are slightly more likely to take it regardless of the situation. Statistics show that people from rural/exurban hometown locations are more likely to be willing to take public transit if they are confident in safety measures being taken. However, rural/exurban was a minimal sample size that could have resulted in data skewing. The confidence intervals ranged in size with some showing more certainty in the results than others.

Table 23: Confidence Intervals by Hometown Type (Urban/Suburban)

Ridership Preference	Urban Virginia		Urban/Suburban (Other US)	
	Minimum	Maximum	Minimum	Maximum
I would not feel comfortable using public transit	31%	38%	19%	25%
I would only use public transit with safety measures taken	50%	57%	42%	50%
I would use public transit regardless of the health crisis	10%	15%	28%	35%

Table 24: Confidence Intervals by Hometown Type (Rural/Exurban)

Ridership Preference	Other Virginia		Rural/Exurban (Other US)	
	Minimum	Maximum	Minimum	Maximum
Would not feel comfortable using public transit	30%	37%	24%	31%
Would only use public transit with safety measures taken	44%	52%	60%	67%
Would use public transit regardless of the health crisis	16%	21%	7%	11%

For public transit, Hypothesis 3 is rejected because there is not a significant difference between urban/suburban and rural/exurban responses. This result is surprising because of the substantially worse impact the Coronavirus had on urban settings compared to rural areas in the early parts of the pandemic. This outcome could be partly attributed to the inexperience of public transit use for people originating in rural/exurban areas. Traditionally, public transit systems are established in larger urban/suburban areas because of population density and the need for mobility. Therefore, people originating from these places are much more familiar with transit systems. With this familiarity of the types of systems, people from urban/suburban areas could feel more comfortable using public transit. Additionally, these people could find a smaller town's public transit system to be less risky than that of an urban/suburban area, making them feel more comfortable with taking shared transportation. Similarly, those that originate from rural areas may be more reluctant to try shared transportation in a more densely populated area because they are accustomed to much less population.

4.2.9 Ridership Factors

In the survey, the respondents were asked to rank a grouping of eight factors from most important to least important when deciding to use public transit. The eight factors included in the ranking were grouped into Coronavirus related precautionary factors and traditional daily decision factors. The Coronavirus factors were cleanliness (disinfected), fresh/clean air, and physical distance. The traditional decision factors included as ranking options were cost, convenience, travel time, and ADA compliance. An open text ‘other’ choice was also included as an option, although unused by survey responders. The factors that were included in the survey were chosen because they encapsulate highly important safety measures for combatting the Coronavirus and important factors that travelers consider when choosing a mode for their trip. Understanding the important factors that riders consider can help transit agencies and decision-makers better formulate their decisions to align with public opinion and tailor the mobility experience to people’s preferences. Comparing the reported importance of Coronavirus factors to the daily choice factors will help understand the importance of an extreme event and how it impacts decision making. It was anticipated that the Coronavirus factors would rank higher than the daily decision factors because of the pandemic's risk. Also, the survey was conducted during the earlier months of the pandemic, when a full understanding of the virus's transmission abilities was unknown. This could heighten the respondent’s response to pandemic concerns. The survey proved the anticipated results correct.

The most common ranking positions from 1-8, where one is the most important and eight is the least important, were cleanliness, physical distance, fresh air, travel time, convenience, cost, ADA compliance and other. Figure 13 shows each factor group's distribution among the ranking positions. For each ranking position (1-8), every factor is presented with the percent of respondents that ranked the factor in the labeled ranking position. For example, ranking position 3, the third most important factor to riders, was the most commonly fresh air, with 30% of respondents ranking fresh air as the third most important factor. The second most common factor put in position 3 was travel time, with 20% of respondents ranking it at this position. Cleanliness was most often placed at position one, the most important factor, with about 50% of the respondents choosing this positioning. The Coronavirus factors were all ranked higher on average than the typical daily ridership factors from the rankings. This follows the anticipated results of this question.

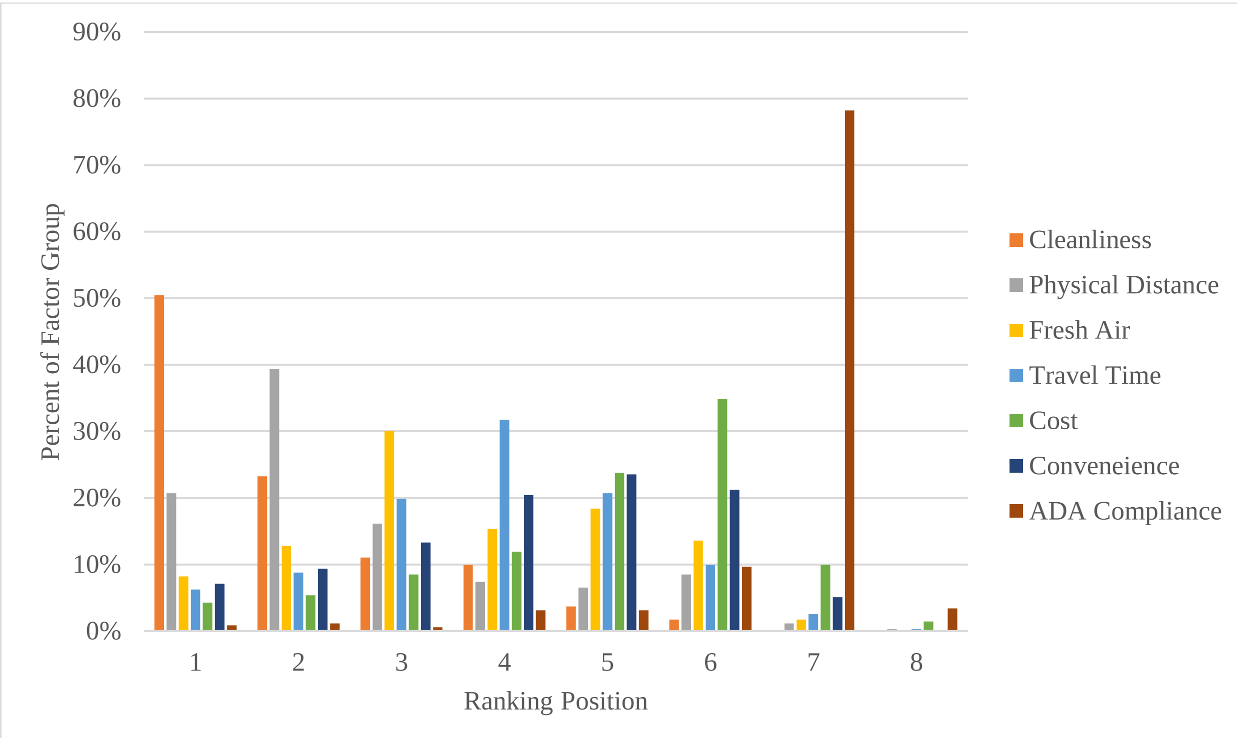

Figure 13: Ranking Positions by Percent of Factor Groups

These results support Hypothesis 4 that was discussed in Chapter Three. These results point to the influence that an extreme event has on ridership decision making. Transit agencies and decision-makers must be as proactive as possible and respond quickly to evolving situations by addressing rider concerns. Agencies may also become more relaxed about normal daily decision factors to better address the Coronavirus factors first. If travel time is slightly increased to ensure better cleanliness of the service vehicle, riders should be less concerned about this during an extreme event based on the results of this study. Prioritizing the safety-related measures that riders associate with riskier behavior will be critical for agencies to provide service that people are willing to use during an unexpected or extreme event.

4.2.10 Bus Capacity

As a follow-up to the survey question asking respondents to rank ridership factors, the respondents were asked to choose the bus capacity they would feel comfortable using during the pandemic without a vaccine or treatment available. The bus capacity buckets were divided into four 25% range buckets and an option saying “I would not feel comfortable taking public transit” was also given. The highest preferred capacity was between 26-50% of the total available bus capacity, which 39% of respondents chose. The second most common response was 0-25% capacity. The distribution of the preferred bus capacities is in Table 25.

Table 25: Distribution of Acceptable Bus Capacities

Acceptable Capacity	Proportion
0-25% of the total capacity	25%
26-50% of the total capacity	39%
51-75% of the total capacity	15%
76-100% of the total capacity	7%
Not comfortable taking public transit	15%

The responses in this survey were statistically significantly different from each other, shown in Table 26. There is an overlap between 51-75% of the total capacity and not feeling comfortable taking public transit, making these choices not statistically significantly different and thus, it cannot be determined which is more preferred. However, most respondents chose an acceptable capacity between 0-50% of the total, and choices were found to be statistically significant. Therefore, there is confidence that most potential riders would not be comfortable taking public transit with any more capacity used than 50% of the total original vehicle capacity. The confidence intervals of this analysis are relatively smaller showing a lower uncertainty level.

Table 26: Confidence Intervals of Acceptable Capacity Proportions

Acceptable Capacity	Minimum	Maximum
0-25% of the total capacity	21%	28%
26-50% of the total capacity	35%	43%
51-75% of the total capacity	11%	18%
76-100% of the total capacity	5%	9%
Not comfortable taking public transit	12%	18%

A limited capacity on public transit was in response to the safety measures encouraged during the pandemic. Physical distance is an important mitigation strategy, and to accomplish this on a public transit vehicle, capacity must be limited. Bus capacity typically includes a seated capacity and standing room capacity, making riders susceptible to coming into very close contact with other riders in a small compact area. This can also have implications for contaminated air when too many people are breathing the same recycled air. The survey suggests that agencies would need to reduce capacity significantly (50%-100% reduction) to provide what 64% of the respondents feel is a comfortable capacity to allow physical distance between riders. This result is in line with what was expected because when presented with a riskier situation, people want to take precautionary measures to mitigate the risk. A busy and packed bus is a risky situation during the pandemic, so understandably, the riders would want to reduce the capacity.

4.2.11 Future Outbreaks

Additional 'waves' of the virus, or periods of higher case numbers, were anticipated during the span of the pandemic. Respondents of the survey were asked about the influence of a possible second or third wave outbreak in Blacksburg. An outbreak is an unanticipated increase in cases of the disease in a short timeframe. It was anticipated that an outbreak would significantly impact people's ridership choices for both public transit and micromobility because it 1) potentially increases the risk of contracting the virus and 2) increases the perceived risk because of the fear associated with it. The study aimed to understand the impact of an outbreak on the respondent's ridership preferences compared to how people responded to the pandemic in general. To do so, the ridership preferences that were determined in question 16 about the pandemic overall were compared to the ridership preferences stated in question 18 of the survey about the impact a future outbreak wave would have.

Table 27 shows the proportion of respondents and their ridership preferences if there was a second or third wave outbreak in the Blacksburg area. 65% of the respondents would prefer not to use shared transportation and either take a different mode or not take the trip. This analysis looked at the 'would not take either of the modes' subsection of respondents to see what their original preference for riding during the pandemic was.

Table 27: Ridership Preferences During an Outbreak

Ridership Preference	Proportion
Public Transit	20%
Micromobility	9%
Either	6%
Neither, I would rather take another mode or not take the trip	65%

Table 28 shows the proportion of people with the original ridership preferences that then reported not being willing to take any shared transportation during an outbreak. More than half of the people that were willing to take public transit during the pandemic if safety measures had been put in place reported not to be willing to ride shared transportation if an outbreak were to occur. While only 13% of those that reported willingness to take public transit without worry about the pandemic changed to not being willing to ride during an outbreak. This means that based on this analysis most of the people that were not worried about the pandemic still would not be worried even if an outbreak were to occur.

Table 28: Public Transit Riders Not Willing to Ride During an Outbreak

Original Ridership Preference	Proportion
I would only use public transit with safety measures taken	64%
I would use public transit regardless of the health crisis	13%

Table 29: Confidence Interval of Ridership Change to Not Willing for Public Transit

Original Ridership Preference	Minimum	Maximum
I would only use public transit with safety measures taken	60%	68%
I would use public transit regardless of the health crisis	10%	16%

These rider preference changes show a significant statistical difference from each other, having confidence intervals with large gaps between, summarized in Table 29. The confidence intervals are small showing some certainty in the analysis. It is concluded that people who were willing to take public transit with safety measures seem less confident that the measures can keep them safe during an outbreak. Therefore, during a riskier time, they are not confident in taking shared transportation because they may not think they can stay safe. On the contrary, the people who did not care before generally do not care during an outbreak. It is important to note that the respondents who would ride regardless of the health crisis make up a much smaller proportion of the survey sample, shown in the sample bias.

Micromobility had a similar outcome to public transit when considering a future outbreak. It was anticipated that people would be more willing to ride micromobility because it is easier to distance from people physically, and it is an open-air mode. The results of this analysis show that about 69% of the people who were willing to ride micromobility during the pandemic are not willing during an outbreak, as shown in Table 30.

Table 30: Micromobility Riders Not Willing to Ride During an Outbreak

Original Ridership Preference	**Proportion**
I would only use micromobility with safety measures taken	69%
I would use micromobility regardless of the health crisis	21%

Table 31: Confidence Interval of Ridership Change to Not Willing for Micromobility

Original Ridership Preference	**Minimum**	**Maximum**
I would only use micromobility with safety measures taken	65%	73%
I would use micromobility regardless of the health crisis	18%	24%

The confidence intervals, shown in Table 31, are far apart from each other, meaning the results are statistically significantly different from each other. These results reject Hypothesis 5 that micromobility would be more readily chosen as the preferred mode during an outbreak. These results differ between the data and the anticipated results could be attributed to a few factors. Micromobility is a shared form of transportation that is a lot less regulated than public transit. This could deter riders from using it because they might have less confidence in the safety strategies being put in place during the health crisis. Also, micromobility is a new mode in which many people may still be uncomfortable. It can be intimidating not knowing where to ride it, how to ride it, and where to park/finish the ride. These factors could also play a role in the decrease in usage during an outbreak. During a riskier time, people may be less likely to do things outside their comfort zone. Overall, respondents showed to be less comfortable with taking all forms of shared transportation. This can be attributed to the perceived risk associated with taking a mode shared with other people. Potential fear of the unknown could influence potential rider's decisions; however, this is difficult to quantitatively include in the analysis.

4.3 FREE-RESPONSE ANSWERS

In the survey, two free-response questions were asked about what measures mobility agencies could take to help make people feel more comfortable - taking public transit and micromobility. An example of supplying disinfecting wipes was given in the question prompt to help the respondents think about possible precautions.

4.3.1 Public Transit

As expected for public transit responses, many responses indicated people would feel more comfortable if masks were strictly enforced, and physical distancing was encouraged whenever possible. Disinfecting wipes were also encouraged, with people saying they would feel more comfortable with wiping down the seat and handlebars they were using. Providing trash receptacles to collect the contaminated wipes would also help reduce the chances of littering. It was agreed that the buses should be continually sanitized whenever possible by the driver to ensure high contact surfaces are being disinfected. Antimicrobial fabrics and materials are materials that inhibit the growth and life of microorganic pathogens. These materials have been used in medical and military settings to protect against contamination. Adding this type of material to high contact surfaces within shared transportation, like handlebars and payment surfaces, could help increase the vehicles' sanitization. To further heighten the sanitization of the public transit vehicles, each vehicle's use should be limited to an appropriately determined number of hours before it would be taken out of service, sent to the garage, and given a high-grade sanitization process.

Survey respondents also commented on system processes and procedures. Capacity was discussed several times, with the concern that too many people filling the busses will cause a physical distancing issue. Limiting this capacity would increase the confidence in riders to be able to stay far away from other riders, and this could include eliminating the standing room. Increasing service frequency while limiting bus capacity was suggested to avoid overcrowding issues and getting too close to other riders. Respondents said promoting a one-way flow through the busses, with the front door being entrance only and the rear door being exit only, would further encourage physical distancing. This process could be very beneficial for public transit systems to discourage colliding interactions between riders during onboarding and alighting.

Transparency of information to let individual riders make informed ridership decisions is important to give confidence in a mode. An online tracking application could be created to implement transparency with potential riders. This online source would indicate the times when a vehicle has last been sanitized. This would help riders feel more comfortable with choosing to ride public transit. As discussed in the literature review, it was found that agencies being more transparent about information regarding the crisis ultimately gives people more confidence in their safety. Publishing the information on the sanitization of the public transit vehicles should give riders more confidence in using the mode. Also, publishing each vehicle's capacity usage on the app will give riders more knowledge to make a ridership decision. This data can also help riders plan which vehicle to ride, helping them better plan a trip. With the ability to plan, potential riders will be more willing to take public transit because they can make it convenient for their mobility needs. Also, adding dynamic signing to each bus to show the current capacity usage will be important in being transparent with potential riders to make a ridership decision. As discussed in this section, the capacity limit preferences ranged between respondents. By presenting them with this information, they can make informed and confident decisions about ridership. Displaying information of this nature is beneficial for ridership following the pandemic as well. By providing real-time information about transit vehicles' status, the mode will become more reliable for riders. Confidence in the reliability of information provided is essential in building trust that public transportation agencies can supply rider mobility needs in a safe manner.

4.3.2 Micromobility

Like public transit, respondents of the survey expressed their desire for disinfectant wipes being supplied at designated pick-up and drop-off locations for micromobility devices. This would allow them to take control of cleaning the device to their desire standard before using it. Touch-free locking and unlocking of the devices can reduce the possibility of transmission through high contact surfaces. The E-scooters had this function already implemented; however, Blacksburg's

Roam Bikeshare system has a keypad unlocking/locking system. Moving this process to a Bluetooth or scanning smartphone application would reduce the exposure to high contact surfaces that could potentially have pathogens of the virus.

Many respondents emphasized the desire to have cleaning and usage data published on the device applications similar to public transit. While disinfectant wipes can be provided, tracking devices' cleanliness can be challenging with this sanitization method because it would be based on the honor system. It could be beneficial in the short term to add a sanitization report on the application before the rider could finish the ride. Ultraviolet (UV) light has been proven to eliminate bacteria and viruses. The wavelength of light required for elimination ranges depending on the pathogen that is trying to be killed. This type of technology is in the early stages of implementation but has been used in health care/hospital settings to sanitize. As this technology becomes more readily produced and available, UV lights could better regulate and track the sanitization of mobility devices. As this study revealed, cleanliness is one of the most important factors to potential riders, and this is expected to continue to be an important factor following the pandemic. If more reliable and trackable sanitization processes are implemented, and this data is published, riders will have a lower risk assessment of the mode and be more willing to take it.

4.4 SUMMARY

The preference survey data collected for this study had both expected and unexpected results. The analysis between students and residents in the Blacksburg community is important in understanding how people with different daily lifestyles make mode choice decisions. Students were more willing to take public transit. This can be attributed to numerous factors, including proximity to bus stops, age and commuting purpose. The age brackets showed to impact public transit ridership preference more significantly than micromobility ridership. Other factors that impact ridership preferences that were looked at are the originating hometown type, factor ranking and acceptable bus capacity. The possibility of a second or third outbreak wave also was analyzed, showing ridership for both modes would decrease. The factors analyzed during this study were considered both in the context of the Coronavirus pandemic and the daily ridership preference. This helped to understand priority and importance to the riders during unexpected times, proving the Coronavirus factors to be much more important to potential riders.

The survey's free-response section showed that publishing real-time data would tremendously benefit the potential rider’s confidence level in taking shared transportation. The more information that can be provided to someone, the more they feel in control of their decision-making. Humans innately seek a sense of control to get the feeling of reducing risk (Changing Minds, n.d.). By providing accurate and on-demand data for people, they will experience a better sense of control, and therefore, can feel less risk engaging in the activity. This would ultimately increase ridership. Additionally, new disinfectant methods were suggested to increase the sanitization of the shared transportation devices and vehicles.

Chapter 5: Summary, Conclusions, and Future Work

5.1 OVERVIEW

This chapter will summarize the study's findings and evaluate the importance and impact these have on the current transportation status. Recommendations to decision-makers and shared transportation agencies/companies will be given. These recommendations will aim to inform their decisions to better address ridership preferences found in the study. The limitations of this study will be discussed. Finally, this section will discuss potential future work that could be conducted to elaborate on this study's findings.

5.2 SUMMARY

This study focused on determining important factors and considerations that potential riders consider when choosing their transportation mode. Specifically focusing on the Coronavirus pandemic, the survey determined the importance of risk and safety when decision-making. To conduct this analysis, a quantitative survey was formulated and distributed to the Blacksburg community. This survey's responses were used to determine important factors of ridership preferences for shared transportation, including public transit and micromobility. Five hypotheses were created and then examined in the analysis. These hypotheses were:

1. Those who are older and those with underlying conditions, both characteristics that put people at higher risk for complications with the Coronavirus, will have a lower percentage of people willing to ride shared transportation.
2. During and coming out of the pandemic, students will be significantly more likely to be willing to ride public transit and micromobility.
3. Those originating from urban/suburban, including Northern Virginia, Richmond, and Hampton Roads, will have a lower percentage of people willing to ride public transit than those originating from more rural areas.
4. Disinfecting of the mode and physical distance from others will be the two highest-ranking factors of importance when deciding whether to take shared transportation.
5. There will be a higher percentage of people willing to take micromobility over public transit during the Coronavirus pandemic, especially during an outbreak because it is easy to disinfect, and contaminated air is less of a concern.

Hypothesis 1 was supported by the results of this study. People that are older and people that have underlying health conditions were found to be generally more cautious when making shared transportation ridership decisions. Older people were found to be much less likely to take public transit, however they had similar attitudes as younger people when considering micromobility. People that have pre-existing conditions known to cause complications with COVID-19 were less comfortable with taking both forms of shared transportation.

The data was broken up into Virginia Tech students and Blacksburg residents, and these groups were compared. In support of Hypothesis 2, students were much more likely to take public transit during the pandemic. However, students were not found to have any statically different preference compared to residents for riding micromobility during the pandemic. The infancy of micromobility leads to unfamiliarity for everyone and can play a role in this indifference between students and residents. The analysis of micromobility was limited by the restricted access to it off-campus and thus making the mode much less useful for residents. Students are more likely to take public transit for various reasons, including proximity to the bus stop, commuting purpose aligning with transit service and lack of choice.

It was anticipated that student's originating location and previous experiences would impact their ridership decisions. Those that originate from a much more densely populated area would be less likely to ride public transit. This was considered because the pandemic had a severe early impact in urban environments. Hypothesis 3 was rejected because there was no significant difference found between the ridership willingness of those that originated from urban/suburban and rural/exurban areas. People from urban/suburban areas are typically more familiar with public transit because it is more prevalent in these areas. This could have influenced the comfort level of these people to take public transit.

The two most influential factors that potential riders considered during the pandemic were the cleanliness (i.e. disinfected) of vehicles and physical distance between riders. The pandemic related factors (cleanliness, physical distance and fresh air) were found to influence rider's willingness to take shared transportation much more heavily than daily riding factors (cost, convenience and travel time). Therefore, Hypothesis 4 was accepted because the pandemic factors were much more important for riders.

It was anticipated that micromobility would be the preferred shared transportation mode over public transit, particularly during an outbreak where there is a heightened concern with the virus spreading. This is because of the distancing from other people, easier cleaning, and little recycled air concerns. However, the study found that both public transit and micromobility would be less desired as a transportation mode, especially during an outbreak in the Blacksburg area. Therefore, Hypothesis 5 was rejected. This can be attributed to the perceived risk associated with outbreaks.

5.3 CONCLUSIONS

This study determined many important factors that have influenced ridership decision-making during the Coronavirus pandemic. Using a stated preference survey, data on potential rider's opinions were collected and analyzed to best understand their thought process when making shared transportation decisions. The data was collected from the Blacksburg residents and Virginia Tech students and can help agencies better address factors that influenced the rider's mode choices. Blacksburg Transit and micromobility agencies in the Blacksburg area can use this study's findings to adjust their services to reflect rider concerns and considerations. The results found riders are more influenced by the Coronavirus pandemic factors than traditional shared transportation factors. Agencies are encouraged to put emphasis on physical distance and cleanliness during the pandemic, even if it means sacrificing scheduling and availability. One of the key takeaways from this study for shared transportation providers was that potential riders want to feel in control and as protected as possible during the pandemic. In this case, the extreme event, the Coronavirus pandemic, has much more influence than everyday factors when potential riders make mode decisions during the event. Shared transportation providers should provide disinfectant options and mandate mask-wearing to make riders feel more comfortable. This sentiment was expressed by most respondents of the survey, that protective measures, namely disinfecting of vehicles and requiring PPE for all users, would make them feel much more comfortable with using shared transportation.

Providing a well-designed and functional platform that contains all data about the vehicles would also encourage the use of shared transportation. Blacksburg Transit has the platform already established, the BT app, that can plot routes and track buses' progress along a route. Using this same platform, Blacksburg Transit should incorporate a section with real-time data, publishing constant updates on each vehicle's cleanliness and capacity in the fleet. Rider’s expressed that they would feel much more comfortable if they knew when the vehicle was last cleaned and how many people are currently riding. Publishing this real-time data would help make people feel more in control of their environment and, therefore, more likely to be willing to take a shared transportation mode even though there may be higher risks involved. Also, being transparent with potential riders by publishing this type of data shows the confidence the agency/company has in their service's safety and reliability. As seen in previous studies, when riders see confidence coming from the shared transportation agencies, they have more confidence in the mode. Therefore, it is suggested that Blacksburg transit publish data on the current used capacity for each vehicle that is in service, detailed cleaning procedures that are being used and an in-real-time log of when vehicles have last been cleaned. Respondents were most comfortable with capacity limited to 50% or less of the original. Implementing these types of restrictions will also increase rider’s confidence in the mode. Micromobility providers are suggested to publish data when devices have been most recently used and an in-real-time log of when each device has last been disinfected. Also, micromobility providers are encouraged to reduce the number of high-contact surfaces as much as possible. Specifically, the New River Valley shared bike service, Roam, is encouraged to move all locking/unlocking features to a mobile app process instead of using keypads.

The Blacksburg Transit system was found to have students more willing to ride public transit than Blacksburg residents. This is understandable because 1) students are primarily younger than the average resident and therefore have a lower risk of complications with the virus, and 2) the system was designed to supply mobility for student needs instead of resident needs. To encourage the use of public transit by all demographics, the route access and distance from a stop should be considered as a function of the type of rider. For example, older people may be less willing to walk farther for a public transit stop. There may be many contributing factors to this, but the physical activity level and mobility of this demographic may be attribute that should be given further consideration. In this case, older people would need to have a service stop located closer to their originating point. For younger people, walking is typically less strenuous, so that stops can be farther from their originating location, and they would still be willing to take it. GIS census data can provide demographic data as a function of location. This type of data should be considered when determining public transit service stops and micromobility locking/unlocking stations. This can be challenging because of the smaller size of the Blacksburg Transit system but should be a consideration for further expansion of the system.

5.4 LIMITATIONS

This study has several limitations due to the nature of a survey and the novelty of the Coronavirus pandemic during the time of the study and the many unknowns that went along with this. A survey type study presents challenges with the balancing of content and length. It is important to capture as much data as possible, while keeping the survey approachable in hopes of encouraging as many respondents as possible. The absence of information could have influenced responses. For example, the acceptable capacity was presented in the survey as a percent of total available bus capacity. Respondents may have not had a full understanding of how much available capacity a bus has (seated and standing) and that 50% capacity may not allow for a 6' separation between every rider.

During the 2-month data collection timeframe, regulations and authority advice was continually changing. This could have impacted the opinions of the respondents, however, was difficult to collect quantitatively through the survey. Furthermore, since there was such little knowledge about the spread and contamination of the virus, many experts around the world were publishing different findings and suggestions. This made some people question the situation and ultimately people had very different beliefs on the appropriate approach to protecting people. With such uncertainty, people had extremely varying opinions on the pandemic which could influence their ridership decisions. External influences, like social pressures, news publications, and political outlooks are assumed to have significantly influenced people's opinion on the pandemic and therefore on ridership preferences during the pandemic. However, none of these external factors were quantitatively collected through this study's survey. This study had a small and specific sample population, based in a college town, so the collection of opinions from people of differing demographics was limited.

Furthermore, Virginia Tech took a testing and quarantining approach for allowing students back on campus for the Fall 2020 semester. This meant that students had access to testing and were required to quarantine if there was a known exposure or symptoms were present. Quarantining meant that people would have little to no need for mobility during that time and therefore would influence mobility choices. This would have an anticipated impact on the ridership of shared transportation. However, this was not explicitly discussed in the survey because the data collection occurred before Virginia Tech's decision was announced. Quarantining and the anticipation of contracting the virus could have implicitly impacted the survey results, but no quantitative data was collected on this influence.

With Blacksburg as the location of the study, the micromobility study was limited. The two major forms of micromobility available were E-scooters and bikeshare. The E-scooters were geofenced to the limits of the Virginia Tech campus. This means riders could only use the devices within the campus borders. Therefore, the use of them for commuting outside of the campus was not an option unless combined with another mode. The bikeshare provides service around the entire town of Blacksburg, and as such is the only micromobility service to fully serve the Blacksburg community. The micromobility results are less significant because of the E-scooter service limitation.

By using a study area like Blacksburg, the results of this study are limited in their application to other locations. As a college town, Blacksburg has unique characteristics that do not align with more traditional urban locations. The results of this study can be used to better inform a future study in an urban area. Targeting the factors that were found to have influence can help focus the scope of a future survey in a different location. However, the specific results of this study are tied to Blacksburg and similar college towns.

5.5 RECOMMENDATIONS FOR FUTURE WORK

The work conducted during this study introduced the factors that influence the potential rider's willingness to use and preference for shared transportation during a global pandemic. The contributions of this study are valuable; however, to fully understand the 'next steps' for mobility providers, a more in-depth study into each factor that was found to be influential should be conducted. This will help to further understand what actions should be taken.

Pandemic fatigue and the hope of an ending should be considered in future research into people's preferences. As the pandemic dragged on, some people's willingness to act as cautiously as they once did, dwindled. People were anxious to get back to a sort of normalcy, and this could impact their ridership preferences. Quantifying the impact of fatigue on a person's decisions would be important.

This study was conducted on a small scale in a relatively small town of Blacksburg, VA. This location had very defining characteristics that limit the results on a broader scale because it is a college town with most of the population being students. The transit and scooter systems are student-centric, which poses external factors on the usage of these modes incorporated in this study. Conducting a large-scale survey in an urban city (with well-developed public transit and micromobility systems) would further develop the factors found in this study. By considering a more robust public transit system, the factors impacting rider decisions of the Coronavirus pandemic (or another extreme event) can be examined more thoroughly. In addition, incorporating a larger population size with wide-ranging daily life activities will help to quantify the varying opinions on the pandemic and how these opinions influenced ridership decisions. Similarly, expanding the study to an urban area should increase the data on micromobility because this mode is much less restrictive in urban settings compared to Blacksburg. Familiarity with the mode and knowledge of regulations would have much less influence on the study in an area that has a comprehensive micromobility system previously implemented.

A study using a multi-disciplinary approach will work to mitigate the unquantifiable external factors that potentially influenced this study's results. This study mostly focused on more traditionally examined engineering factors. Working to quantify more perspective-based factors such as comfortability with risk, social influence, and published media influence will help to better understand every factor playing a role in a rider's decision-making. While, these factors may not be under the control of mobility providers, they can better inform ridership predictions and therefore mobility supply.

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APPENDIX A: SURVEY QUESTIONS

Q1 This research project is designed to help understand how the COVID-19 pandemic is impacting ridership of public transit and micromobility in the Blacksburg, Virginia area. This survey is meant for Virginia Tech students and those that live and/or commute in Blacksburg or the New River Valley area.

As a thank you for taking the survey, we are raffling off Amazon gift cards. Enter your email at the end of the survey for a chance to win.

Q2 Are you a Virginia Tech student?

- ○ Yes
- ○ No

Q3 How many years have you lived in Blacksburg?

- ○ 1 year or less
- ○ 2
- ○ 3
- ○ 4
- ○ 5 or more years

Display This Question:

If Are you a Virginia Tech student? = Yes

Q4 Where are you originally from?

- Northern Virginia, Richmond area, or Hampton Roads
- Other regions of Virginia
- Other parts of the US - Urban/Suburban areas
- Other parts of the US - Rural/Exurban areas
- International

Display This Question:

If Are you a Virginia Tech student? = Yes

Q5 Where do you live?

- On-campus
- Oak Lane
- Off-campus in Blacksburg
- Off-campus outside of Blacksburg

Skip To: Q7 If Where do you live? = On-campus

Skip To: Q7 If Where do you live? = Oak Lane

Skip To: Q7 If Where do you live? = Off-campus outside of Blacksburg

Q6 Do you live close to a Blacksburg Transit stop?

- Yes
- No

Q7 What is your age?

- 0-19 years
- 20-29 years
- 30-44 years
- 45-54 years
- 55-64 years
- 65-74 years
- 75-84 years
- 85+ years

Q8 Do you have any conditions that puts you at higher risk for complications with COVID-19 as defined by the CDC? These can include asthma, liver disease, diabetes, lung disease, kidney disease being treated with dialysis, serious heart conditions, immunocompromised, hemoglobin disorders, severe obesity.

- Yes
- No

Skip To: Q10 If Do you have any conditions that puts you at higher risk for complications with COVID-19 as define... = No

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Display This Question:

If Do you have any conditions that puts you at higher risk for complications with COVID-19 as define... = Yes

Q9 During the COVID-19 pandemic and as we emerge from it, do you think you are more cautious when making transportation commuting decisions because of these existing conditions?

- ○ Yes
- ○ No
- ○ Sometimes, when ____

Q10 Before the COVID-19 pandemic, on a given week day, what was your commuting or primary trip?

- ○ Commuting to/from work in Blacksburg (off campus)
- ○ Going to/from the Virginia Tech campus
- ○ Other ____

Q11 What was your primary mode of transportation before the COVID-19 pandemic?

- ○ Personal Automobile/Motorcycle
- ○ Bike
- ○ Walk
- ○ Public Transit (bus)
- ○ Micromobility (E-Scooters, E-bikes, or E-skateboards)
- ○ Other ____

Q12 On average, how long is your daily commute?

For example:
The Edge to Burruss - 0.70 miles
The Cellar to Lane Stadium - 0.90 miles
Foxridge to Perry St Garage- 2.1 miles
Terrace View to Cookout - 2.8 miles

- ○ 0-0.25 miles
- ○ 0.26-0.75 miles
- ○ 0.76-1.5 miles
- ○ 1.6-3 miles
- ○ 3+ miles

Display This Question:

If What was your primary mode of transportation before the COVID-19 pandemic? = Bike

Or What was your primary mode of transportation before the COVID-19 pandemic? = Walk

Or What was your primary mode of transportation before the COVID-19 pandemic? = Micromobility (E-Scooters, E-bikes, or E-skateboards)

Q13 Does inclement weather affect how you commute? Select all weather conditions that apply.

- ▢ Yes, Rain
- ▢ Yes, Snow
- ▢ Yes, Cold Temperature
- ▢ Yes, Hot Temperature
- ▢ Yes, Wind
- ▢ No

Display This Question:

If Does inclement weather affect how you commute? Select all weather conditions that apply. != No

And If

What was your primary mode of transportation before the COVID-19 pandemic? = Walk

Or What was your primary mode of transportation before the COVID-19 pandemic? = Bike

Or What was your primary mode of transportation before the COVID-19 pandemic? = Micromobility (E-Scooters, E-bikes, or E-skateboards)

Q14 What other mode would you choose during the inclement weather?

- ◯ Personal Automobile
- ◯ Public Transit (bus)
- ◯ Other ____

Q15 How does the current public health crisis, COVID-19, affect your attitude towards using public transit?

- ◯ I would use public transit regardless of the health crisis
- ◯ I would only use public transit if I was confident that strategic physical distancing and cleaning measures had been taken
- ◯ I would not feel comfortable using public transit

Q16 How does the current public health crisis, COVID-19, affect your attitude towards using shared micromobility (shared E-scooters, shared bikes)?

- ◯ I would use shared micromobility regardless of the health crisis
- ◯ I would only use shared micromobility if I was confident that strategic physical distancing and cleaning measures had been taken
- ◯ I would not feel comfortable using shared micromobility

Q17 In light of the COVID-19 pandemic, if your only option was shared mobility which mode would you feel more comfortable using when returning to Blacksburg for the Fall 2020 semester.

- ○ Public Transit (Bus)
- ○ Micromobility (E-scooter, E-bike, E-skateboard)
- ○ Neither, I would rather take another mode or not take the trip

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Q18 In the future, if there was a second or third wave outbreak of COVID-19 that occurred in Blacksburg, what shared mobility mode would you feel comfortable taking for your daily commute?

- ○ Public Transit (Bus)
- ○ Micromobility (E-scooter, E-bike, E-skateboard)
- ○ Either
- ○ Neither, I would rather take another mode or not take the trip

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Q19 Rank the factors that you would consider most important when deciding what mode of transportation to take during this public health crisis? 1 is most important to you, 8 is least important.

Click and drag each factor to rerank to your preference.
______ Cleanliness (disinfection)
______ Physical distance between riders
______ Fresh or clean air
______ How long it takes
______ Lowest cost
______ Most convenient
______ ADA compliant accessibility
______ Other

Q20 Without a treatment or vaccine for COVID-19, at what percent of total capacity would you feel comfortable taking the bus?

- ○ 0-25% of the total capacity
- ○ 26-50% of the total capacity
- ○ 51-75% of the total capacity
- ○ 76-100% of the total capacity
- ○ I would not feel comfortable taking public transit.

Q21 During the pandemic, would you feel more comfortable taking shared micromobility (E-scooters, E-bikes) for a shorter duration trip rather than for a longer duration trip?

- ○ Yes, I would take shared micromobility for a trip that takes 10 minutes or less
- ○ No, I would not take shared micromobility for any amount of time
- ○ I would feel comfortable taking shared micromobility no matter the duration

Q22 What measure(s) could mobility agencies take to help make you feel more comfortable with taking public transit during and following the COVID-19 pandemic?

For example, would supplying disinfecting wipes, so that you could wipe down your seat or handle bars make you feel more comfortable with taking that mode of transportation?

Q23 What measure(s) could mobility agencies take to help make you feel more comfortable with taking shared micromobility during and following the COVID-19 pandemic?

For example, would supplying disinfecting wipes, so that you could wipe down your seat or handle bars make you feel more comfortable with taking that mode of transportation?

Q24 Please enter your Email address if you would like to be entered into a raffle to win a $25 Amazon gift card. If not, please click next to end the survey.