Enhancing Delivery of Operations by Optimizing the Omni-Channel Supply Chain through Delivery as a Service

Marcella Kaplan

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

Kevin Heaslip, Chair
Bryan Katz, Co-Chair
Susan Hotle

April 22, 2021
Blacksburg, VA

Keywords:
Delivery, Delivery Model, Omni-Channel, COVID-19

Enhancing Delivery of Operations by Optimizing the Omni-Channel Supply Chain through Delivery as a Service

Marcella Kaplan

ABSTRACT

The need for delivery grew significantly during the COVID-19 pandemic because people avoided activities in public to limit the spread of the virus. The purpose of this research was to evaluate how the pandemic influenced many individual's delivery preferences through the administration of a stated preference survey targeted at residents in the New River Valley, Virginia. Conclusions revealed from the survey show that people want more efficient and accessible delivery services. A new delivery ecosystem called Delivery as a Service (DaaS) was developed using the input from the survey, existing service-based models being widely implemented in many industries, and emerging technologies.

This thesis details a framework for DaaS derived by defining major actors, characteristics, and a method to measure the effectiveness of a DaaS system. This comprehensive definition of integrated delivery services illustrates areas for future research to further optimize the DaaS system. DaaS has the potential to significantly change the current delivery ecosystem through increased delivery accessibility and efficiency. Goods can be brought to users at a faster rate and on a larger scale. Autonomous vehicle and drone delivery technologies can significantly reduce the cost while correspondingly reducing the time of delivery. DaaS is a concept that is needed for people to thrive in modern times and brings the opportunity to provide added benefits to even rural areas.

Enhancing Delivery of Operations by Optimizing the Omni-Channel Supply Chain through Delivery as a Service

Marcella Kaplan

GENERAL AUDIENCE ABSTRACT

The need for delivery grew significantly during the COVID-19 pandemic because people avoided activities in public to limit the spread of the virus. The purpose of this research was to evaluate how the pandemic influenced many individual's delivery preferences through the administration of a stated preference survey targeted at residents in the New River Valley, Virginia. Conclusions revealed from the survey show that people want more efficient and accessible delivery services. A new delivery ecosystem called Delivery as a Service (DaaS) was developed using the input from the survey, existing service-based models being widely implemented in many industries, and emerging technologies.

This thesis details a framework for DaaS derived by defining major actors, characteristics, and a method to measure the effectiveness of a DaaS system. This comprehensive definition of integrated delivery services illustrates areas for future research to further optimize the DaaS system. DaaS has the potential to significantly change the current delivery ecosystem through increased delivery accessibility and efficiency. Goods can be brought to users at a faster rate and on a larger scale. Autonomous vehicle and drone delivery technologies can significantly reduce the cost while correspondingly reducing the time of delivery. DaaS is a concept that is needed for people to thrive in modern times and brings the opportunity to provide added benefits to even rural areas.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

Chapter 1: Introduction

1.1 Necessity for Research

The novel coronavirus (COVID-19) pandemic created an environment where nearly all aspects of mobility changed to adapt to the state of the world. The CDC recommended that people quarantine if they were potentially exposed to the virus, avoid close contact with others, and stay at home as much as possible (CDC, 2020). There was limited access to businesses because most schools closed, non-essential stores were closed, and non-essential businesses switched to working remotely. Those schools and businesses that remained open or re-opened during the pandemic implemented capacity constraints so that people could physically distance themselves. People sought to take fewer trips and opted to have more goods delivered to their homes, causing the multi-channel supply chain, such as food delivery from restaurants or goods delivery, to evolve. Delivery ensured people could get the supplies they needed without putting their health at risk by enabling medication and Personal Protective Equipment (PPE) distribution.

The changing landscape of delivery services resulting from the COVID-19 pandemic and technology advancements lead to a new delivery ecosystem framework: Delivery as a Service (DaaS). This research focuses on developing a new customer-centric delivery framework to mitigate the frustrations that individuals experience with delivery. This study will fill a void by clearly defining people's delivery frustrations and how the COVID-19 pandemic changed their delivery preferences to allow delivery agencies to improve current practices. The expectation is that this model will serve as the basis for implementing service-based delivery models within existing supply chains.

1.2 Research Questions

This research seeks to determine: *1) What delivery characteristics do customers value?; and 2) How can these characteristics be used to define DaaS Measures of Effectiveness (MOEs) and a DaaS framework that also enhances the omni-channel supply chain?* The ability to understand customer's perceptions of delivery services will provide the means to answer these questions. Several research hypotheses that support the research questions were constructed to develop a stated preference survey that investigated which delivery characteristics customers value. Understanding similar service-based ecosystems such as Mobility as a Service (MaaS) and the current supply chain can further answer these research questions. Forming a comprehensive understanding of what the customer wants and what the delivery supply chain can provide will lead to developing a DaaS ecosystem.

1.3 Research Problem and General Approach

Existing delivery options are creating a considerable number of frustrations for customers and are not meeting demand. DaaS is a term that currently does not exist; however, some components are seen in current delivery models. One example of a delivery platform similar to DaaS are third-party restaurant delivery apps because they provide on-demand user-centric service. However, this is only a small subset of the still unknown potential DaaS holds. Emerging autonomous and drone transportation technologies are only just beginning to take shape and are deficient in large-scale implementation. Much like the mobility ecosystem before MaaS was introduced, it is unknown how DaaS will interact with the existing delivery ecosystem. Therefore, there is a lack of knowledge of the extent of DaaS applications.

To develop a robust definition of DaaS, each component in the ecosystem and its potential to make DaaS successful were evaluated by a stated preference survey and applying similar characteristics from other service-based systems, such as MaaS. The survey aimed to assess the perceived service quality of delivery services offered in the New River Valley (NRV), Virginia. The survey results were then used to determine necessary factors that should be included in a DaaS framework to meet user expectations. A significant element of delivery is the method of transportation used to bring an item to the consumer, and DaaS ultimately seeks to amplify this factor within the omni-channel supply chain to produce a better service.

1.4 Research Objective

The purpose of this study is to conduct a stated preference survey to craft a comprehensive definition of DaaS that includes characteristics, MOEs, and a DaaS framework. DaaS provides a framework that can be easily integrated into the omni-channel supply chain. Emerging technologies hold the potential to further enhance DaaS and the omni-channel supply chain overall. MOEs are defined using conclusions made from the stated preference survey to evaluate a DaaS ecosystem's success. By developing an understanding of DaaS and how it could look in the future, potential opportunities can be acknowledged, and challenges can be addressed in advance.

1.5 Anticipated Contributions

The survey conducted and the DaaS framework defined in this research each provides several contributions to the delivery industry. This study showed an individual's true perception of delivery services offered in the NRV. The survey developed a method for measuring customer perception of delivery services that could be replicated to evaluate other delivery services, including future DaaS models. Surveying customer perception of their service can show delivery agencies where their products excel or may need improvement. Current opinions about delivery services are essential to consider when improving an existing model or developing a new system.

The framework for DaaS implementation developed in this research can help visualize the future of the delivery industry. This study provides insights that allow agencies to plan and be prepared for future innovations in delivery. The DaaS framework can incorporate various delivery services and be integrated into the existing delivery supply chain. DaaS is a delivery model that can constantly be expanded and built upon to accommodate future innovations and growth.

1.6 Document Organization

The succeeding chapters of this report are organized as follows. Chapter 2 reviews the literature on how changing delivery and mobility models, technologies, and the omni-channel supply chain supported DaaS concept development. Chapter 3 explains the methodology for conducting a stated preference survey to develop the DaaS framework. A thorough analysis of and conclusions from the survey are detailed in Chapter 4. DaaS is defined, including characteristics, a framework, and integration in the omni-channel supply chain, in Chapter 5. The paper is concluded in Chapter 6 by outlining the significant concepts and providing suggestions for future research.

Chapter 2: Review of Literature

2.1 Introduction

The purpose of this literature review is to discuss relevant research about topics that influence delivery services. This research details how factors described in this literature review, such as emerging technologies and existing delivery models and supply chains, can be merged to enhance delivery by promoting the integration of a DaaS framework. To provide a complete understanding of how DaaS was developed, five aspects that shape the proposed framework and characteristics of DaaS are described. The notion of integrating delivery services stems from delivery's expansion during the COVID-19 pandemic is first discussed. Second, it is described how the Mobility as a Service (MaaS) concept, existing delivery business models, supply chains, as well as current and evolving delivery technologies create a base for the DaaS framework. More specifically, this chapter will examine how current delivery services can be measured using a customer perception survey and how DaaS can be integrated into the omni-channel supply chain.

2.2 Overview of How the COVID-19 Pandemic Accelerated Delivery

During the COVID-19 pandemic, people were encouraged to stay home as much as possible and only go out for essential travel, driving the consumer's desire to have goods delivered. Delivery services such as Amazon Prime experienced shipping delays from supply chain and logistics issues due to the high demand as well as other impacts of the COVID-19 pandemic, such as worker shortages (*Amazon Prime Delivery Experiencing Big Delays Due to COVID-19*, 2020). Preferences for grocery shopping were directly affected by the number of COVID-19 cases in an area, which caused demand for grocery delivery to increase in places with a high number of cases (Grashuis et al., 2020). The increase in demand made delivery workers more essential than ever in bringing food, medication, and other goods to people who either could not or would not go out to purchase said items (Freytas-Tamura & Singer, 2020).

The need for essential workers in the delivery industry was shown by INRIX Research, which used INRIX Trip Analytics to analyze national, regional, and state freight movement before and during the COVID-19 pandemic. INRIX found that while personal travel decreased by an average of 46 percent across the United States, freight movement only decreased by 13 percent on average. Some states saw a higher shift, such as a 20 percent decrease in Texas, likely due to manufacturing and oil production reductions. On the opposite end, the Western region (including Alaska, Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, and Wyoming) had only seen a six percent decrease in freight movement (Pishue, 2020).

Though there was some variation in regional and state freight movement decreases, a 13 percent average decrease shows there was still a significant need for goods movement across the country (Pishue, 2020). The freight movement reductions could likely be explained by a decrease in oil demand and the closure of storefronts and sit-down restaurants. However, the freight decreases were probably not as dramatic as personal travel decreases because there was a higher demand for delivery. Consumers still needed the goods that stores could not provide, so they ordered them online, which kept the freight industry operating closer to typical rates than personal travel.

Aside from traffic changes, consumer shopping preferences (in-person versus online) shifted in support of the notion that delivery service demand increased due to the COVID-19

pandemic. A more specific example is that online grocery delivery and pickup shopping continuously increased each month since the start of the pandemic (Table 1), according to the Brick Meets Click/Mercatus Grocery Shopping Survey. Online grocery delivery and pickup grew significantly not only from August 2019 but throughout the pandemic as well (*June 2020 Online Grocery Scorecard,* 2020). The increase in grocery delivery services was correlated to the pandemic and people's desire to remain home.

Table 1: Brick Meets Click/Mercatus Grocery Shopping Survey Results, adapted from *June 2020 Online Grocery Scorecard,* 2020

Performance Metrics[1, 2]	**August 2019**	**March 2020**	**April 2020**	**May 2020**	**June 2020**
Sales (Past 30 days)	$1.2 Billion	$4.0 Billion	$5.3 Billion	$6.6 Billion	$7.2 Billion
Spend (Average per order)	$72	$85	$85	$90	$84
Orders (# Past 30 days)	16.1 Million	46.9 Million	62.5 Million	73.5 Million	85.0 Million
Customers (# Active during past 30 days)	16.1 Million	39.5 Million	40.0 Million	43.0 Million	45.6 Million
Frequency (Monthly average/customer)	1.0	1.2	1.6	1.7	1.9

[1]Total past 30-day activity in the United States
[2]Excludes online orders shipped to home via common or contract parcel carriers

The COVID-19 pandemic also presented a greater drive to bring successful autonomous and drone delivery solutions to the market. Deployment of these innovative technologies made safer and contactless delivery possible in rural and urban locations worldwide and reduced risk posed to delivery workers (Ackerman, 2020; Bogaisky, 2020; Szymkowski, 2020a, 2020b). When storefronts were forced to close, restaurant delivery provided by third-party apps allowed restaurants to continue earning revenue.

The COVID-19 pandemic created an even greater desire for delivery than ever before and forced advancements within delivery technology. According to Cohen and Jones, advances in transportation technology have moved along relatively smoothly with three fundamental shifts: connectedness, ubiquitous sensing, and artificial intelligence (AI). However, if transportation technology were to progress at a "jerkier" rate, then the impacts would be implicated or heightened in the results. Cohen and Jones then describe that managing change properly is imperative for transportation planning (Cohen & Jones, 2020).

Cohen and Jones' theory can be seen in how delivery companies were forced to adapt to provide increased delivery demand due to the COVID-19 pandemic rapidly. In March 2020, everyone suddenly had to stay at home and wanted to order as many items as possible to avoid going out to stores. The pandemic presented an environment where the transportation and delivery industries were forced to progress at a "jerkier" rate to accommodate the unexpected change in consumer behavior. As a result, a more service-based delivery model is becoming more prevalent.

2.3 Mobility as a Service Metrics

Innovative transportation technologies are similarly impacting the mobility space to the delivery space. The mobility industry is growing and changing due to various implications, including continuously increasing demand on existing transportation systems and consumers' desire for easily accessible and convenient transportation services (Kamargianni et al., 2016; Li

et al., 2019). As innovations are introduced within the mobility space, the complexity of using these new transportation choices often deters people (Kamargianni et al., 2016). However, new technologies and innovations are stirring consumers' desire for mobility services that better meet their individual needs. As a result of this shift in demand for innovative mobility technologies, a new mobility business model emerged to provide customer-centric mobility, called Mobility as a Service (MaaS) (Li et al., 2019).

More specifically, the MaaS Alliance defined MaaS as "the integration of various forms of transport services into a single mobility service accessible on-demand," (*What Is MaaS?*, 2020). In a MaaS scheme, a single app will provide a user with access to different forms of mobility within an area (such as a city). A MaaS app gives the user access to a suite of transport options such as subway, bus, bike-sharing, ridesharing, and car rental, allowing them to pay for these transport options through a single channel. MaaS simplifies planning and taking a trip for the user by providing a seamless, value-added service in a single tool (Kamargianni & Matyas, 2017; *What Is MaaS?*, 2020).

Currently, for transportation, users have to use different tools and payment methods for various transport forms. Also, there is a lack of planning platforms for and information about intermodal trips. The benefit of MaaS is that it removes these "pain points" by providing a user-centric platform. Another attribute is that a MaaS platform is based on a model where several different transport options are essentially distributed by a single MaaS provider, which restructures the entire mobility supply based on user demand. Technology is at the core of MaaS and provides a digital platform that can influence mobility decisions (Jittrapirom et al., 2017; Kamargianni & Matyas, 2017). Key characteristics of MaaS are: (Jittrapirom et al., 2017)

1. Integration of transport modes into a single platform
2. Payment options
3. One platform with several mobility options
4. Multiple actors
5. Enabled by technology
6. Focused on user demand
7. Requires the user to register on the platform
8. Personalization tailored to the user
9. User can customize service options

The above characteristics were comprehensive in designing a MaaS framework from a qualitative perspective. However, a limiting factor is the lack of metrics to evaluate the effectiveness of MaaS implementation. There is a need for a quantitative system of measurement that can be used to assess a MaaS scheme.

2.4 Evolving Delivery Models and Supply Chains

As e-commerce increasingly becomes the primary mode for shopping (whether it be for goods, grocery, or restaurant delivery), a company's delivery models and the overall supply chain must adjust to accommodate the transition. Delivery models are evolving to incorporate emerging technologies and meet consumer preferences, similarly to how mobility service models are shifting. MaaS models provide a foundation reference for the DaaS framework and characteristics.

Companies are changing their delivery models to provide a more customer-centric service and are shifting towards service-based delivery. Amazon, for example, evolved the

conventional delivery model into a flat-rate subscription delivery model (Morganti et al., 2014). Amazon provides a unique delivery model because users who subscribe to gain services like faster shipping and grocery delivery (*Amazon.Com: Amazon Prime*, 2020).

Third-party meal delivery companies developed a delivery model that is becoming more popular because users can order from a greater variety of restaurants through a single, convenient platform. Hirschberg et al. (2016) proposed a delivery model for third-party meal delivery apps where there are three main components: the restaurant, customer (or user), and deliverer. The utilization of third-party delivery apps provides greater revenue, new customers, free marketing provided by the platform, and a new logistics network for the restaurant. However, a drawback is the lack of ability to control the customer experience. The main benefits to the customer are convenience and choice. The deliverer finds the opportunity to own the customer experience now as long as it can overcome the initial investment struggle (Hirschberg et al., 2016).

E-grocery delivery models are unique because the model must account for perishable goods and time sensitivity. The e-grocery delivery model includes: new actors, new relations between those actors, and added supply methods. The main new actors that come into play are producers, wholesalers, and logistics service providers. E-grocery introduces a delivery method where goods are moved from the producer to the consumer (Saskia et al., 2016).

2.4.1 Shift from Multi-Channel to Omni-Channel Supply Chain

Evolving delivery models create a need to transition to a supply chain model that can supply the high level of service that a customer-centric delivery model requires. The desire for faster delivery (hours vs. days) due to a rise in e-commerce has led to several logistics and supply chain changes, such as delivery time and storage (Saskia et al., 2016).

A multi-channel supply chain's main characteristic is that physical and online retailers are divided (Piotrowicz & Cuthbertson, 2014). In a multi-channel supply chain (Figure 1), there are separate distribution channels and possibly dedicated warehouses or stores for traditional retail versus online orders. Orders can either be fulfilled from the closest store to the customer or dynamically. Decisions can be made dynamically via real-time supply chain information and decision models, which work together to determine which online sale will be fulfilled by which logistics facility (Melacini et al., 2018).

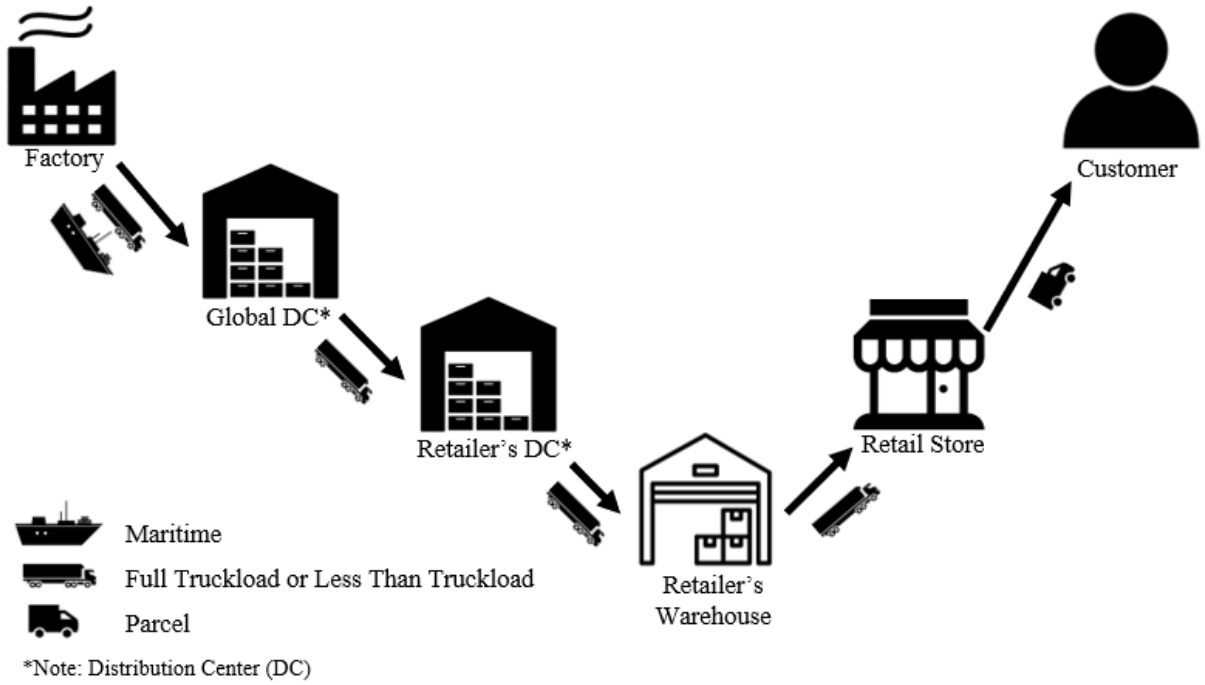


Figure 1: Multi-Channel Supply Chain, adapted from Horvath (2020)

Dynamic fulfillment technology has created a shift towards the omni-channel supply chain model as e-commerce becomes more common and customers become more demanding (Melacini et al., 2018; Mosquera et al., 2017). To move to the omni-channel supply chain (Figure 2), retailers can use existing infrastructure to integrate return channels as well as both traditional and online order and distribution channels. Real-time technology facilitates the merge between channels by providing a way to track supply from different order channels and distribute (or collect returns) via the same integrated channels (Melacini et al., 2018).

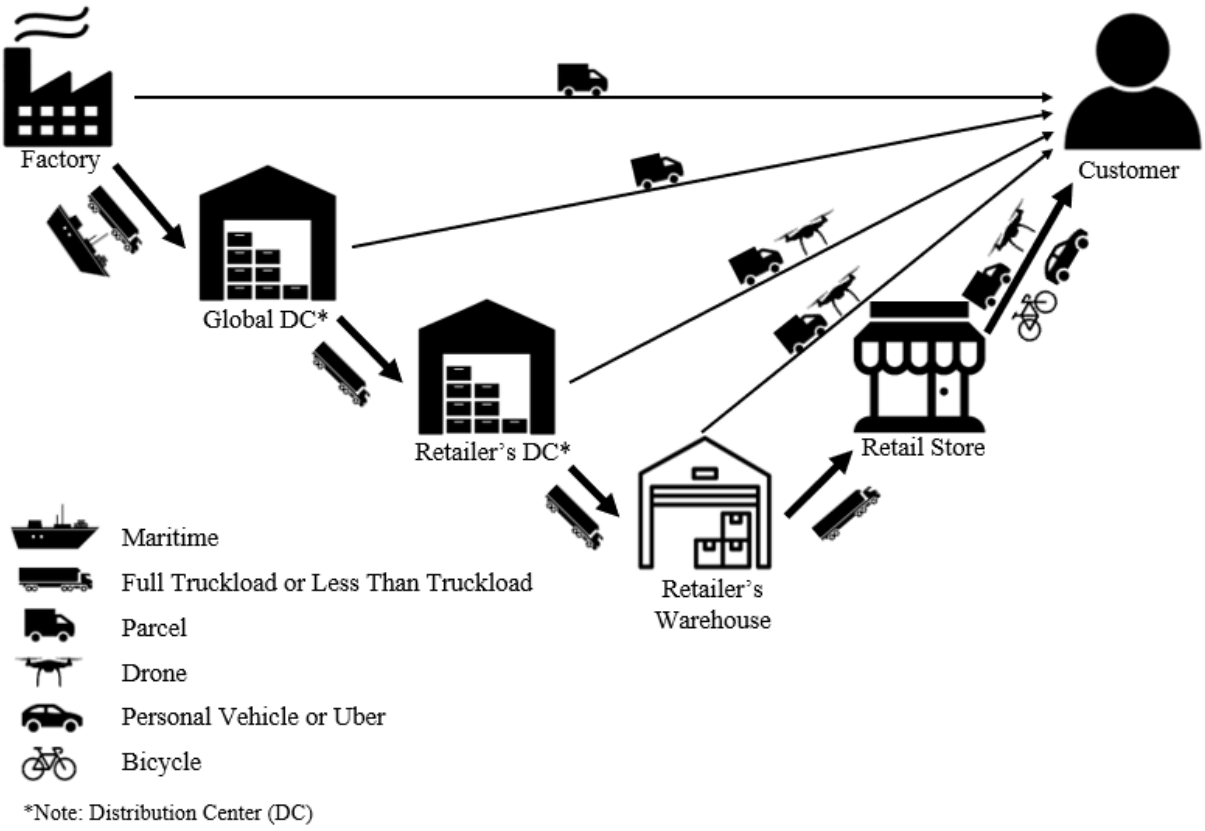


Figure 2: Omni-Channel Supply Chain adapted from Horvath (2020)

Customers desire the ability to seamlessly move between channels, fast delivery, and innovative delivery options. Retailers seek to meet customer demand and improve accessibility by providing new cost-efficient delivery methods that maintain or improve the current level of service, such as using shipping optimization to reduce shipping cost and time. Real-time information in the omni-channel supply chain provides the means to reduce costs and improve the e-fulfillment process's efficiency (Fairchild, 2014; Melacini et al., 2018).

Growing customer expectations are a significant driver behind the desire for producers to provide an integrated shopping experience. However, an overall seamless channel integration experience is challenging for retailers to deliver, even though it is a large component of the omni-channel supply chain concept (Piotrowicz & Cuthbertson, 2014). The DaaS business model offers a means to provide a seamless customer experience by integrating with the omni-channel supply chain.

2.5 Technologies that Enable Delivery

Similar to MaaS, DaaS is enabled through technology integration. Any technologies that enhance delivery could be applicable, but the most notable improve the user's experience and accessibility or enhance delivery efficiency. The following emerging technologies are not an exhaustive list but describe the most disruptive technologies that could facilitate faster, safer, and more cost-effective delivery services.

2.5.1 Third-Party Delivery Apps

Today, there is a new evolution of delivery services that include Uber Eats, DoorDash, and other third-party delivery companies. These new services allow the user to order from several different restaurants through one app. App and online food delivery industry growth rates have improved as more and more people desire food delivery convenience since it allows the user to save time and effort (Singh, 2019; Yeo et al., 2017). Current trends show that first, convenience is key, and second, users are interested in trying new concepts and platforms (Fromm, 2019).

2.5.2 Road Autonomous Delivery Robots

Road Autonomous Delivery Robots (RADR) are not limited by human factors such as fatigue and can enable new 24-hour operations delivery models. RADR can significantly reduce costs for small package deliveries and likely increase vehicle miles traveled (VMT) from current delivery models. Higher VMT could lead to a significant increase in congestion, especially in large deployments. RADR can also have difficulties in challenging navigation situations. Another drawback is that RADR have limited storage space and a limited driving range, so they are only ideal for short-distance deliveries. As consumers' demand for faster delivery increases, RADR may be a solution to satisfy that demand (Jennings & Figliozzi, 2020). One proposed solution to the mentioned issues for RADR is to have RADR deliver to pick-up stations located throughout neighborhoods. This solution ideally applies to same-day delivery scenarios (Ulmer & Streng, 2019).

Nuro is an autonomous delivery company that is testing its vehicles on public roads in Texas, Arizona, and California (*Nuro R2 Autonomous Delivery Vehicle Gets Green Light*, 2020). The Nuro R2 vehicle is specifically designed for autonomous grocery delivery and does not have any seating or driving controls. The COVID-19 pandemic "has 'expedited the public need for contactless delivery services,'" and Nuro is helping by delivering groceries and supplies to those in need (Szymkowski, 2020a). Contactless delivery is quickly becoming an essential service around the world. Nuro proposes that in the future, their vehicle will provide more than just grocery delivery: their vehicles will be able to handle any errand, such as dry cleaning (*Nuro — Product*, 2020).

Pony.ai is an autonomous driving and mobility service that is backed by Toyota and has been testing its Robotaxi service in pilots in Guangzhou, China, and California (*Pony.Ai Raises $400 Million from Toyota to Accelerate Autonomous Driving Development*, 2020). Pony.ai has shifted its services in Irvine, California, during the COVID-19 pandemic to deliver essential goods and groceries. Since the service is fully autonomous, there is no need for human interaction, and therefore delivery personnel will not be put at risk. Pony.ai will add delivery capacity to Irvine's system and be completely contactless (Szymkowski, 2020b).

2.5.3 Sidewalk Autonomous Delivery Robots

Research conducted on the benefits of Sidewalk Autonomous Delivery Robots (SADR), accompanied by vans, found that delivery time and cost are reduced. Miles traveled on roads by delivery vans and trucks are also reduced when using SADR. A drawback of SADR is their need to travel on sidewalks and occasionally on the road and the congestion and safety issues that could arise on sidewalks (Jennings & Figliozzi, 2019).

2.5.4 Drone Delivery

Like autonomous delivery, drone delivery is penetrating the delivery services market faster than ever before, especially since most online orders, for example, 86% of Amazon orders, weigh less than 5 pounds (Guglielmo, 2013). The use of drones for delivery services is still a new concept that is being researched and tested. Some well-known research is vehicle routing problems for drone delivery (Dorling et al., 2017), joint ground and aerial delivery service optimization and planning framework (Sawadsitang et al., 2019), and a solution to the last-mile problem in urban settings that includes autonomous drone delivery to balconies (Brunner et al., 2019).

While drone delivery technology is still mainly in the research and testing phases, several companies provide drone delivery services for specific items. Wing is a drone delivery company created by Google operating in Australia, Finland, and the United States. In the United States, Wing is delivering items under three pounds from FedEx, Walgreens, and a local merchant called Sugar Magnolia to residents in Christiansburg, Virginia (*Wing*, 2020). Drone delivery is another DaaS platform that makes the delivery of various goods convenient and straightforward for the user. Demand for delivery from Wing increased significantly during the COVID-19 pandemic, with some popular items being toilet paper and coffee. Wing helped the retailers and restaurants partnered with to earn revenue that they would not otherwise have been able to (Bogaisky, 2020).

Zipline is a company that has autonomous fixed-wing delivery drones that have been used to deliver blood to hospitals and clinics. Zipline has operated in Rwanda, Ghana, and India and is working towards expanding into the United States. "Zipline is acting as a centralized distribution network for COVID-19 supplies in Ghana and Rwanda" by delivering necessary items such as PPE in addition to its current blood and medication deliveries (Ackerman, 2020). In the past, Zipline has only dropped supplies off at specific points, but they have been looking into providing neighborhood drop-off points. COVID-19 may accelerate the process since contactless delivery was best during the pandemic (Ackerman, 2020).

2.6 An Omni-Channel PZB Model to Measure Perceived Service Quality

Since DaaS is a user-centric model, the quality of service must be evaluated to determine if the model is effective. Though there are a limited number of customer service-based models in the literature, the Parasuraman, Zeithaml, and Berry (PZB) model appears to be the most widely used model (Parasuraman et al., 1985, 1988).

Parasuraman et al. (1985) first proposed ten service quality determinants that could be used to establish the perceived service quality: access, communication, competence, courtesy, credibility, reliability, responsiveness, security, tangibles, and understanding/knowing the customer. The 10 item PZB model was then further refined when Parasuraman et al. (1988) proposed a service quality measurement scale that included 22 items and five dimensions:

1. Tangibles: "Physical facilities, equipment, and appearance of personnel."
2. Reliability: "Ability to perform the promised service dependably and accurately."
3. Responsiveness: "Willingness to help customers and provide prompt service."
4. Assurance: "Knowledge and courtesy of employees and their ability to inspire trust and confidence."
5. Empathy: "Caring, individualized attention the firm provides its customers."

The above measurement scale was refined by Shi et al. (2020) to represent customer experience more accurately in the omni-channel supply chain. Shi et al. (2020) conducted interviews and focus groups to determine which factors influence the omni-channel experience and consequently defined five omni-channel experience dimensions (Table 2).

Table 2: Omni-Channel Experience Dimensions, adapted from Shi et al. (2020)

Dimension	Definition
1. Connectivity	"The extent to which the cross-channel service content and information are linked and interconnected."
2. Integration	"The extent to which customer perceives all information systems and management operations are unified and integrated well across channels."
3. Consistency	"The extent to which customers experience both content and process consistency of interactions across channels."
4. Flexibility	"The extent to which customers are provided with flexible options and experience the continuity when migrating tasks from one channel to another channel."
5. Personalization	"The extent to which a customer perceives that the omnichannel retailer provides its customers with individualized attention."

The above five dimensions were then grouped into two perceived innovation characteristics: perceived compatibility and perceived risk. Perceived compatibility is when customers perceive experiences in the shopping process to be enhanced and includes connectivity, integration, and consistency. Perceived risk includes consistency, flexibility, and personalization and is when there are uncertainty and unease. A 22-item 7-point Likert scale survey was then conducted to analyze omni-channel shopping intention (Shi et al., 2020). Fairchild (2014) developed a similar survey to evaluate the omni-channel supply chain from the customer's perspective.

Since the DaaS framework directly integrates with the omni-channel supply chain, a DaaS model's characteristics can be expected to directly influence Shi et al.'s (2020) five omni-channel experience dimensions. A successful DaaS model should improve each omni-channel experience dimension. Therefore, a survey about customer's perceived service quality of delivery services can be used to determine a DaaS business model's success. The survey conducted to validate the proposed theoretical framework in this paper is primarily influenced by the PZB model and the work of Shi et al. (2020).

2.7 Conclusion

The major conclusions from the literature review are:

- The COVID-19 pandemic created a greater need for service-based delivery models and accelerated innovations of touchless delivery technology.
- Delivery models are evolving in a parallel manner to how mobility models developed to incorporate MaaS.
- Delivery models and supply chains are advancing towards a DaaS framework as companies look to provide a more customer-centric service.
- The DaaS business model offers a means to provide a seamless customer experience by integrating with the omni-channel supply chain.
- Several technologies are emerging in the delivery space that could facilitate more accessible and efficient delivery services such as DaaS.

- A customer perception survey about delivery services can be used to determine the customer's perceived service quality of a DaaS business model.

These conclusions were used to develop the survey described in Chapter 3 and analyzed in Chapter 4. The survey evaluates delivery preferences in the NRV and how the COVID-19 pandemic changed people's delivery habits. Chapter 5 details a comprehensive definition of DaaS and how it can integrate into and enhance the omni-channel supply chain. DaaS is derived from the knowledge of MaaS, delivery supply chains, and emerging technologies outlined in this literature review and the conclusions made from the survey.

Chapter 3: Research Methodology

3.1 Introduction

The purpose of this chapter is to detail the methodology used to develop the survey, collect data, and analyze the results. More specifically, the survey platform used, how the needed sample size was determined, and how the survey was distributed are communicated, and the statistical and partitioning methods used for analysis are explained. An overarching research question and 56 hypotheses investigating the research question are detailed to guide the methods for analyzing the survey results. The research question will ultimately decide what customer's perceptions of current delivery services are and how those factors work together to create DaaS.

3.2 A Survey of Customer's Current Perceptions of Delivery Services

The purpose of a DaaS model is to provide improved service. Still, because DaaS does not yet exist, it is essential to determine what characteristics of existing delivery services are most important to customers. Developing an understanding of customer's current delivery perceptions will highlight what aspects of current delivery services could be changed or improved. Notably, DaaS would be implemented within the omni-channel supply chain, not as a stand-alone service. Evaluating what customers look for in a delivery service can also improve the overall supply chain.

3.2.1 About the Survey

The literature described that it could be challenging to measure customer's perception of a service accurately and explained that a survey about customer perception could obtain the most accurate results (Parasuraman et al., 1985, 1988). Therefore, a survey was developed to capture customer perception of current delivery services in the New River Valley (NRV), Virginia. The survey included 38 questions total and divided those questions into two parts: demographic and delivery questions. The survey included 12 demographic questions to aid in data analysis but kept the respondent's identities anonymous. There were 26 questions about delivery presented in various manners, including Likert scale, multiple-choice, and ranking questions. One question had an open-ended portion where respondents could describe their satisfaction level with delivery services in the NRV. The survey can be found in Appendix A. After the survey was developed, it was approved by the Virginia Tech Human Research Protection Program (HRPP) as not research involving human subjects as defined by U.S. Department of Health and Human Services (HHS) and Food and Drug Administration (FDA) regulations. The memo from HRPP is in Appendix B.

The survey was first developed and then tested by colleagues familiar with the survey's content and purpose. Testing allowed the survey to be refined to collect data that was adequately related to this study. Once the survey was complete, it was distributed to residents of the NRV. The survey was distributed after enough time had passed since the start of the pandemic (in March 2020) to ensure that people had adjusted to a "normal" pandemic daily routine. People had moved beyond the pandemic's initial panic and past the thought that the situation was temporary. Therefore, survey responses about the use of and opinions about delivery services pre-, during, and post-pandemic would likely be more accurate than if the survey were conducted in March 2020.

3.2.1.1 How the Survey was Developed

The first section of the survey was coded with demographic questions chosen based on the survey's purpose and could help categorize and analyze the data (Fink, 2002). Location was an essential factor in this survey because it is directly related to the respondent's delivery options. Therefore, two of the demographic questions asked about in which county, city, or town the respondent resided. The NRV was chosen as the survey's location to portray peoples' opinions of delivery services from different perspectives because there is a mix of urban and rural environments. The NRV includes Montgomery, Pulaski, Floyd, and Giles Counties and the independent city of Radford. Additionally, the large population of students who attend Virginia Tech and Radford within the NRV provides an additional perspective of delivery services.

The remainder of the survey was coded to include Likert scale questions, multiple-choice, open-ended, and ranking questions to best capture customer perception of delivery services in the NRV. The survey asked respondents questions about how they used delivery services pre-pandemic, used delivery services during the pandemic, and think they will use delivery services post-pandemic to analyze whether the COVID-19 pandemic changed how people use delivery services. Some questions asked whether the respondents were generally satisfied or unsatisfied with delivery services in the NRV and what specific factors individuals were most frustrated with when ordering food or package delivery. Respondents were also asked to rank the reasons why they choose to use delivery services. These survey questions were specifically developed to form an overall picture of why people use delivery and what people want in a delivery service.

3.2.1.2 Sample Size Determination

Equation 1 was used to determine the necessary sample size using a 90% confidence interval and a 5% margin of error (*Sample Size Calculator*, 2021). A z-score of 1.645 was used for a 90% confidence interval, and the likely sample proportion used was 50% since this value was unknown. As of 2019, the total population of the NRV was 182,147, which resulted in a needed sample size of 272 (*Census Profile*, 2021). The survey conducted for this research collected 304 useable responses overall, which resulted in a lower margin of error of 4.73%.

$$Sample\ size = \frac{\frac{z^2 p(1-p)}{e^2}}{1+\left(\frac{z^2 p(1-p)}{e^2 N}\right)} \qquad \text{Equation 1}$$

where:

N = population size
e = margin of error (percentage in decimal form)
z = z-score
p = likely sample proportion

3.2.1.3 The Survey Platform

Data was collected for this study anonymously using Qualtrics XM, a third-party online survey platform (*Qualtrics XM - Experience Management Software*, 2021). The Qualtrics XM platform provides simple formatting that is interactive and easy for respondents to understand. Sections of the survey (demographic and delivery questions) were divided into separate pages that respondents could access using forward arrows. The platform also made it possible to program an introduction page that explained the survey's purpose to respondents and required that respondents reside within the NRV (Figure 3). The survey was also programmed to require

respondents to answer every question to avoid incomplete responses. Additionally, the platform made it possible for an anonymous link to the survey to be provided to respondents. Qualtrics XM was the chosen platform for conducting the survey because it was provided to Virginia Tech faculty and students for free.

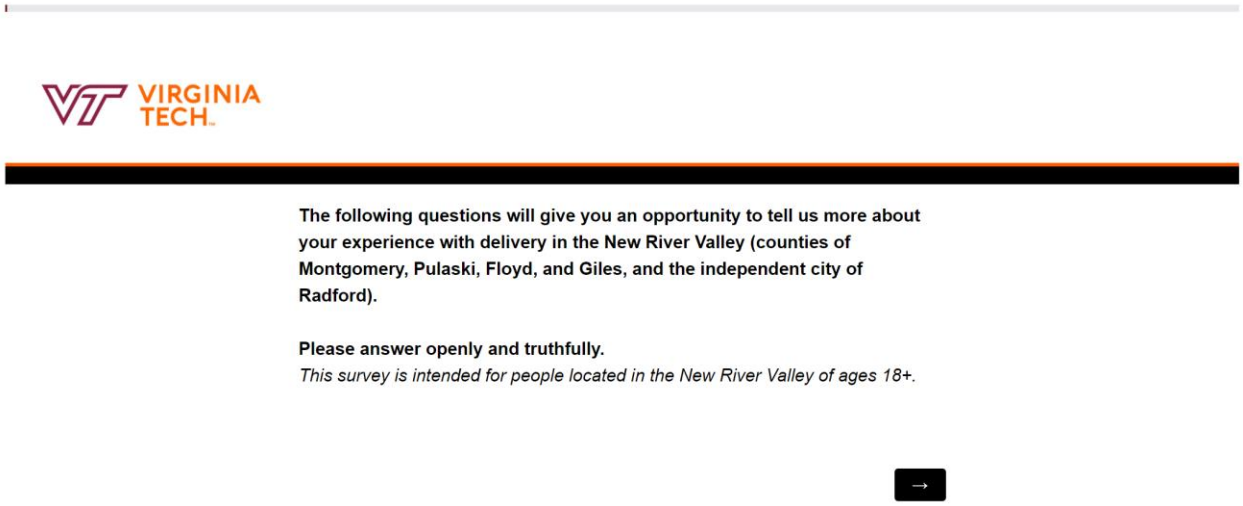


Figure 3: Qualtrics XM Delivery Survey Introduction Page

Qualtrics XM also included features for data analysis which were used to analyze the survey results because of its simplicity. The platform's analysis features were straightforward and intuitive. The Data feature was used to filter and clean the data to remove incomplete responses before generating Reports in Qualtrics XM to analyze the responses. The data could be visualized in different formats such as bar graphs and pie charts in the Reports feature. Data from different questions could also be compared using the breakout feature. The visualization and breakout features in Qualtrics XM were used to generate the figures used in this research. The survey data was also exported to Excel for further analysis in R, a programming language for statistical computing.

3.2.1.4 How the Survey was Distributed

The survey was primarily distributed via social media platforms and various Google listservs for Virginia Tech. The survey was posted to several different Facebook groups (Table 3) that targeted residents in the NRV. Each Facebook group was chosen because it had a following that primarily included residents in the NRV, and they had a large following. The selected Facebook groups provided the potential for the post about the survey to be viewed about 85,900 times. The groups also had consistent posts throughout the day as well as active and engaging users. A message included that encouraged participants to forward the survey to other people they know in the NRV to increase the number of survey participants. Four hundred five total responses were collected, and 304 responses were used for this analysis after the data was cleaned to remove incomplete responses.

Table 3: Facebook Group Members

Facebook Group	Membership (as of January 2021)
Everything Blacksburg	10,638
Everything Christiansburg	13,889
Everything Christiansburg Uncensored	3,602
Everything New River Valley	1,267
Pulaski: Talk of the Town	7,896
Everything Giles	1,212
Giles County Uncensored	83
We Are Radford	5,442
Floyd Group	8,877
Blacksburg Library, Montgomery-Floyd Regional Library, VA	2,054
Virginia Tech Class of 2021	6,541
Virginia Tech Class of 2022	7,847
Virginia Tech Class of 2023	8,139
Virginia Tech Class of 2024	3,145
Virginia Tech Class of 2024 (Official)	5,309
TOTAL	**85,941**

3.3 Survey Analysis

The survey data was statistically analyzed using descriptive and inferential statistics to evaluate overall customer perception of delivery preferences in the NRV. The hypotheses used to develop the survey questions and outline analysis methods detailed. The primary analysis methods included analyzing the response distributions of the data and conducting Mann-Whitney U-Tests. The analysis will be conducted based on these Hypotheses in Chapter 4, and the conclusions from the analysis will be discussed and applied to the DaaS framework in Chapter 5.

3.3.1 Survey Research Question and Hypotheses

The survey aims to evaluate customer's perceptions of delivery services to formulate which delivery characteristics customers value. DaaS is a customer-centric service that will be developed based on customer perception of delivery. The following research questions were established to guide the survey analysis:

> Research Questions: 1) What delivery characteristics do customers value?; and 2) How can these characteristics be used to define DaaS MOEs and a DaaS framework that also enhances the omni-channel supply chain?

Several research hypotheses were constructed regarding customer perception of delivery services in the NRV to investigate the above research questions. The survey was formed to collect data that would evaluate the validity of the following research hypotheses:

Location (L) and Delivery Frustrations Hypotheses:

L-1. People who live in more rural areas will not be frustrated more frequently with food delivery apps or websites being difficult to use than people who live in more urban areas.

L-2. People who live in more rural areas will be frustrated more frequently with food from food delivery being too cold or too warm than people who live in more urban areas.

L-3. People who live in more rural areas will be frustrated more frequently with food deliveries being late than people who live in more urban areas.

L-4. People who live in more rural areas will not be frustrated more frequently with food delivery items missing from their order than people who live in more urban areas.

L-5. People who live in more rural areas will not be frustrated more frequently with food delivery fees being too high than people who live in more urban areas.

L-6. People who live in more rural areas will not be frustrated more or less frequently with package delivery apps or websites being difficult to use than people who live in more urban areas.

L-7. People who live in more rural areas will not be frustrated more or less frequently with package delivery items being damaged or broken than people who live in more urban areas.

L-8. People who live in more rural areas will be frustrated more frequently with package deliveries being late than people who live in more urban areas.

L-9. People who live in more rural areas will not be frustrated more or less frequently with package delivery items missing from their order than people who live in more urban areas.

L-10. People who live in more rural areas will not be frustrated more or less frequently with food delivery fees being too high than people who live in more urban areas.

Vehicle Ownership (VO) and Delivery Frequency Hypotheses:

VO-1. Before the pandemic, people who do not have access to a personal vehicle will not order delivery from third-party restaurant delivery apps more frequently than people who do have access to a personal vehicle before.

VO-2. Before the pandemic, people who do not have access to a personal vehicle will not order grocery delivery more frequently than people who do have access to a personal vehicle before.

VO-3. Before the pandemic, people who do not have access to a personal vehicle will not order package delivery more frequently than people who do have access to a personal vehicle before.

VO-4. During the pandemic, people who do not have access to a personal vehicle will order delivery from third-party restaurant delivery apps more frequently than people who do have access to a personal vehicle before.

VO-5. During the pandemic, people who do not have access to a personal vehicle will order grocery delivery more frequently than people who do have access to a personal vehicle before.

VO-6. During the pandemic, people who do not have access to a personal vehicle will order package delivery more frequently than people who do have access to a personal vehicle before.

VO-7. After the pandemic, people who do not have access to a personal vehicle will order delivery from third-party restaurant delivery apps more frequently than people who do have access to a personal vehicle before.

VO-8. After the pandemic, people who do not have access to a personal vehicle will order grocery delivery more frequently than people who do have access to a personal vehicle before.

VO-9. After the pandemic, people who do not have access to a personal vehicle will order package delivery more frequently than people who do have access to a personal vehicle before.

Delivery Satisfaction (S) Hypotheses:

S-1. People who live in more rural areas will be less satisfied with delivery services than people who live in more urban areas.

S-2. Non-students will be less satisfied with delivery services than students.

Delivery Service Frequency of Use (F) Before, During, and After the Pandemic Hypotheses:

F-1. People will use third-party restaurant delivery apps less frequently before than during the pandemic.

F-2. People will use third-party restaurant delivery apps less frequently before than after the pandemic.

F-3. People will use third-party restaurant delivery apps equally frequently during than after the pandemic.

F-4. People will use grocery delivery less frequently before than during the pandemic.

F-5. People will use grocery delivery less frequently before than after the pandemic.

F-6. People will use grocery delivery equally frequently during than after the pandemic.

F-7. People will use package delivery less frequently before than during the pandemic.

F-8. People will use package delivery less frequently before than after the pandemic.

F-9. People will use package delivery equally frequently during than after the pandemic.

Types of Food Delivery Frustrations (FF) Hypotheses:

FF-1. When ordering food delivery, people are less frequently frustrated that the app or website was difficult to use than that the food was too cold or too warm.

FF-2. When ordering food delivery, people are less frequently frustrated that the app or website was difficult to use than that the delivery was late.

FF-3. When ordering food delivery, people are less frequently frustrated that the app or website was difficult to use than that items were missing from the order.

FF-4. When ordering food delivery, people are less frequently frustrated that the app or website was difficult to use than that the fees were too high.

FF-5. When ordering food delivery, people are less frequently frustrated that the food was too cold or too warm than that the delivery was late.

FF-6. When ordering food delivery, people are less frequently frustrated that the food was too cold or too warm than that items were missing from the order.

FF-7. When ordering food delivery, people are less frequently frustrated that the food was too cold or too warm than that the fees were too high.

FF-8. When ordering food delivery, people are more frequently frustrated that the delivery was late than that items were missing from the order.

FF-9. When ordering food delivery, people are less frequently frustrated that the delivery was late than that the fees were too high.

FF-10. When ordering food delivery, people are less frequently frustrated that items were missing from the order than that the fees were too high.

Food Delivery Preferences (P) Hypothesis:

P-1. More people will prefer to order food delivery from a third-party app than directly from a restaurant.

Types of Package Delivery Frustrations (PF) Hypotheses:

PF-1. When ordering package delivery, people are less frequently frustrated that the app or website was difficult to use than that an item was damaged or broken.

PF-2. When ordering package delivery, people are less frequently frustrated that the app or website was difficult to use than that the delivery was late.

PF-3. When ordering package delivery, people are less frequently frustrated that the app or website was difficult to use than that items were missing from the order.

PF-4. When ordering package delivery, people are less frequently frustrated that the app or website was difficult to use than that the fees were too high.

PF-5. When ordering package delivery, people are less frequently frustrated that an item was damaged or broken than that the delivery was late.

PF-6. When ordering package delivery, people are more frequently frustrated that an item was damaged or broken than that items were missing from the order.

PF-7. When ordering package delivery, people are less frequently frustrated that an item was damaged or broken than that the fees were too high.

PF-8. When ordering package delivery, people are more frequently frustrated that the delivery was late than that items were missing from the order.

PF-9. When ordering package delivery, people are more frequently frustrated that the delivery was late than that the fees were too high.

PF-10. When ordering package delivery, people are less frequently frustrated that items were missing from the order than that the fees were too high.

Differences and Similarities between Food and Package Delivery Frustrations (FPF) Hypotheses:

FPF-1. People are frustrated that the app or website was difficult to use more frequently for food delivery than package delivery.

FPF-2. People are frustrated that the delivery was late more frequently for food delivery than for package delivery.

FPF-3. People are frustrated that items were missing from the order more frequently for food delivery than package delivery.

FPF-4. People are frustrated that the fees were too high more frequently for food delivery than for package delivery.

Reasons (R) People Use Delivery Services Hypothesis:

R-1. People most often use delivery services because of their convenience rather than other reasons such as safety, time savings, comfort, cost, or accessibility.

3.3.2 Statistical Methods for Analysis

Before conducting an in-depth analysis of the survey responses, the data were cleaned to remove any incomplete responses. The original 405 survey responses were reduced to 304 responses used for analysis after the data was cleaned. Many of the responses that had to be removed were because respondents did not answer the Likert scale questions. Methods that were used for analyzing the cleaned data included descriptive and inferential statistics. For a large portion of the analysis, Mann-Whitney U-Tests were conducted in R. The Mann-Whitney U-Test, also known as the Wilcoxon Rank Sum Test, is a nonparametric test that compares two independent groups. The Mann-Whitney U-Test was chosen because the collected data was ordinal rather than dichotomous. The test was performed as a two-sided test where the null hypothesis was that the distributions of two populations are equal, and the alternative hypothesis was that the distributions of two populations are not equal (*Mann Whitney U Test (Wilcoxon Rank Sum Test)*, 2017). A p-value from a hypothesis below an alpha of 0.05 means the difference between the two questions' responses was significant. A p-value above 0.05 means the difference is insignificant. R, a programming language for statistical computing, was chosen because it is a free software environment that is easily accessible and intuitive (*R: The R Project for Statistical Computing*, 2021). A correlation table for the collected responses is in Appendix C. Spearman Rank Correlation with pairwise deletion was used because the data was ordinal.

Questions 14, 15, and 16 asked how often the respondent used certain delivery services before, during, and after the pandemic, respectively, as well as Questions 19 and 20, which asked about the respondent's frustrations with food and package delivery, respectively, were primarily used for analysis. Also, there were two ranking questions at the end of the survey (Questions 22 and 23) with a lower response rate than other survey questions, so incomplete responses to these questions were not considered when the data was cleaned. Question 22 had 267 responses, and Question 23 had 288 responses. Though the survey took less than 5 minutes to complete on average, the reduced number of completed responses for these two questions could be because respondents no longer wanted to fill out the survey when they reached the end. Question 23, which asked respondents to rank why they used delivery services from most to least important, was analyzed because it had a higher response rate than Question 22, which asked respondents to rank why they used delivery services before the pandemic from most to least important. Questions for analysis were selected based on which would best represent people's current opinions, preferences, and frustrations towards delivery services. These results were then used to understand what characteristics needed to be represented in DaaS to make it an optimal delivery service.

3.3.3 Partitioning the Data

Spending power for delivery services is typically correlated to their income. Therefore, it was necessary first to ensure that the survey responses presented a comprehensive sample of the annual income demographic seen in the NRV. Figure 4 shows the distribution of annual income that survey respondents reported. The high percentage of income under $50,000 is likely due to a high College and University student population. Also, slightly more than 12% of respondents chose not to report their income which could cause a skew in the results as well.

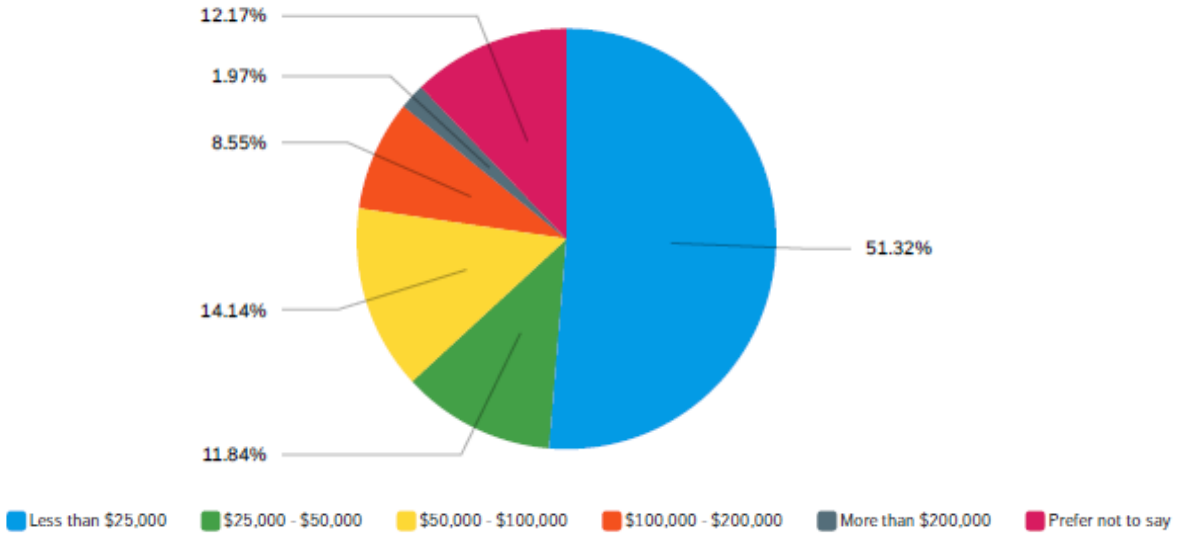


Figure 4: Annual Income Distribution for Survey

Figure 5 shows the distribution of household income in the NRV from 2019 that Census Reporter reported. The number of household incomes below $50,000 is the highest, as shown in the survey data. The number of incomes between $50,000 to $100,000 is similarly the second highest in both datasets. One crucial difference between the two data samples is that the survey did not specifically ask for individual or household income, but the data from Census Reporter reports household income. Though the survey responses did differ from the demographics reported by Census Reporter, they are nearly accurate because Census Reporter also said their margin of error is at least 10% (*Census Profile*, 2021). The similarity between the data presented by Census Reporter and collected by the survey means that the captured data likely represents a near-comprehensive capture of income distribution in the NRV.

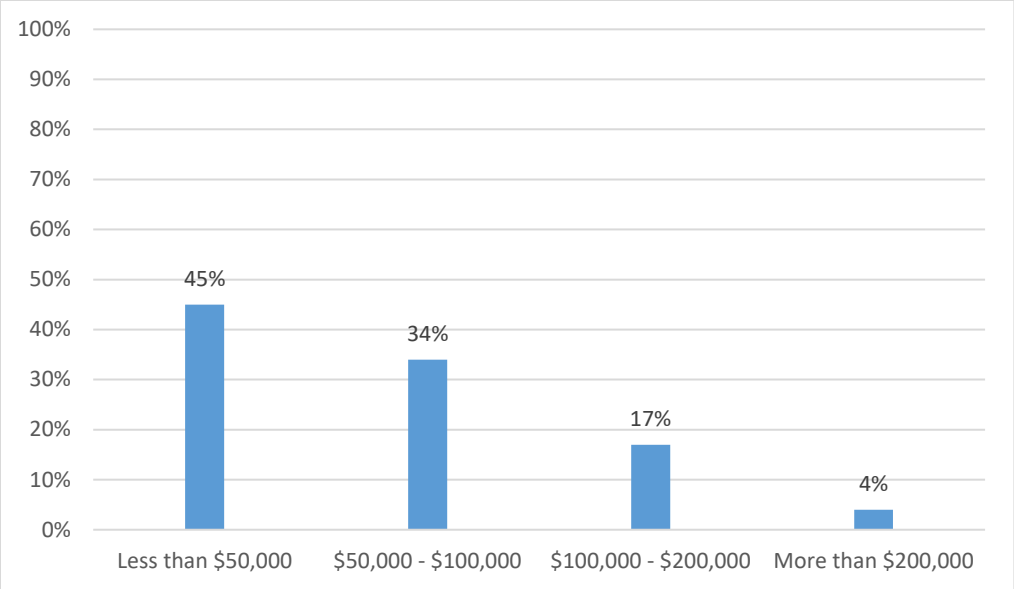


Figure 5: NRV 2019 Household Income, adapted from *Census profile* (2021)

One demographic that was thought to have a large impact on people's delivery preferences was their location. People who live in more rural areas would likely not have access to the same options as people who live in towns or cities. Figure 6 shows that 258 of the people who responded to the survey live within town or city limits in the NRV, while 46 did not. Differences in responses to other questions were analyzed based on their locations to see how delivery frustrations and satisfaction compared. Mann-Whitney U-Tests were conducted to see if there was a significant difference in the frequency of different delivery frustrations, for food (Question 19) and package (Question 20) delivery, based on the respondent's location. A Mann-Whitney U-Test comparing satisfaction with delivery in the NRV (Question 17) by location was conducted because it was thought that people's location impacted their frustrations with delivery services. In addition, student and non-student status were compared to delivery satisfaction to show significance because student status and location were thought to be related.

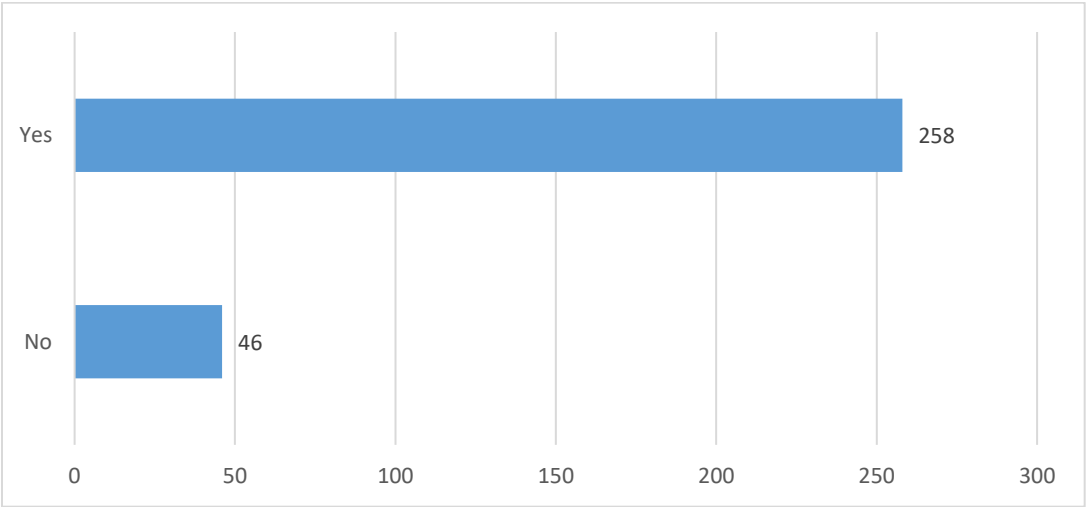


Figure 6: Number of Survey Respondents Who Do and Do Not Live within Town or City Limits

Similar to how location was thought to impact delivery preferences, vehicle ownership (Figure 7) was supposed to affect how often people used delivery and their opinions of delivery services. Frequency of use of third-party restaurant app, grocery, and package delivery before, during, and after the pandemic, Questions 14, 15, and 16, respectively, were compared to whether respondents did or did not own or have access to a vehicle in a Mann-Whitney U-Test. It was hypothesized that if people did not have access to a personal vehicle, they would likely use delivery services more frequently because it is more difficult for them to go to a store or restaurant. Also, it was thought that those who do not have access to a vehicle would significantly increase their use of delivery services during the pandemic. It would be more dangerous for them to use other transportation forms such as taking the bus or using a ride-sharing service.

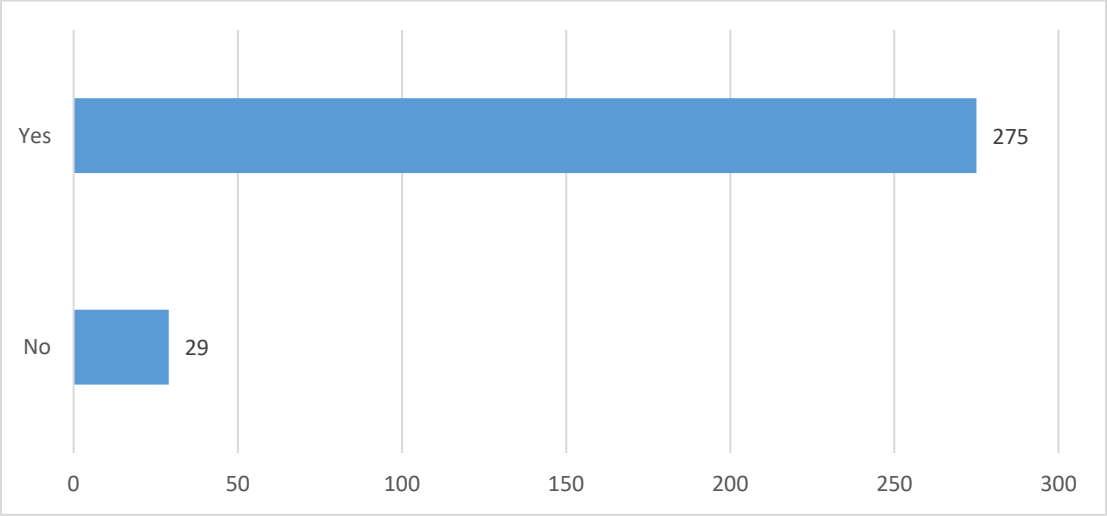


Figure 7: Number of Survey Respondents Who Do and Do Not have Access to a Vehicle

Responses across similar questions were compared to show significance between delivery use before, during, and after the pandemic and different frustrations associated with food and package delivery. It was hypothesized that respondents would increase their use of delivery services during and after the pandemic compared to before. The frequency of use of third-party restaurant delivery apps, grocery delivery, and package delivery before (Question 14), during (Question 15), and after (Question 16) the pandemic was analyzed in Mann-Whitney U-Tests to look for significance. In addition, delivery frustrations associated with food and packages, in Questions 19 and 20, respectively, were compared to find significance in what delivery factors cause the most frustration. Responses to various survey questions are compared and analyzed in the following chapter to show the significance and develop conclusions about delivery preferences in the NRV. Chapter 4 uses the methodology and hypotheses defined in this chapter to guide and structure the sections.

Chapter 4: Survey Analysis and Results

4.1 Introduction

This analysis aims to formulate an answer to the research question using the hypotheses outlined in Chapter 3 as guidance. Delivery preferences are first analyzed by specified demographics and then by frequency of use, frustrations, and preferences that survey respondents reported. The analysis will conclude by providing an overview of the survey results. Chapter 5 will build upon these results to answer the research question and develop the MOEs of a DaaS framework.

4.2 Delivery Preferences by Demographic

Factors that influence different delivery preferences are first analyzed by location and vehicle ownership demographics. These demographics can help interpret why people have particular delivery preferences and frustrations to understand what they are. These factors can then create a better delivery service that is both more efficient and accessible.

4.2.1 Location and Delivery Frustrations

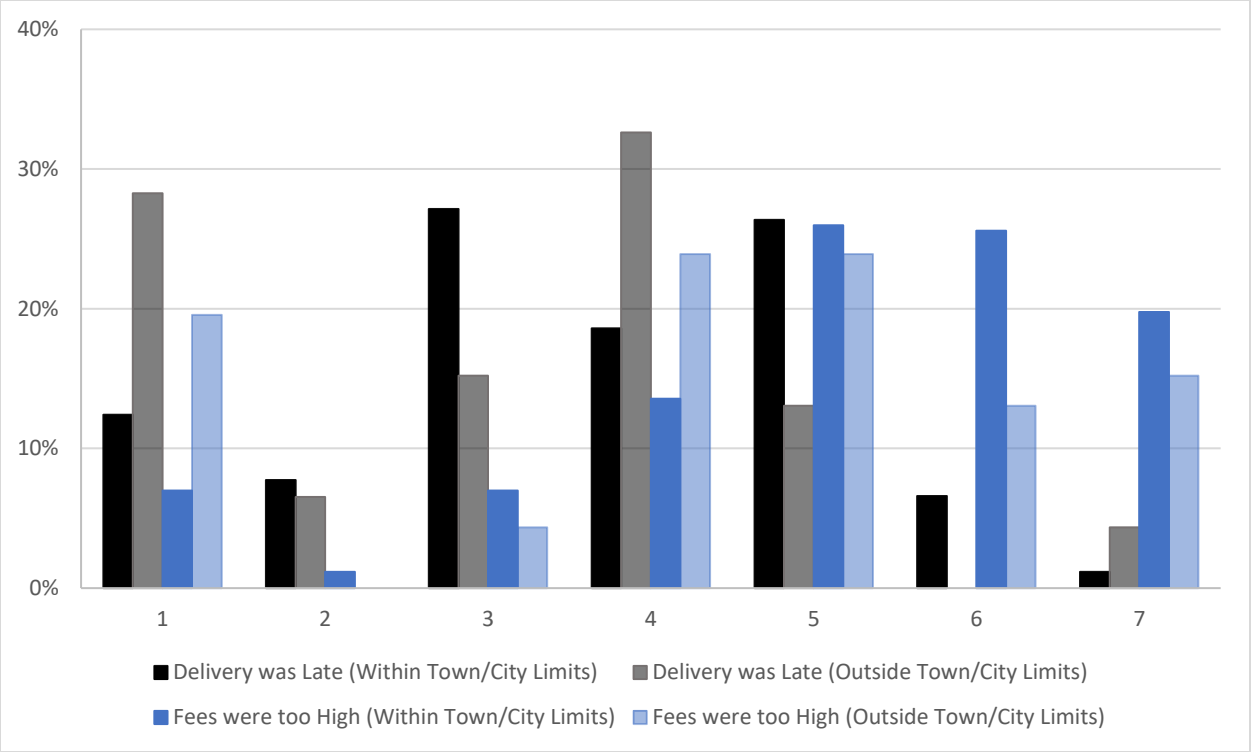
Table 4 shows the results of Mann-Whitney U-Tests that were executed to evaluate whether there was a significant difference in people's frustrations with food delivery services if they lived within or outside of town or city limits in the NRV. The findings supported hypotheses L-1 and L-4 but did not support hypotheses L-2 and L-3 (Table 6). People had similar frustrations with the app or website being difficult to use, food being too cold or too warm, and items missing, regardless of location, because p-values were highly insignificant. According to the Mann-Whitney U-Test, the null hypothesis of equal distributions between populations was rejected for the delivery was late and fees were too high frustrations at p-values of 0.0477 and 0.0143, respectively. Therefore, those living within town or city limits reported statistically significant different frustration frequencies regarding late deliveries and high fees than those living outside of town or city limits. Response distributions shown in Figure 8 indicate that hypothesis L-3 was not supported because those who lived in more urban areas had a higher response rate for "occasionally" and "frequently" being frustrated with late deliveries than those who lived in more rural areas. Figure 8 also shows that hypothesis F-5 was not supported because the distributions differ.

Table 4: Location and Food Delivery Frustrations Mann-Whitney U-Test Comparison

Food Delivery Frustrations*	**Live within Town/City Limits**	**Live outside Town/City Limits**	**P-Value****
	Sample Size	**Sample Size**	
App or website was difficult to use	258	46	0.7064
Food was too cold or too warm	258	46	0.7599
Delivery was late	258	46	0.0477
Items were missing from your order	258	46	0.9520
Fees were too high	258	46	0.0143

*Ranking System: 1=Never, 2=Very Rarely, 3=Rarely, 4=Neutral, 5=Occasionally, 6=Frequently, 7=Very Frequently

**A p-value below 0.05 is considered significant



Ranking System: 1=Never, 2=Very Rarely, 3=Rarely, 4=Neutral, 5=Occasionally, 6=Frequently, 7=Very Frequently

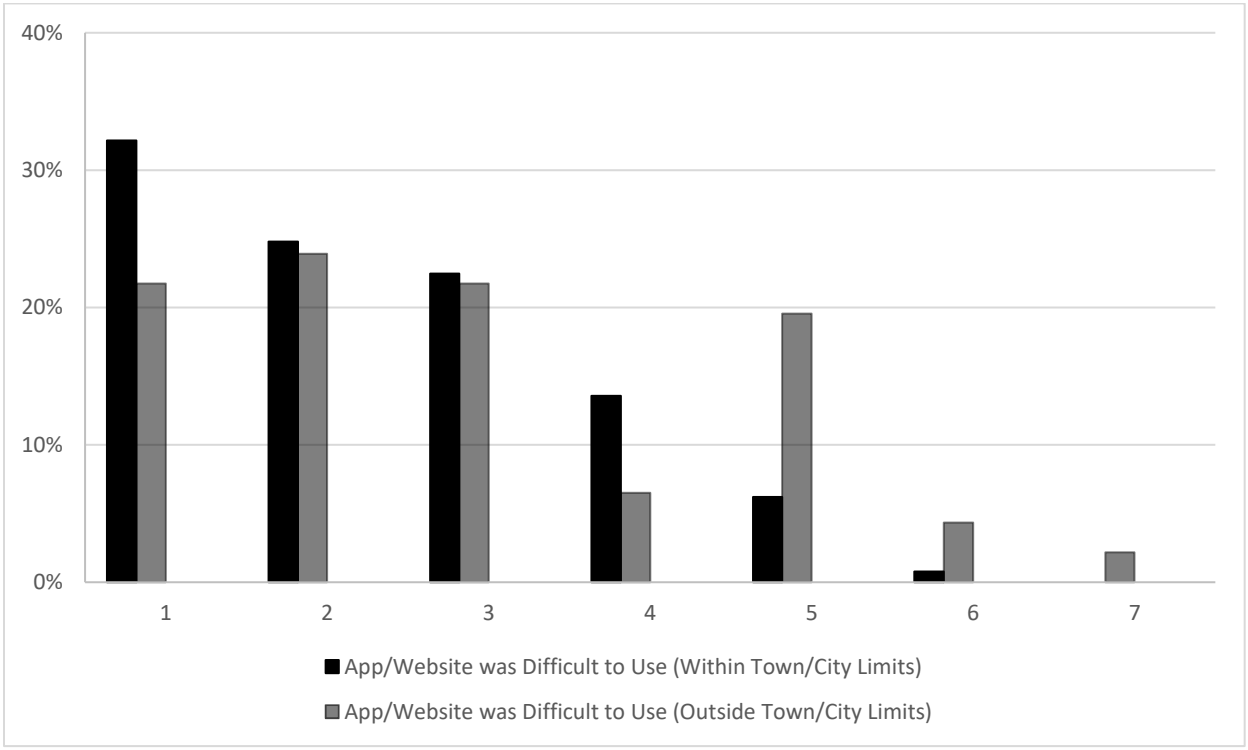
Figure 8: Location and Food Delivery Frustrations Response Distribution with Significant P-Values

Mostly high p-values were found when comparing package delivery frustrations for the same demographic in Table 5. All p-values except that for the app or website being difficult to use were greater than 0.05. The data supported hypotheses L-7, L-9, and L-10 because people who lived in more rural areas were not experiencing significantly greater or lesser frustrations with package delivery services even though they may have lived farther away. The analysis, however, did not support hypothesis L-8, which hypothesized that people who lived in more rural areas would have more frequent frustrations with late package deliveries. Therefore, it is likely that there were not many perceived differences in package delivery times by location. For the app or website was difficult to use package frustration, the null hypothesis of equal distributions between populations was rejected according to the Mann-Whitney U-Test at a p-value of 0.0273. Therefore, those who lived within town or city limits reported statistically different frustration frequency for the app or website being difficult to use than those who lived outside of town or city limits. The significantly higher frustrations with package delivery apps or websites were notable because this was not similarly found for food delivery frustrations (Table 4). Response distributions shown in Figure 9 indicate that the data also did not support hypothesis L-6. A higher response rate for the "occasionally," "frequently," and "very frequently" categories for those who lived in more rural areas than those who lived in more urban areas, in Figure 9, did not support hypothesis L-6.

Table 5: Location and Package Delivery Frustrations Mann-Whitney U-Test Comparison

Package Delivery Frustrations*	Live within Town/City Limits	Live outside Town/City Limits	P-Value**
	Sample Size	Sample Size	
App or website was difficult to use	258	46	0.0273
Item was damaged or broken	258	46	0.6957
Delivery was late	258	46	0.8407
Items were missing from your order	258	46	0.9317
Shipping fees were too high	258	46	0.2191

*Ranking System: 1=Never, 2=Very Rarely, 3=Rarely, 4=Neutral, 5=Occasionally, 6=Frequently, 7=Very Frequently
**A p-value below 0.05 is considered significant



Ranking System: 1=Never, 2=Very Rarely, 3=Rarely, 4=Neutral, 5=Occasionally, 6=Frequently, 7=Very Frequently

Figure 9: Location and Package Delivery Frustrations Response Distribution with Significant P-Values

Table 6: Location (L) and Delivery Frustrations Hypothesis Summary

Hypothesis Number	Hypothesis	Result
L-1	People who live in more rural areas will not be frustrated more frequently with food delivery apps or websites being difficult to use than people who live in more urban areas.	Supported
L-2	People who live in more rural areas will be frustrated more frequently with food from food delivery being too cold or too warm than people who live in more urban areas.	Not Supported
L-3	People who live in more rural areas will be frustrated more frequently with food deliveries being late than people who live in more urban areas.	Not Supported
L-4	People who live in more rural areas will not be frustrated more frequently with food delivery items missing from their order than people who live in more urban areas.	Supported
L-5	People who live in more rural areas will not be frustrated more frequently with food delivery fees being too high than people who live in more urban areas.	Not Supported
L-6	People who live in more rural areas will not be frustrated more or less frequently with package delivery apps or websites being difficult to use than people who live in more urban areas.	Not Supported
L-7	People who live in more rural areas will not be frustrated more or less frequently with package delivery items being damaged or broken than people who live in more urban areas.	Supported
L-8	People who live in more rural areas will be frustrated more frequently with package deliveries being late than people who live in more urban areas.	Not Supported
L-9	People who live in more rural areas will not be frustrated more or less frequently with package delivery items missing from their order than people who live in more urban areas.	Supported
L-10	People who live in more rural areas will not be frustrated more or less frequently with food delivery fees being too high than people who live in more urban areas.	Supported

4.2.2 Vehicle Ownership and Delivery Frequency

Hypotheses VO-1, VO-2, and VO-3 (Table 10) were supported because whether an individual did or did not own or have access to a vehicle did not significantly impact their use of delivery services before the pandemic (Table 7). P-values were well above 0.05, meaning that the relationship was not significant. Safety may not have been a concern before the pandemic, and people who did not have access to a personal vehicle felt comfortable traveling via public transit, such as Blacksburg Transit and Radford Transit, or ride-hailing services, such as Uber or Lyft (*Blacksburg Transit*, 2021; *Radford Transit*, 2021). Before the pandemic, there was no need for people to change their habits, and those who did not have a personal vehicle had safe and accessible travel options.

Table 7: Vehicle Access and Pre-Pandemic Delivery Frequency of Use Mann-Whitney U-Test Comparison

Delivery Use Before the Pandemic*	Vehicle Ownership or Access	No Vehicle Ownership or Access	P-Value**
	Sample Size	Sample Size	
Third-Party Restaurant Delivery Apps	275	29	0.2084
Grocery Delivery	275	29	0.2404
Package Delivery	275	29	0.3186

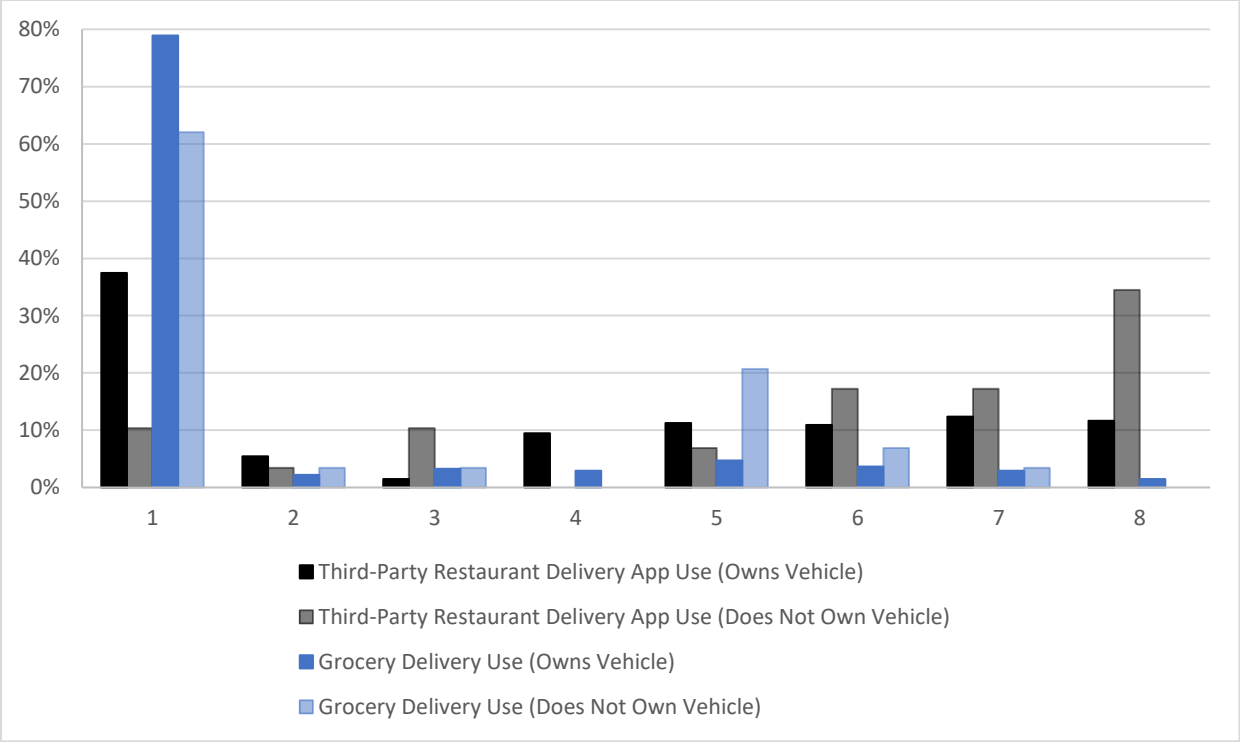
*Ranking System: 1=Never, 2=Once a year, 3=Once every 6 months, 4=Once every 3 months, 5=Once a month, 6=Once every 2 weeks, 7=Once per week, 8=More than once per week
**A p-value below 0.05 is considered significant

Table 8 details the difference between delivery use for individuals who did and did not have vehicle access during the pandemic. The p-value of 0.0002 for third-party restaurant delivery means the null hypothesis for the Mann-Whitney U-Test was rejected and supports hypothesis VO-4 (in Table 10) because it shows a significant difference between the two groups. Figure 10 indicates that individuals who did not own or have access to a personal vehicle used third-party app delivery services significantly more than individuals who had vehicle access because the group without vehicle access had a greater response rate for a higher frequency of use than the group with vehicle access. The data also supports VO-5 because the p-value of 0.0410 was significant. Therefore, grocery delivery use did decrease greatly from a p-value of 0.2404 before the pandemic in Table 7. The decrease in p-value shows a greater difference in grocery delivery use frequency between the group that had access to a vehicle and the group that did not. Response distributions in Figure 10 show that while the majority of both populations responded "never," those without a vehicle had a bimodal distribution with a 21% chance of stating "once a month." The data did not support VO-6 because the p-value (0.3261) did not show significance. People without vehicle access likely changed their habits to use delivery services, specifically third-party restaurant apps, even more than those with vehicle access during the pandemic due to personal safety concerns and reluctance to use other transit options.

Table 8: Vehicle Access and Pandemic Delivery Frequency of Use Mann-Whitney U-Test Comparison

Delivery Use During the Pandemic*	Vehicle Ownership or Access	No Vehicle Ownership or Access	P-Value**
	Sample Size	Sample Size	
Third-Party Restaurant Delivery Apps	275	29	0.0002
Grocery Delivery	275	29	0.0410
Package Delivery	275	29	0.3261

*Ranking System: 1=Never, 2=Once a year, 3=Once every 6 months, 4=Once every 3 months, 5=Once a month, 6=Once every 2 weeks, 7=Once per week, 8=More than once per week
**A p-value below 0.05 is considered significant



Ranking System: 1=Never, 2=Once a year, 3=Once every 6 months, 4=Once every 3 months, 5=Once a month, 6=Once every 2 weeks, 7=Once per week, 8=More than once per week

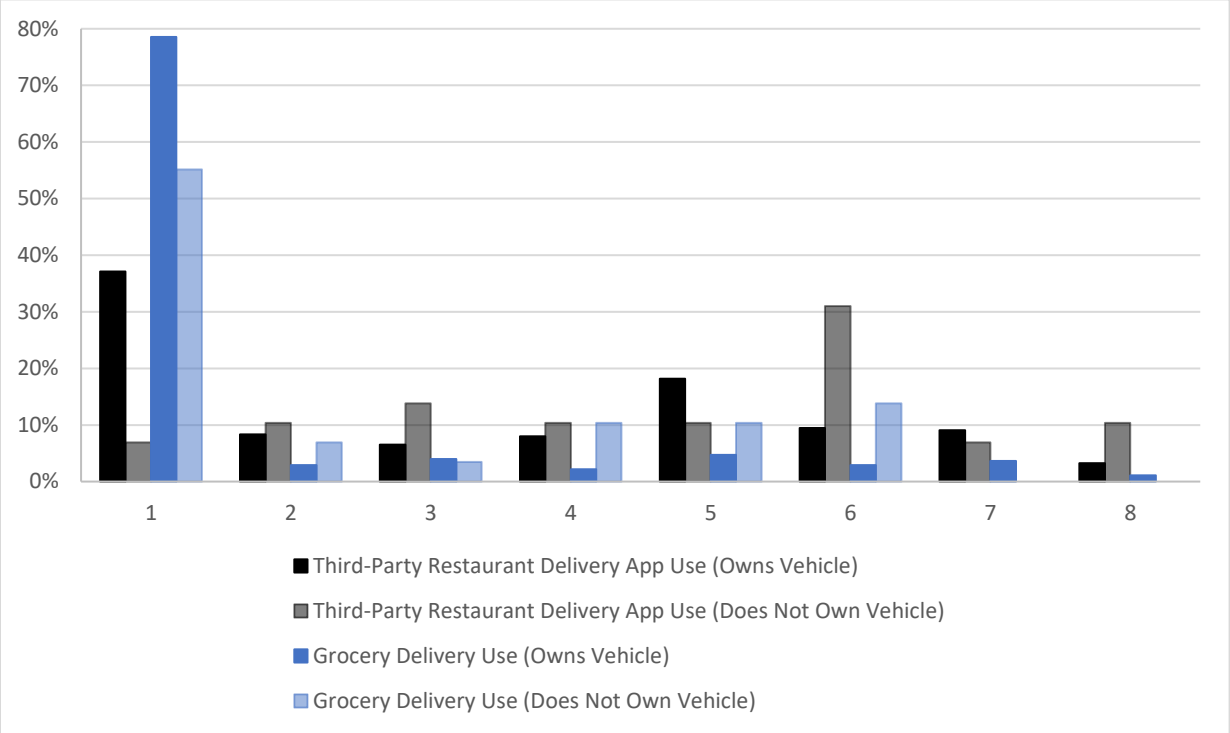
Figure 10: Vehicle Access and Delivery Frequency of Use During the Pandemic Response Distribution with Significant P-Values

Table 9 shows similar significance for delivery use frequency after the pandemic to that seen in Table 8 for delivery use frequency during the pandemic. According to the Mann-Whitney U-Test, the null hypothesis of equal distributions between populations was rejected for third-party restaurant delivery app and grocery delivery use after the pandemic at p-values of 0.0015 and 0.0074, respectively. Therefore, those owning a vehicle reported statistically significant different behavior regarding third-party app and grocery delivery than respondents without a vehicle. Response distributions in Figure 11 support hypothesis VO-7 (Table 10) because those without a vehicle had a 31% chance of stating “once a month.” Figure 11 also supports hypothesis VO-8 because those without a vehicle had greater response distributions for use “once every 3 months,” “once a month,” and “once every two weeks” than those with a vehicle. The significance of grocery delivery use decreased greatly from a p-value of 0.2404 before the pandemic in Table 7 and 0.0410 during the pandemic in Table 8. However, the data did not support hypothesis VO-9. The COVID-19 pandemic created a need for people, especially those without vehicle access, to use delivery services. The data supports that it is likely that habits changed regarding the use of third-party restaurant delivery apps and grocery delivery, especially for those who did not own personal vehicles.

Table 9: Vehicle Access and Post-Pandemic Delivery Frequency of Use Mann-Whitney U-Test Comparison

Delivery Use After the Pandemic*	Vehicle Ownership or Access	No Vehicle Ownership or Access	P-Value**
	Sample Size	Sample Size	
Third-Party Restaurant Delivery Apps	275	29	0.0015
Grocery Delivery	275	29	0.0074
Package Delivery	275	29	0.4572

*Ranking System: 1=Never, 2=Once a year, 3=Once every 6 months, 4=Once every 3 months, 5=Once a month, 6=Once every 2 weeks, 7=Once per week, 8=More than once per week
**A p-value below 0.05 is considered significant



Ranking System: 1=Never, 2=Once a year, 3=Once every 6 months, 4=Once every 3 months, 5=Once a month, 6=Once every 2 weeks, 7=Once per week, 8=More than once per week

Figure 11: Vehicle Access and Post-Pandemic Delivery Frequency of Use Response Distribution with Significant P-Values

Table 10: Vehicle Ownership (VO) and Delivery Frequency Hypothesis Summary

Hypothesis Number	Hypothesis	Result
VO-1	Before the pandemic, people who do not have access to a personal vehicle will not order delivery from third-party restaurant delivery apps more frequently than people who do have access to a personal vehicle before.	Supported
VO-2	Before the pandemic, people who do not have access to a personal vehicle will not order grocery delivery more frequently than people who do have access to a personal vehicle before.	Supported
VO-3	Before the pandemic, people who do not have access to a personal vehicle will not order package delivery more frequently than people who do have access to a personal vehicle before.	Supported
VO-4	During the pandemic, people who do not have access to a personal vehicle will order delivery from third-party restaurant delivery apps more frequently than people who do have access to a personal vehicle before.	Supported
VO-5	During the pandemic, people who do not have access to a personal vehicle will order grocery delivery more frequently than people who do have access to a personal vehicle before.	Supported
VO-6	During the pandemic, people who do not have access to a personal vehicle will order package delivery more frequently than people who do have access to a personal vehicle before.	Not Supported
VO-7	After the pandemic, people who do not have access to a personal vehicle will order delivery from third-party restaurant delivery apps more frequently than people who do have access to a personal vehicle before.	Supported
VO-8	After the pandemic, people who do not have access to a personal vehicle will order grocery delivery more frequently than people who do have access to a personal vehicle before.	Supported
VO-9	After the pandemic, people who do not have access to a personal vehicle will order package delivery more frequently than people who do have access to a personal vehicle before.	Not Supported

4.2.3 NRV Delivery Satisfaction by Location and Student Status

Table 11 details the results of a Mann-Whitney U-Test conducted to analyze the difference in opinion about delivery satisfaction in the NRV between individuals who lived within and outside of town or city limits. The results displayed a p-value of 0.0008, which is highly significant and supports hypothesis S-1 (Table 13). The response distributions in Figure 12 represent that people who lived outside of town or city limits were more unsatisfied than those who lived within town or city limits, with a 35% and 8% chance of unsatisfaction, respectively.

Table 11: Delivery Satisfaction and Location Mann-Whitney U-Test Comparison

	Live within Town/City Limits	**Live outside Town/City Limits**	**P-Value****
	Sample Size	**Sample Size**	
Delivery Satisfaction*	258	46	0.0008

*Ranking System: 1=Satisfied, 2=Neutral, 3=Unsatisfied

**A p-value below 0.05 is considered significant

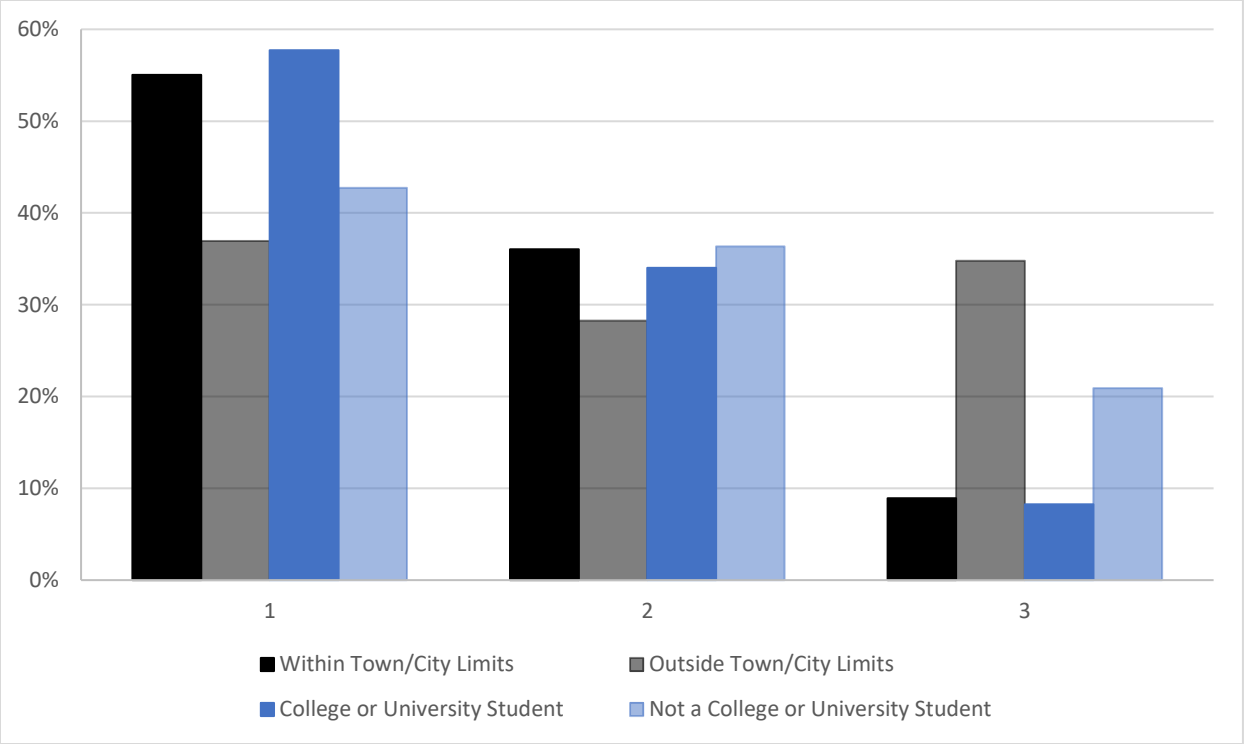
Survey respondents were also asked to describe why they were satisfied, neutral, or unsatisfied with delivery services in the NRV. Individuals who were satisfied with delivery services wrote that they were satisfied because delivery was convenient and saved time. However, many unsatisfied individuals with delivery services wrote that they lived too far away to get delivery or did not have enough delivery choices. Those who were unsatisfied also described that the drivers often got lost, packages were sometimes delivered to their neighbors, fees were too high, or delivery took too much time. Most of the delivery frustrations were due to the individuals living outside of town or city limits. Overall, it appears that people were frustrated with current delivery services and desired more efficient and accessible delivery options.

In addition, the survey asked respondents to indicate whether they were college or university students or not because NRV houses several colleges and universities, including Virginia Tech and Radford. One hundred ninety-four respondents stated that they were students and 110 respondents indicated that they were not students at the time of survey completion. Table 12 details the results of a Mann-Whitney U-Test conducted to analyze the difference in opinion about delivery satisfaction in the NRV between students and non-students. The results show that the null hypothesis of equal distributions between populations was rejected at a p-value of 0.0021. This is highly significant and represents that students and non-students had different satisfaction levels towards delivery services in the NRV. The difference likely supports hypothesis S-2 (Table 13) because most students lived within town or city limits. Figures 12 and 13 also explain the significance of a p-value of 0.0021 because students and non-students had a clear opposite opinion of satisfaction with delivery services in the NRV. A greater proportion of students were satisfied, and a greater proportion of non-students were unsatisfied with delivery services in the NRV.

Table 12: Delivery Satisfaction and Student Status Mann-Whitney U-Test Comparison

	College/University Student	**Not a College/University Student**	**P-Value****
	Sample Size	**Sample Size**	
Delivery Satisfaction*	194	110	0.0021

*Ranking System: 1=Satisfied, 2=Neutral, 3=Unsatisfied
**A p-value below 0.05 is considered significant



Ranking System: 1=Satisfied, 2=Neutral, 3=Unsatisfied

Figure 12: Delivery Satisfaction, Location, and Student Status Response Distribution with Significant P-Values

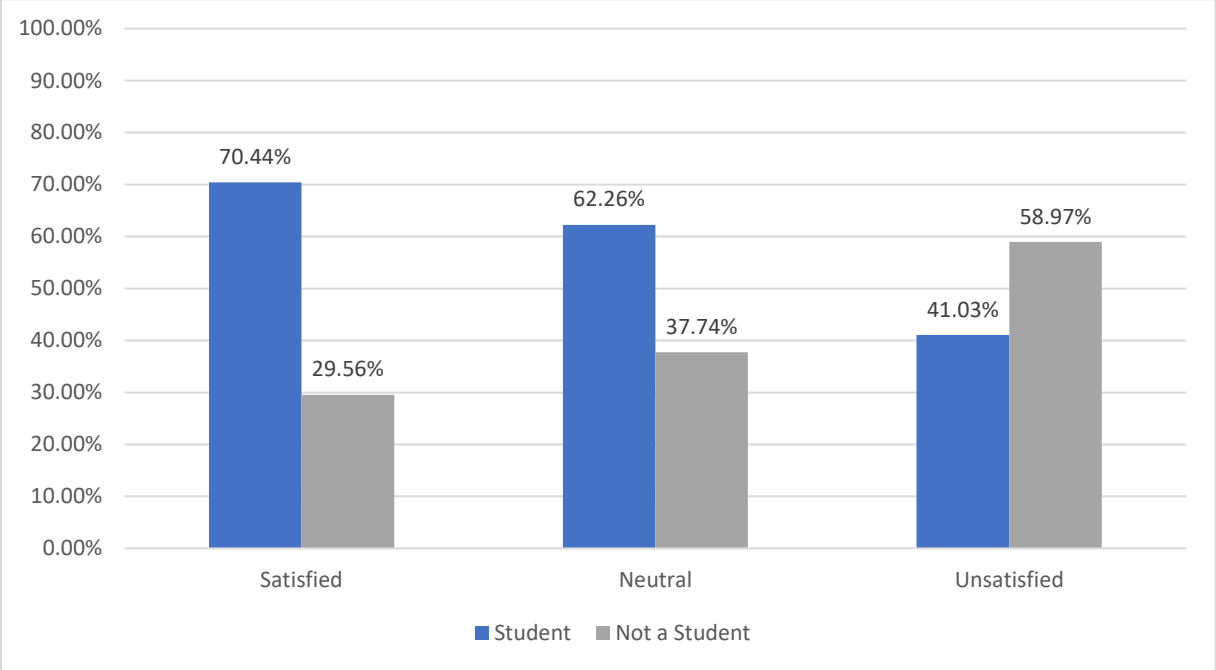


Figure 13: Delivery Satisfaction and Student Status Bar Graph

Table 13: Delivery Satisfaction (S) Hypothesis Summary

Hypothesis Number	Hypothesis	Result
S-1	People who live in more rural areas will be less satisfied with delivery services than people who live in more urban areas.	Supported
S-2	Non-students will be less satisfied with delivery services than students.	Supported

4.2.4 Delivery Preferences by Demographic Analysis Results

The main conclusions from the results of section 4.2 are:

- People who lived in more rural areas were significantly more frequently frustrated with high food delivery fees than people who lived in more urban areas.
- People who lived in more rural areas were significantly more frequently frustrated that an app or website was difficult to use when ordering package delivery than people who lived in more urban areas.
- The COVID-19 pandemic significantly increased the use of third-party restaurant delivery apps and grocery delivery for people who did not have access to a personal vehicle compared to those who did have access to a personal vehicle.
- People who lived in more rural areas were significantly more unsatisfied with the delivery services available to them than people who lived in more urban areas.

4.3 Delivery Use, Frustrations, and Preferences

The survey included questions about how the COVID-19 pandemic changed people's delivery preferences, what frustrates people when they use delivery, and why people choose to use delivery services. These three main types of questions were formulated to develop an overall picture of customer perception of delivery services in the NRV that could be used as a baseline for developing DaaS MOEs and framework.

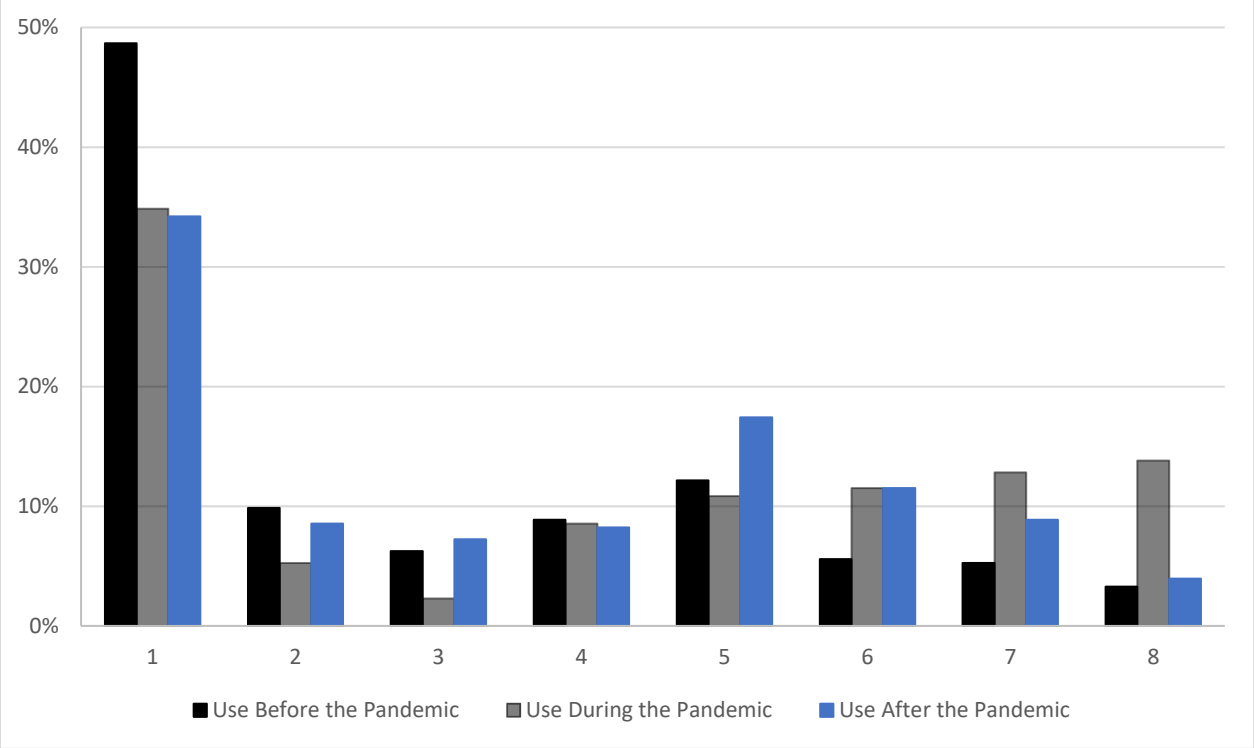
4.3.1 Delivery Service Frequency of Use Before, During, and After the Pandemic

Survey respondents were asked to indicate how frequently they used third-party restaurant apps, grocery, and package delivery before and during the pandemic and predict how often they believed they would use these delivery services after the pandemic ends. Mann-Whitney U-Tests of delivery use before, during, and after the pandemic for third-party restaurant apps and groceries are detailed in Tables 14 and 15, respectively. All p-values were highly significant, excluding grocery delivery use during compared to after the pandemic, which means that the null hypothesis of equal distributions between populations was rejected. Response distributions in Figure 14 support hypotheses F-1 and F-2 but do not support hypothesis F-3 (Table 17). Response distributions for third-party app delivery use during and after the pandemic were greater than those for before the pandemic on the right side of Figure 14. In addition, hypothesis F-3 was not supported because it was hypothesized that using third-party delivery apps after the pandemic ends would be the same as during the pandemic. However, the response distributions indicated that use after the pandemic would decrease. This expected decrease could be due to the high frustration with delivery fees associated with third-party restaurant apps or because people planned to return to eating at restaurants once the pandemic ends.

Table 14: Third-Party Restaurant Delivery App Frequency of Use Mann-Whitney U-Test Comparison

Variable 1*	Sample Size	Variable 2*	Sample Size	P-Value**
Use before the pandemic	304	**Use during the pandemic**	304	0.0000
Use before the pandemic	304	**Use after the pandemic**	304	0.0000
Use during the pandemic	304	**Use after the pandemic**	304	0.0139

*Ranking System: 1=Never, 2=Once a year, 3=Once every 6 months, 4=Once every 3 months, 5=Once a month, 6=Once every 2 weeks, 7=Once per week, 8=More than once per week
**A p-value below 0.05 is considered significant



Ranking System: 1=Never, 2=Once a year, 3=Once every 6 months, 4=Once every 3 months, 5=Once a month, 6=Once every 2 weeks, 7=Once per week, 8=More than once per week

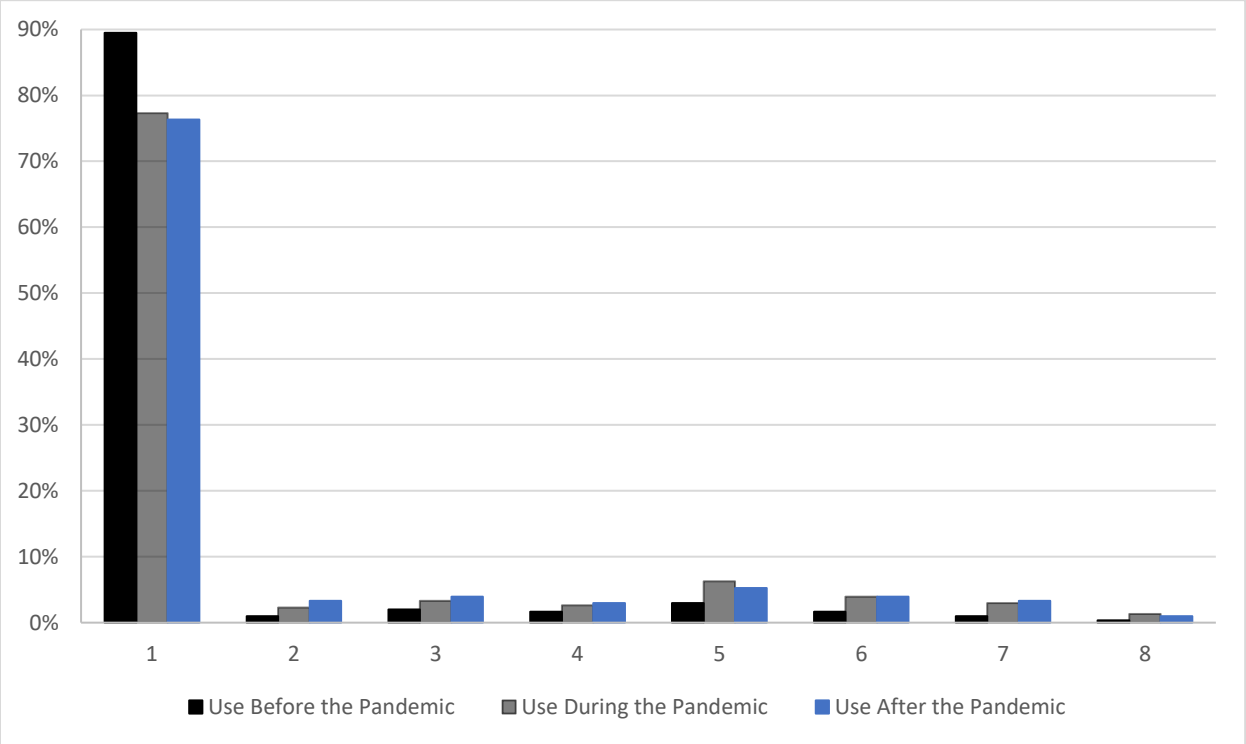
Figure 14: Third-Party Restaurant Delivery App Frequency of Use Response Distribution with Significant P-Values

Table 15: Grocery Delivery Frequency of Use Mann-Whitney U-Test Comparison

Variable 1*	Sample Size	Variable 2*	Sample Size	P-Value**
Use before the pandemic	304	**Use during the pandemic**	304	0.0000
Use before the pandemic	304	**Use after the pandemic**	304	0.0000
Use during the pandemic	304	**Use after the pandemic**	304	0.8526

*Ranking System: 1=Never, 2=Once a year, 3=Once every 6 months, 4=Once every 3 months, 5=Once a month, 6=Once every 2 weeks, 7=Once per week, 8=More than once per week
**A p-value below 0.05 is considered significant

Response distributions in Figure 15 support hypotheses F-4, F-5, and F-6 (Table 17) because though the majority of respondents never used grocery delivery, the frequency of use for those who did significantly increased from before to during and before to after the pandemic. Hypothesis F-6 is supported because people increased their use and predicted that they will keep this same habit once the pandemic ends. The response distributions in Figure 15 highlighted that grocery delivery frequency of use during and after the pandemic were nearly the same. Overall, the pandemic permanently changed people's habits by increasing the frequency in which they used grocery delivery.



Ranking System: 1=Never, 2=Once a year, 3=Once every 6 months, 4=Once every 3 months, 5=Once a month, 6=Once every 2 weeks, 7=Once per week, 8=More than once per week

Figure 15: Grocery Delivery Frequency of Use Response Distribution with Significant P-Values

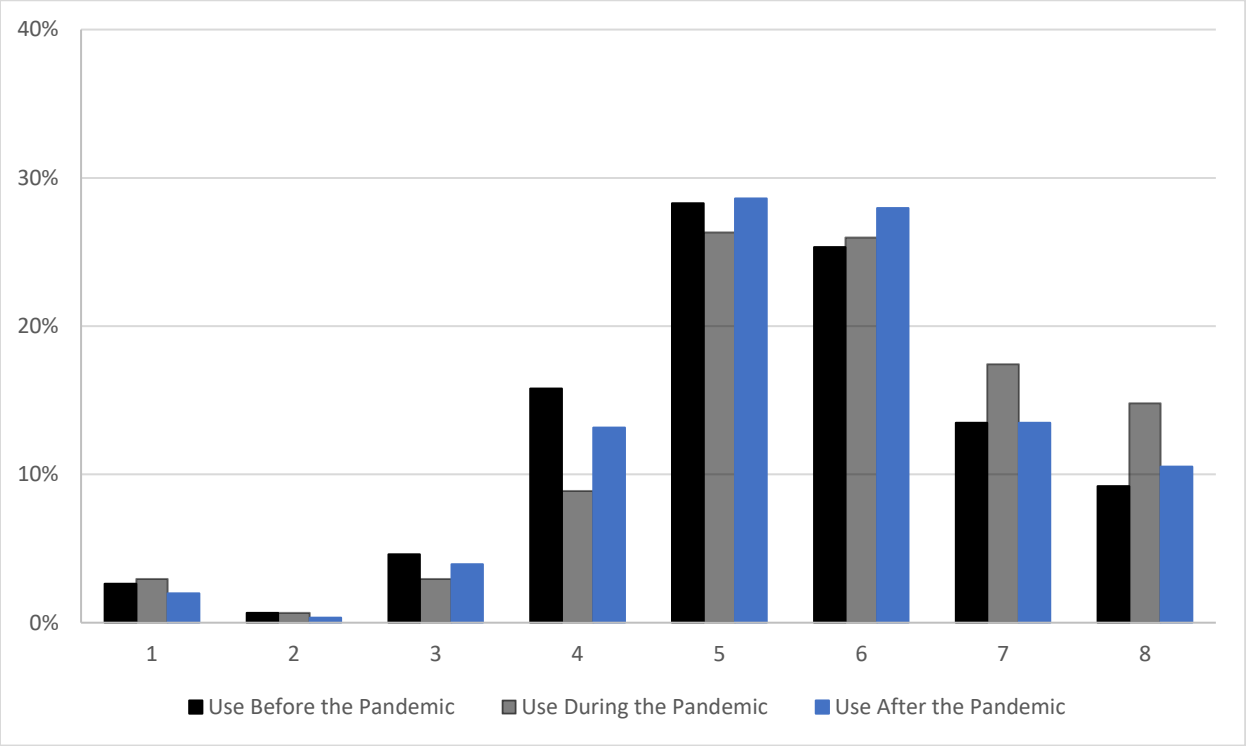
Mann-Whitney U-Tests for package delivery use before, during, and after the pandemic are shown in Table 16. According to the Mann-Whitney U-Test, the null hypothesis of equal distributions between populations was rejected for package delivery use from before to during and during to after the pandemic at p-values of 0.0018 and 0.0381, respectively. Response distributions in Figure 16 support hypothesis F-7 but did not support hypotheses F-8 and F-9 in Table 17. Figure 16 supports hypothesis F-7 because the chance of responses in the “once every 2 weeks,” “once per week,” and “more than once per week” categories was greater during than before the pandemic. The data did not support hypothesis F-8 because people planned to return to their original use frequency, which can be seen with similar response distributions in Figure 16 for before and after the pandemic. Hypothesis F-9 was also not supported because people did not predict that they will use package delivery equally frequently during and after the pandemic. Therefore, the data shows that people planned to decrease their use of package delivery after the

pandemic ends. Overall, the p-value results for package delivery were likely less significant than third-party apps or grocery delivery because people were already accustomed to ordering packages for delivery. In contrast, third-party apps and grocery delivery were newer choices for people. It is also notable that a greater proportion of respondents indicated that they never used third-party app or grocery delivery than package delivery.

Table 16: Package Delivery Frequency of Use Mann-Whitney U-Test Comparison

Variable 1*	Sample Size	Variable 2*	Sample Size	P-Value**
Use before the pandemic	304	**Use during the pandemic**	304	0.0018
Use before the pandemic	304	**Use after the pandemic**	304	0.2536
Use during the pandemic	304	**Use after the pandemic**	304	0.0381

*Ranking System: 1=Never, 2=Once a year, 3=Once every 6 months, 4=Once every 3 months, 5=Once a month, 6=Once every 2 weeks, 7=Once per week, 8=More than once per week
**A p-value below 0.05 is considered significant



Ranking System: 1=Never, 2=Once a year, 3=Once every 6 months, 4=Once every 3 months, 5=Once a month, 6=Once every 2 weeks, 7=Once per week, 8=More than once per week

Figure 16: Package Delivery Frequency of Use Response Distribution with Significant P-Values

Table 17: Delivery Frequency of Use (F) Before, During, and After the Pandemic Hypothesis Summary

Hypothesis Number	Hypothesis	Result
F-1	People will use third-party restaurant delivery apps less frequently before than during the pandemic.	Supported
F-2	People will use third-party restaurant delivery apps less frequently before than after the pandemic.	Supported
F-3	People will use third-party restaurant delivery apps equally frequently during than after the pandemic.	Not Supported
F-4	People will use grocery delivery less frequently before than during the pandemic.	Supported
F-5	People will use grocery delivery less frequently before than after the pandemic.	Supported
F-6	People will use grocery delivery equally frequently during than after the pandemic.	Supported
F-7	People will use package delivery less frequently before than during the pandemic.	Supported
F-8	People will use package delivery less frequently before than after the pandemic.	Not Supported
F-9	People will use package delivery equally frequently during than after the pandemic.	Not Supported

4.3.2 Types of Food Delivery Frustrations

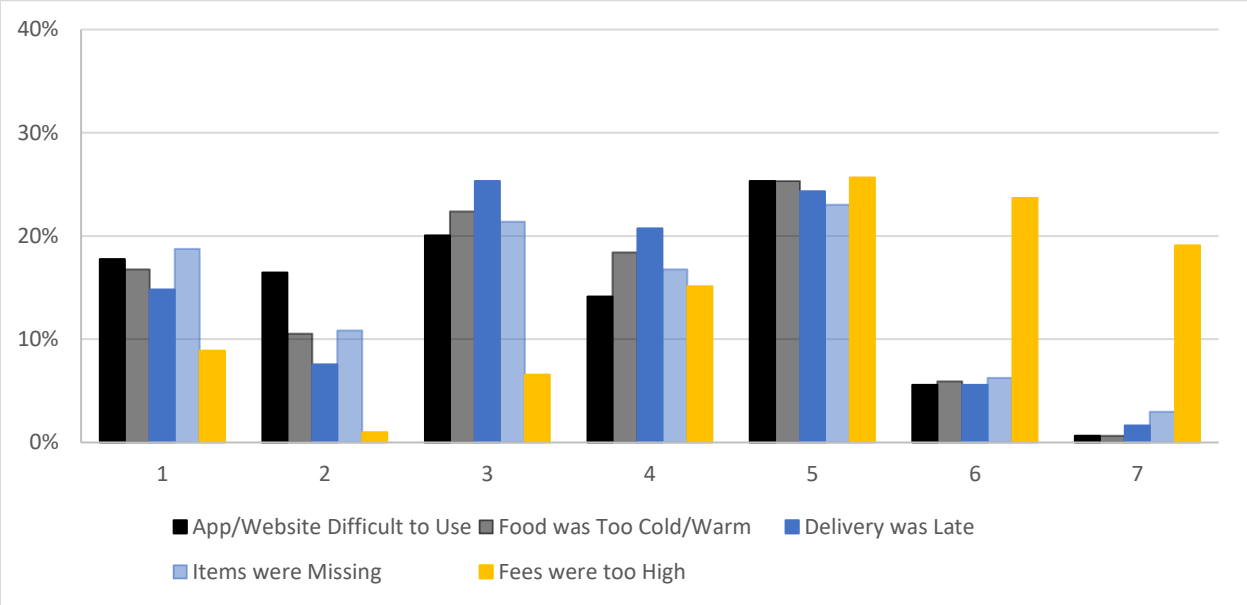
Question 19 in the survey asked respondents to rank how often they were frustrated with specific food delivery issues. Table 18 outlines the results of Mann-Whitney U-Tests that were conducted to compare each food delivery frustration. The highlighted p-values in Table 18 are considered significant, which means that the null hypothesis of equal distributions between populations was rejected. Response distributions in Figure 17 support hypotheses FF-4, FF-7, FF-9, and FF-10 (Table 19). The response distribution shows that people were most frustrated with high delivery fees. The data did not support hypotheses FF-1, FF-2, FF-3, FF-5, FF-6, and FF-8 (Table 19). However, a close to a significant p-value of 0.0835 was found for the comparison between the app or website was difficult to use and the delivery was late food delivery frustration. Though the p-value is still considered insignificant, it is notable because the data shows that people were not often frustrated with the technology associated with food delivery but had greater frustrations with the time estimates and high fees. It is also notable that the response distribution in Figure 17 for being frustrated “occasionally was similar for each frustration. Therefore, each frustration with food delivery was occasionally experienced and means there is a need to mitigate these negative experiences.

Table 18: Food Delivery Frustrations Mann-Whitney U-Test Comparison

Variable 1*	Sample Size	Variable 2*	Sample Size	P-Value**
App or website was difficult to use	304	**Food was too cold or too warm**	304	0.3101
App or website was difficult to use	304	**Delivery was late**	304	0.0835
App or website was difficult to use	304	**Items were missing from your order**	304	0.4106
App or website was difficult to use	304	**Fees were too high**	304	0.0000
Food was too cold or too warm	304	**Delivery was late**	304	0.5004
Food was too cold or too warm	304	**Items were missing from your order**	304	0.8766
Food was too cold or too warm	304	**Fees were too high**	304	0.0000
Delivery was late	304	**Items were missing from your order**	304	0.4090
Delivery was late	304	**Fees were too high**	304	0.0000
Items were missing from your order	304	**Fees were too high**	304	0.0000

*Ranking System: 1=Never, 2=Very Rarely, 3=Rarely, 4=Neutral, 5=Occasionally, 6=Frequently, 7=Very Frequently

**A p-value below 0.05 is considered significant



Ranking System: 1=Never, 2=Very Rarely, 3=Rarely, 4=Neutral, 5=Occasionally, 6=Frequently, 7=Very Frequently

Figure 17: Food Delivery Frustrations Response Distribution

Table 19: Types of Food Delivery Frustrations (FF) Hypothesis Summary

Hypothesis Number	Hypothesis	Result
FF-1	When ordering food delivery, people are less frequently frustrated that the app or website was difficult to use than that the food was too cold or too warm.	Not Supported
FF-2	When ordering food delivery, people are less frequently frustrated that the app or website was difficult to use than that the delivery was late.	Not Supported
FF-3	When ordering food delivery, people are less frequently frustrated that the app or website was difficult to use than that items were missing from the order.	Not Supported
FF-4	When ordering food delivery, people are less frequently frustrated that the app or website was difficult to use than that the fees were too high.	Supported
FF-5	When ordering food delivery, people are less frequently frustrated that the food was too cold or too warm than that the delivery was late.	Not Supported
FF-6	When ordering food delivery, people are less frequently frustrated that the food was too cold or too warm than that items were missing from the order.	Not Supported
FF-7	When ordering food delivery, people are less frequently frustrated that the food was too cold or too warm than that the fees were too high.	Supported
FF-8	When ordering food delivery, people are more frequently frustrated that the delivery was late than that items were missing from the order.	Not Supported
FF-9	When ordering food delivery, people are less frequently frustrated that the delivery was late than that the fees were too high.	Supported
FF-10	When ordering food delivery, people are less frequently frustrated that items were missing from the order than that the fees were too high.	Supported

4.3.3 Food Delivery Preferences

When asked if people preferred to order food delivery directly from a restaurant or through third-party apps, the results did not support hypothesis P-1 (Table 20) because 196 people responded that they preferred to order directly from restaurants. In contrast, 60 preferred third-party apps, and 48 did not order food delivery (Figure 18). The responses from these food delivery preferences were compared to what respondents wrote when asked why they were satisfied, neutral, or unsatisfied with delivery in Question 17. It was found that respondents who stated they ordered directly from restaurants said they did not like that third-party apps take a cut from the restaurant's earnings and that the fees associated with third-party apps were too high. They also described frustrations with the time it took for a delivery through third-party apps to arrive. Individuals who stated that they order from third-party apps preferred their convenience. Those who did not order food delivery from restaurants cited their reasons as high cost and lack of accessibility because they lived in rural areas.

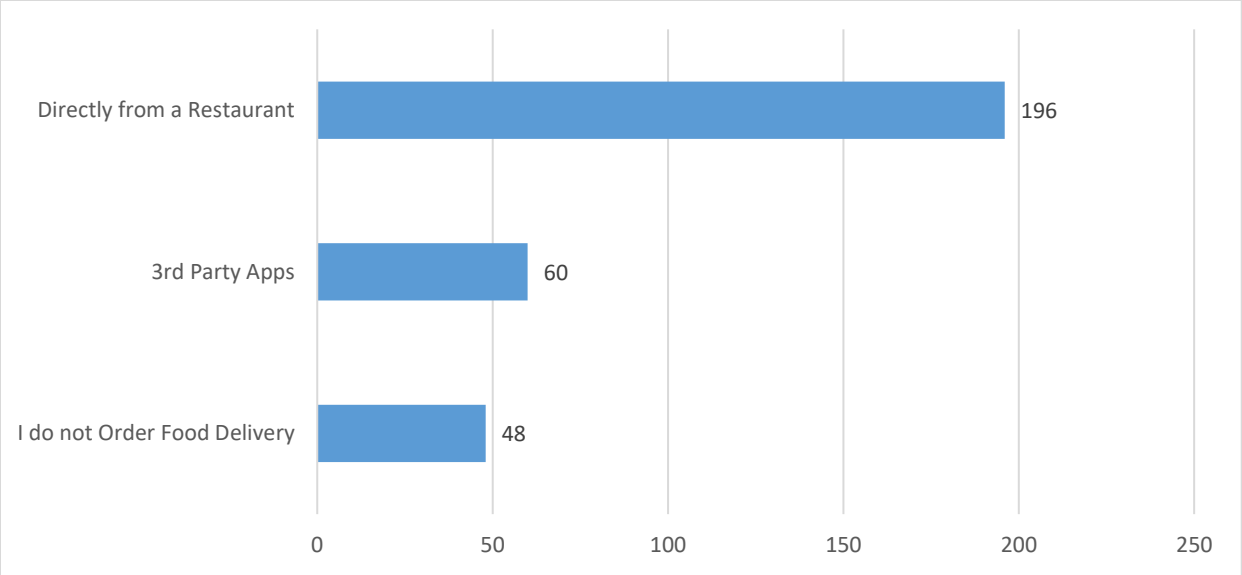


Figure 18: Food Delivery Preferences

Table 20: Food Delivery Preferences (P) Hypothesis Summary

Hypothesis Number	Hypothesis	Result
P-1	More people will prefer to order food delivery from a third-party app than directly from a restaurant.	Not Supported

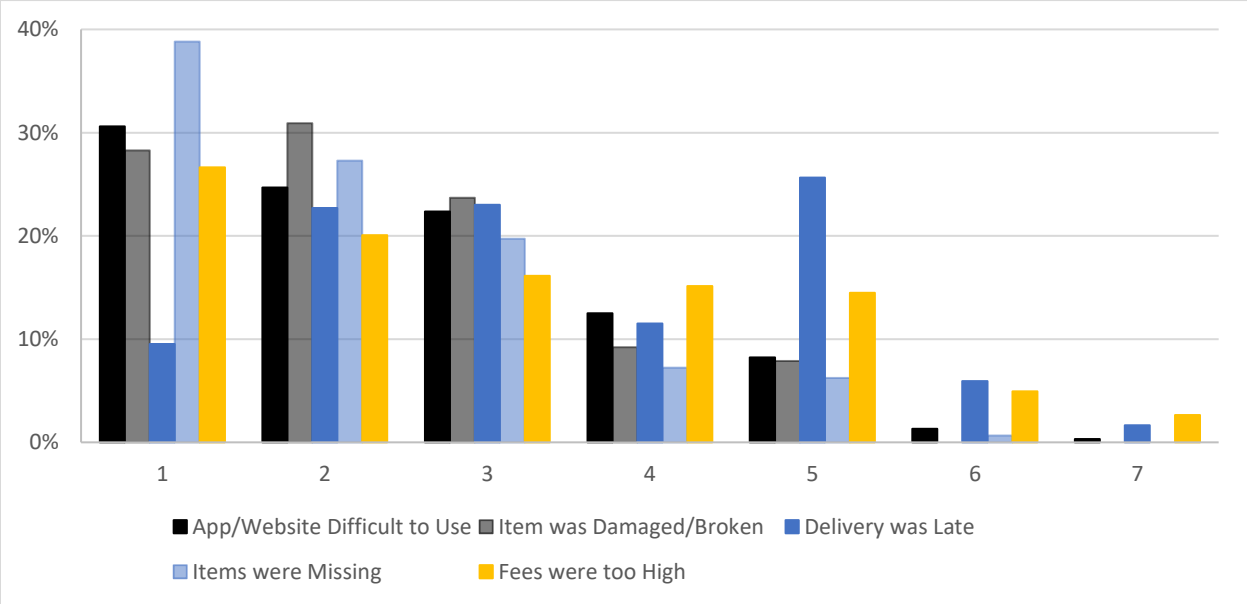
4.3.4 Types of Package Delivery Frustrations

Table 21 describes Mann-Whitney U-Tests for package delivery frustrations. Nearly all comparisons, except between the app or website was difficult to use, and the item was damaged or broken, were significant according to the Mann-Whitney U-Test. The null hypothesis of equal distributions between populations was rejected for these comparisons, which means that Variables 1 and 2 showed statistically significant different behavior. Response distributions in Figure 19 indicate that the data did not support hypothesis PF-1, but hypotheses PF-2, PF-4, PF-5, PF-6, PF-7, PF-8, PF-9, and PF-10 were supported (Table 22). The response distributions for higher frustrations with package deliveries arriving late and high fees in Figure 19 were greater than other frustrations on the right side of the distribution. In addition, the delivery was late frustration had a relatively high chance of occurring "occasionally" (26%), but a relatively low chance of occurring "never" (10%). Therefore, late deliveries were a significant frustration for people when ordering package delivery. Additionally, hypothesis PF-3 was not supported, but the comparison still presented a significant p-value of 0.0034. However, because the app or website was difficult to use had a higher response distribution chance of occurring than items missing from your order in Figure 19, the significance was seen in the opposite sense from the hypothesis. Overall, people were most frustrated with high shipping fees and late deliveries.

Table 21: Package Delivery Frustrations Mann-Whitney U-Test Comparison

Variable 1*	Sample Size	Variable 2*	Sample Size	P-Value**
App or website was difficult to use	304	**Item was damaged or broken**	304	0.5103
App or website was difficult to use	304	**Delivery was late**	304	0.0000
App or website was difficult to use	304	**Items were missing from your order**	304	0.0034
App or website was difficult to use	304	**Shipping fees were too high**	304	0.0016
Item was damaged or broken	304	**Delivery was late**	304	0.0000
Item was damaged or broken	304	**Items were missing from your order**	304	0.0139
Item was damaged or broken	304	**Shipping fees were too high**	304	0.0001
Delivery was late	304	**Items were missing from your order**	304	0.0000
Delivery was late	304	**Shipping fees were too high**	304	0.0000
Items were missing from your order	304	**Shipping fees were too high**	304	0.0000

*Ranking System: 1=Never, 2=Very Rarely, 3=Rarely, 4=Neutral, 5=Occasionally, 6=Frequently, 7=Very Frequently
**A p-value below 0.05 is considered significant



Ranking System: 1=Never, 2=Very Rarely, 3=Rarely, 4=Neutral, 5=Occasionally, 6=Frequently, 7=Very Frequently

Figure 19: Package Delivery Frustrations Response Distribution

Table 22: Types of Package Delivery Frustrations (PF) Hypothesis Summary

Hypothesis Number	Hypothesis	Result
PF-1	When ordering package delivery, people are less frequently frustrated that the app or website was difficult to use than that an item was damaged or broken.	Not Supported
PF-2	When ordering package delivery, people are less frequently frustrated that the app or website was difficult to use than that the delivery was late.	Supported
PF-3	When ordering package delivery, people are less frequently frustrated that the app or website was difficult to use than that items were missing from the order.	Not Supported
PF-4	When ordering package delivery, people are less frequently frustrated that the app or website was difficult to use than that the fees were too high.	Supported
PF-5	When ordering package delivery, people are less frequently frustrated that an item was damaged or broken than that the delivery was late.	Supported
PF-6	When ordering package delivery, people are more frequently frustrated that an item was damaged or broken than that items were missing from the order.	Supported
PF-7	When ordering package delivery, people are less frequently frustrated that an item was damaged or broken than that the fees were too high.	Supported
PF-8	When ordering package delivery, people are more frequently frustrated that the delivery was late than that items were missing from the order.	Supported
PF-9	When ordering package delivery, people are more frequently frustrated that the delivery was late than that the fees were too high.	Supported
PF-10	When ordering package delivery, people are less frequently frustrated that items were missing from the order than that the fees were too high.	Supported

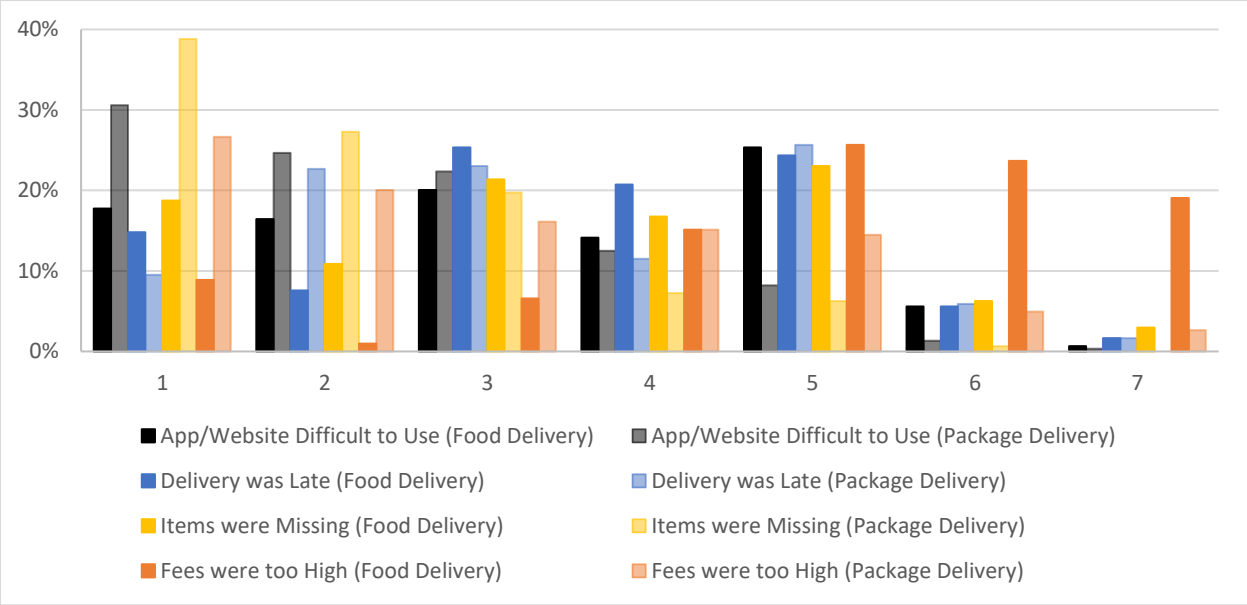
4.3.5 Differences and Similarities between Food and Package Delivery Frustrations

Every p-value from the Mann-Whitney U-Tests was well below 0.05 for each frustration, except late deliveries, which means the null hypothesis of equal distributions between populations was rejected (Table 23). A p-value of 0.3049 shows that the data did not support hypothesis FPF-2 but that people had similar frustrations about late deliveries for both food and packages. Response distributions shown in Figure 20 indicate that people were overall less frustrated with package than food delivery because the chance of being more frequently frustrated was higher for each food delivery frustration. Therefore, hypotheses FPF-1, FPF-3, and FPF-4 (Table 24) were supported. Fees were too high for food delivery had the highest distribution for occurring “frequently” and “very frequently,” with a 24% and 19% chance, respectively. Overall, the comparison indicated a need for better delivery services in general, specifically in food delivery.

Table 23: Food and Package Delivery Frustrations Mann-Whitney U-Test Comparison

Delivery Frustrations*, ***	Food Delivery	Package Delivery	P-Value**
	Sample Size	Sample Size	
App or website was difficult to use	304	304	0.0000
Delivery was late	304	304	0.3049
Items were missing from your order	304	304	0.0000
Fees were too high	304	304	0.0000

*Ranking System: 1=Never, 2=Very Rarely, 3=Rarely, 4=Neutral, 5=Occasionally, 6=Frequently, 7=Very Frequently
**A p-value below 0.05 is considered significant
***Note: Food was too cold or too warm and an item is damaged or broken are not comparable and therefore not included



Ranking System: 1=Never, 2=Very Rarely, 3=Rarely, 4=Neutral, 5=Occasionally, 6=Frequently, 7=Very Frequently

Figure 20: Food and Package Delivery Frustrations Response Distributions

Table 24: Differences and Similarities between Food and Package Delivery Frustration (FPF) Hypothesis Summary

Hypothesis Number	Hypothesis	Result
FPF-1	People are frustrated that the app or website was difficult to use more frequently for food delivery than for package delivery.	Supported
FPF-2	People are frustrated that the delivery was late more frequently for food delivery than for package delivery.	Not Supported
FPF-3	People are frustrated that items were missing from the order more frequently for food delivery than for package delivery.	Supported
FPF-4	People are frustrated that the fees were too high more frequently for food delivery than for package delivery.	Supported

4.3.6 Reasons People Use Delivery Services

Respondents were asked to rank the reasons, including convenience, safety, time savings, comfort, cost, and accessibility, for why they used delivery from most to least important to them, from one to six, respectively. Note that this question was asked during the pandemic, which likely influenced people's responses, especially in the safety category. The medians from the 288 ranked responses are summarized in Table 25. Hypothesis R-1 (Table 26) is supported because convenience was most often ranked as most important. After all, it had the lowest median (1.0) among the data. The remainder of the medians were fairly similar, but the median for cost was the highest at 5.0, which means that it was most often ranked as one of the least important reasons to use delivery. The stark difference in ranking for convenience versus cost highlights that people value delivery as a convenient service and not due to cost.

Table 25: Descriptive Statistics for Ranked Reasons to Use Delivery Services

Reason to Use Delivery Services	Median	Count
Convenience	1.0	288
Safety	3.5	288
Time Savings	3.0	288
Comfort	4.0	288
Cost	5.0	288
Accessibility	4.0	288

*Ranking System: 1 (Most Important) to 6 (Least Important)

Table 26: Reasons (R) People Use Delivery Services Hypothesis Summary

Hypothesis Number	Hypothesis	Result
R-1	People most often use delivery services because of their convenience rather than other reasons such as safety, time savings, comfort, cost, or accessibility.	Supported

4.3.7 Delivery Use, Frustrations, and Preferences Analysis Results

The main conclusions from the results of section 4.3 are:

- People significantly increased their frequency of use of third-party restaurant delivery apps from before to during the pandemic.
- People significantly increased their frequency of use of third-party restaurant delivery apps from before to after the pandemic.
- People planned to significantly decrease their use of third-party restaurant delivery apps from during to after the pandemic.
- People significantly increased their grocery delivery use from before to during the pandemic and planned to maintain this increased frequency of use after the pandemic ends.
- People significantly increased their use of package delivery from before to during the pandemic.
- After the pandemic ends, people plan to decrease package delivery back to the frequency that they used it before the pandemic.

- For food delivery, people were significantly most frequently frustrated with high fees.
- More people prefer to order food delivery directly from a restaurant than through third-party apps.
- For package delivery, people were significantly most frequently frustrated with late deliveries.
- People were more frequently frustrated that an app or website was difficult to use, items were missing from an order, and the fees were too high when ordering food delivery than when ordering package delivery.
- People were similarly frequently frustrated with late deliveries for food and package delivery.
- People most often chose to use delivery services because of their convenience.

4.4 Conclusions

The purpose of the analysis was to answer the research questions: 1) What delivery characteristics do customers value?; and 2) How can these characteristics be used to define DaaS MOEs and a DaaS framework that also enhances the omni-channel supply chain? The survey data revealed that the use of delivery services increased during the pandemic and will likely experience a permanent increase in usage. Though many people will return to physically going to restaurants and stores after the pandemic ends, many people will still use delivery more often after than they did before the pandemic. Survey respondents also noted their desire for more efficient delivery services to reduce late deliveries. Additionally, survey respondents valued the time that could be saved from ordering grocery delivery. The survey conclusions revealed that people desire the following factors in a delivery service:

- User-friendly and intuitive technology
- Reasonable cost
- Accessibility for everyone
- Efficiency to mitigate frustrations
- A convenient service
- Time savings

The pandemic introduced a new way of life, and the delivery system needs to be prepared and have the capacity to accommodate delivery needs. DaaS provides a method to mitigate the delivery frustrations expressed in the survey and provide a seamless delivery service. Now that it is clear what people want in a delivery service, DaaS can be designed to meet customer expectations. Chapter 5 will describe how the DaaS framework will incorporate the above six factors that the survey indicated people want in a delivery service.

Chapter 5: Discussion

5.1 Introduction

The purpose of this chapter is to describe DaaS comprehensively and to detail how the conclusions from the survey were used to develop a delivery service model that would improve the customer's experience. Existing MaaS characteristics definitions were first used to build core characteristics of DaaS. An overall DaaS framework, which included MOEs from survey conclusions for a DaaS platform's success, and a definition of DaaS were then created. This chapter concludes by discussing how DaaS would integrate into the omni-channel supply chain and enhance the customer's experience of the five omni-channel experience dimensions (Shi et al., 2020).

5.2 Characteristics of DaaS

This section will describe how the nine core characteristics that Jittrapirom et al. (2017) outlined for MaaS and survey conclusions can be similarly applied to DaaS. Each MaaS characteristic was modified to fit DaaS applications, and the descriptions were re-defined. Each DaaS characteristic and how it was derived from MaaS or the survey are described to develop the overall DaaS framework. All nine proposed DaaS characteristics are summarized from the user's perspective in section 5.2.8 in Table 28. The characteristics are baseline requirements for the DaaS platform that must leave room for scalability and optimization.

5.2.1 Integration of Products

MaaS integrates different transportation services into one platform. DaaS does the same for delivery services within the omni-channel supply chain. A DaaS platform should be interoperable so that any type of delivery service could integrate its products to increase delivery convenience. The survey indicated that users prefer a convenient service. Therefore, the user should be able to view the DaaS platform and see every delivery service that is available to them. Alongside interoperability, a DaaS platform must also have the scalability to integrate future additional delivery services and new technologies.

5.2.2 Payment Options and Digital Platform

Most websites and apps offer various payment options for the user, which can include credit cards, e-wallets, mobile payments, and other similar payment options. A DaaS platform should have a variety of payment options to provide accessibility. MaaS systems are easy-to-use and accessible because they have several payment options offered via a digital platform that is easily within reach for users. DaaS should be similarly available to users as a single digital platform, such as an app or website, that offers multiple delivery options. The DaaS platform should be easy to use because the survey results indicated that users experience frustrations with platform accessibility. DaaS' digital platform would be a single platform that works as an extension to the delivery services offered in the omni-channel supply chain. The platform also connects delivery services provided in the omni-channel supply chain to the customer.

5.2.3 Multiple Actors

The omni-channel supply chain is a system of different components that work together to deliver the customer. The existing omni-channel supply chain mainly involves three major actors: the producer, deliverer, and customer. Introducing DaaS to the omni-channel supply

chain will include integrating a DaaS company as a new component into the system. The DaaS company plays a central role in the model by providing technology, such as an app, to interact with all other actors in the delivery supply chain. The DaaS company's technology interface would be a central point of information about all delivery services offered to the customer. The DaaS customer or user would interface directly with the DaaS platform to order goods or services. The producer would provide information about goods or services directly to the DaaS company, and the DaaS interface will relay this information to the user and the deliverer. The deliverer would provide information about the delivery timeline and location to the DaaS company, and the DaaS company will communicate with the user and the producer. All actors in the omni-channel supply chain would be interconnected by a web of information that the DaaS interface houses. Core DaaS actors are summarized in the following:

- User – Interfaces through the DaaS company's platform to order items for delivery and receive information about their delivery order
- Producer – Interfaces through the DaaS company's platform to receive and relay delivery orders and information
- Deliverer – A vehicle fleet or individuals that interface through the DaaS company's platform receive and relay delivery orders and information
- DaaS Company – Provides DaaS technology interfaces
    - DaaS Frontend Technology Platform – Interacts with the user, deliverer, and producer
    - DaaS Backend Technology – Supports the Frontend interface

5.2.4 Use of Technologies

The central technology used for DaaS, as well as MaaS, is the digital platform. All actors within the supply chain would utilize the digital platform to connect them to other components of the omni-channel supply chain. However, integrating additional innovative technology into the delivery ecosystem can provide a means for better service quality. The survey indicated that people desire an efficient and convenient delivery service, which innovative technologies can further strengthen. The technologies and their potential applications are summarized in Table 27 from the Literature Review can further enhance DaaS by making delivery services more efficient and accessible. A drone may be better suited to deliver an item in some locations, while in other areas, an autonomous vehicle may provide optimal service depending on the user's expectations.

Table 27: Summary of Technologies in Delivery Applications

Technology	Delivery Applications
Third-Party Delivery Apps	1. Give the user access to multiple local restaurants from one platform 2. Offer local grocery delivery
Road Autonomous Delivery Robots (RADR)	1. Deliver goods, food, medication.
Sidewalk Autonomous Delivery Robots (SADR)	1. Deliver small packages of goods, food, medication.
Drones	1. Deliver small packages of goods, food, medication. 2. Can be deployed in any setting (rural, suburban, or suburban)

5.2.5 Demand Orientation

MaaS is successful and innovative because it focuses on the user rather than the transportation system. When the MaaS system is user-centric, the focus is on providing the optimal service for the user. As a result, all other components of the transportation system come together naturally. The DaaS platform should therefore be demand-oriented to provide delivery services that meet the needs of the user. DaaS' user-centric platform will seek to provide on-demand delivery that is efficient and accessible for the user, which will mitigate the frustrations found from the survey.

5.2.6 Registration Requirement

DaaS would require users to register an account, similar to requirements in MaaS platforms, to improve user experience. Registration would create a unique user account with information such as home address and payment method to make ordering easier and faster. When each user has a designated account, the platform can save their settings and provide recommendations based on their preferences. The DaaS platform can show users what delivery options are available to them based on their location. A registered payment method would make ordering easier for the user and allow subscription services to be added to individual accounts.

5.2.7 Personalization and Customization

Requiring users to register an account enables their accounts to be personalized and customized to their liking. The DaaS platform would be personalized to each unique user to provide accurate recommendations. The DaaS platform would have a customization feature where users could change the interface based on their preferences.

5.2.8 Summary

The characteristics that Jittrapirom et al. (2017) outlined for MaaS inspired DaaS's core characteristics, summarized in Table 28 from the user's perspective. Orienting DaaS from the user's perspective is essential because DaaS aims to provide the optimal delivery service that is efficient and accessible to the user. DaaS should supply a convenient service that accommodates the user's wants and needs. The nine core characteristics for DaaS outlined in this section set up the background to define a DaaS framework in the following section.

Table 28: Core Characteristics of DaaS

Core Characteristic	Description
1. Integration of Products	DaaS platforms provide users with the ability to order from several different providers, and potentially within several different categories of goods, from one platform.
2. Payment Options	Users have to ability to choose from a variety of payment options within the DaaS platform.
3. Digital Platform	A DaaS app or website where users can view options for goods and services that can be delivered.
4. Multiple Actors	A DaaS system is comprised of several actors who work in tandem to provide delivery services. Four main actors include the DaaS company, producer, deliverer, and user. Several additional entities, such as technology providers or vehicle fleets, could also become part of the system to create an optimal business model.
5. Use of Technologies	Technologies that enable DaaS could include apps or websites that have added customer value, such as simplifying the user's experience or providing various delivery options. Forms of autonomous and drone delivery and other emerging transportation technologies can enable DaaS as well.
6. Demand Orientation	DaaS is centered around the user's experience and caters to the demand of the user.
7. Registration Requirement	The user typically must register to join a DaaS platform. Registration may be free or require a subscription payment.
8. Personalization	A DaaS platform is designed to cater to the user's preferences by developing past searches and orders into a unique personalized interface.
9. Customization	Customization allows users to shape a DaaS interface to their liking.

5.3 DaaS Framework

The characteristics of a DaaS system and data collected from the survey about customer perception of delivery services can be used to define a DaaS model's framework further. The survey was conducted to identify factors that people disliked and were frustrated with in delivery services. Recognizing these current frustrations made it possible to develop a delivery service model that could reduce these frustrations by enhancing the customer's experience and the omni-channel supply chain. MOEs for DaaS were developed based on the customer's current delivery frustrations because the purpose of DaaS is to improve the customer's delivery experience. The characteristics and MOEs of DaaS were then used to define a comprehensive definition and overall framework for DaaS.

5.3.1 Measures of Effectiveness

The success of a DaaS system that has the previously defined characteristics can be measured by the factors that survey respondents indicated as important to them. Many survey respondents stated that they were unsatisfied with current delivery services and desired delivery services that were user-friendly, intuitive, cost-effective, accessible, efficient, convenient, and time-effective. Therefore, the following MOEs for DaaS were developed from the survey's conclusions to measure the factors users look for in an optimal delivery service.

5.3.1.1 User-Centric

The survey showed a desire for delivery services that can cater to individual needs, especially since the survey revealed that the general use of delivery services increased because of the COVID-19 pandemic. Respondents indicated that they frequently experienced frustrations with current delivery services and desired a convenient delivery service overall. DaaS seeks to provide a user-centric service to eliminate any delivery aspects that cause an adverse reaction in users, such as those indicated in the survey. A DaaS system will be user-centric if the platform

and services are user-friendly and intuitive. A user should not have any frustrations when using DaaS. In addition, the user-centricity of a DaaS system can be evaluated by each of the following MOEs (cost-effective, accessible, efficient, and convenient) because they ultimately promote a user-centric service.

5.3.1.2 Cost-Effective

High delivery fees were among the most frequent frustrations that survey respondents reported, especially for third-party app restaurant delivery. High fees could likely be the reason why a significant proportion of survey respondents said that they planned to decrease their frequency of use of third-party delivery apps after the pandemic ends. They may believe that the cost of third-party apps is too high for the service they provide. People likely will not want to pay for a service if the cost is greater than the service's value. To avoid losing customers, DaaS should provide a cost-effective service that increases the appeal of delivery to the user.

5.3.1.3 Accessible

Compared to survey respondents who lived in more urban areas, respondents who lived in more rural areas indicated that they were significantly less satisfied with delivery services available to them. Respondents who lived outside of town or city limits described that they were frustrated by the lack of delivery options, especially from restaurants, and were frustrated with packages being delivered to the wrong address. Lack of delivery service accessibility is the cause of these frustrations, and therefore, DaaS seeks to provide a more accessible delivery service. Innovative technologies, such as drones, can be integrated with DaaS systems to make it easier and faster to deliver to rural areas.

5.3.1.4 Efficient

In addition to lack of accessibility, survey respondents indicated that late deliveries were a frequent frustration, especially for package deliveries. Late deliveries likely could be a result of inefficient delivery systems. DaaS strives to provide the most efficient delivery service that is possible. Integrating emerging technologies with DaaS and within the omni-channel supply chain could increase DaaS' delivery services efficiency. Efficient delivery services could also correspond to time savings because people often use delivery services to save time. For example, having groceries delivered rather than physically going to the grocery store could save a significant amount of time. DaaS combined with innovative technology could improve delivery efficiency and save time for users.

5.3.1.5 Convenient

Survey respondents indicated that they mainly used delivery services because of their convenience, and the pandemic intensified their desire for convenient delivery services. When people do not want to cook or go out to a restaurant, whether it be due to time constraints or safety concerns from the pandemic, they can order food for delivery. People are likely willing to pay for delivery fees because of the convenient service that food delivery provides. Similarly, people want grocery delivery convenience so that they do not have to take the time out of their busy lives to drive to the store and pick out each grocery item themselves. They likely want the convenience of having their grocery items delivered to their doorstep at the click of a button. People also like the convenience of package delivery so they can conveniently order all of their goods from their computer or phone, rather than having to drive to several different stores to

purchase each item they need. DaaS can cater to the convenience that users look for in a delivery service. DaaS will provide greater convenience than what is currently offered by increasing delivery accessibility and efficiency. The omni-channel supply chain services can be enhanced by DaaS and streamlined to the user via a single user-centric platform.

5.3.1.6 Summary

A DaaS system's success can be measured by how well it mitigates frustrations that people frequently experience in delivery services, such as those concluded from the survey. A successful DaaS model should enhance the omni-channel supply chain by providing a user-centric service. The DaaS MOEs derived from frustrations indicated in the survey are summarized in Table 29. The integration of emerging technologies, such as drones or autonomous vehicles, with DaaS and within the omni-channel supply chain can enhance the supply chain and the user's experience. DaaS characteristics and MOEs of a DaaS system are used to develop a comprehensive definition of DaaS in the following section.

Table 29: DaaS Measures of Effectiveness (MOEs)

MOE	Description
1. User-Centric	A DaaS model's main priority is the user because user satisfaction often correlates to user retention. The user requires the following metrics to be met to continue using the DaaS platform's service. The user also looks for technology that is simple and user-friendly.
2. Cost-Effective	The ability to minimize delivery costs is essential to the DaaS model. The cost of delivery service should be equivalent to the service that is provided.
3. Accessible	A DaaS system should provide the same level of delivery service to users, regardless of location.
4. Efficient	The user expects delivery services to be efficient. Deliveries should arrive on time, and the DaaS platform should be transparent and accurate with delivery time estimates.
5. Convenient	DaaS should offer convenient delivery options to the user.

5.3.2 Delivery as a Service Definition

The above characteristics and MOEs were used to develop the following definition: DaaS involves multiple actors who work collectively to provide a user-centric and technology-enabled delivery service accessible on demand. The "service" component of DaaS can be seen through the user-centric aspects in several additional forms, such as increased convenience, ease of use, safety, cost savings, or other services that may not be found elsewhere.

Figure 21 describes the framework of a DaaS model in detail. In a DaaS model, a DaaS company will provide a technology platform that can be used by the user, deliverer, and producer to facilitate goods delivery from the producer to the user. DaaS technology has a backend software system that supports the user-facing frontend app or website platform. The user will interact with the DaaS frontend platform to order items for delivery. Whether it be an individual or a form of delivery technology, the deliverer will exchange information about the delivery with the frontend platform to learn where to bring the delivery. The deliverer will also exchange information with the DaaS platform to inform both the user and the producer of the delivery status. The producer will exchange information with the DaaS platform to receive delivery orders and to provide updates to the user and the deliverer. Overall, each component of the DaaS model works in conjunction to seamlessly integrate with the omni-channel supply chain and provide the optimal level of delivery service to the user.

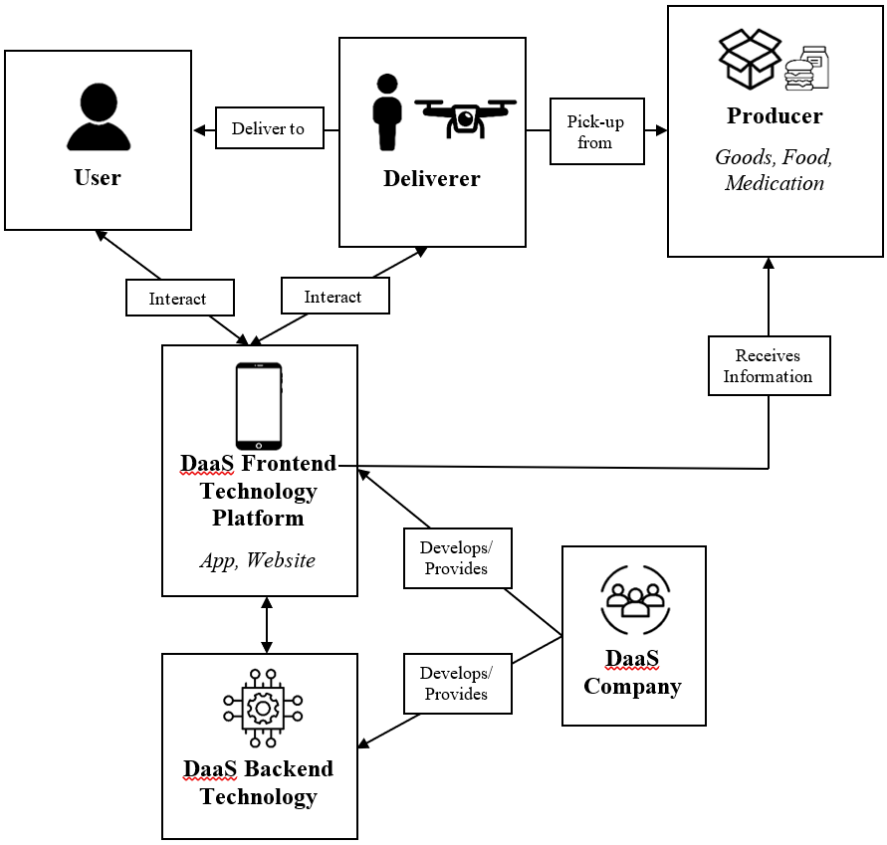


Figure 21: DaaS Model

5.4 DaaS and the Omni-Channel Supply Chain

A comprehensive definition of DaaS has been defined by identifying DaaS characteristics that are baseline requirements for the platform and how a DaaS model's success can be measured. MOEs were developed from a survey that indicated people's perceived delivery service quality in the NRV. The survey highlighted delivery factors that caused dissatisfaction and frustrations with delivery services which were then used to establish MOEs that would reduce these frustrations in a DaaS model. These characteristics and MOEs were then used to establish a definition and framework of DaaS. This section describes how the DaaS model can directly integrate with and enhance the omni-channel supply chain.

Figure 22 displays how DaaS could interact with the omni-channel supply chain. DaaS would be integrated similarly to how MaaS was integrated within transportation services. MaaS added a new level of customer interaction with transportation services that allowed customers to interact with any form of transportation through a single platform that acted as a communication point. DaaS will enable the customer to utilize any delivery services in the omni-channel supply chain through the DaaS platform. The DaaS platform improves the customer's delivery experience because the customer only needs to interact with a single app or website rather than a separate platform for each channel. Likewise, each omni-channel supply chain channel and actors within each channel would communicate with the customer through the DaaS platform.

The producer and deliverer will use the DaaS platform to exchange information with the customer and receive information about the delivery request. Integrating a DaaS platform into the omni-channel supply chain increases the overall efficiency, accessibility, and convenience of delivery because there is only one point of interaction. The DaaS platform facilitates communication between the customer and every channel and actor in the supply chain. Additionally, autonomous and drone technology can further improve the speed and capacity of the DaaS delivery process.

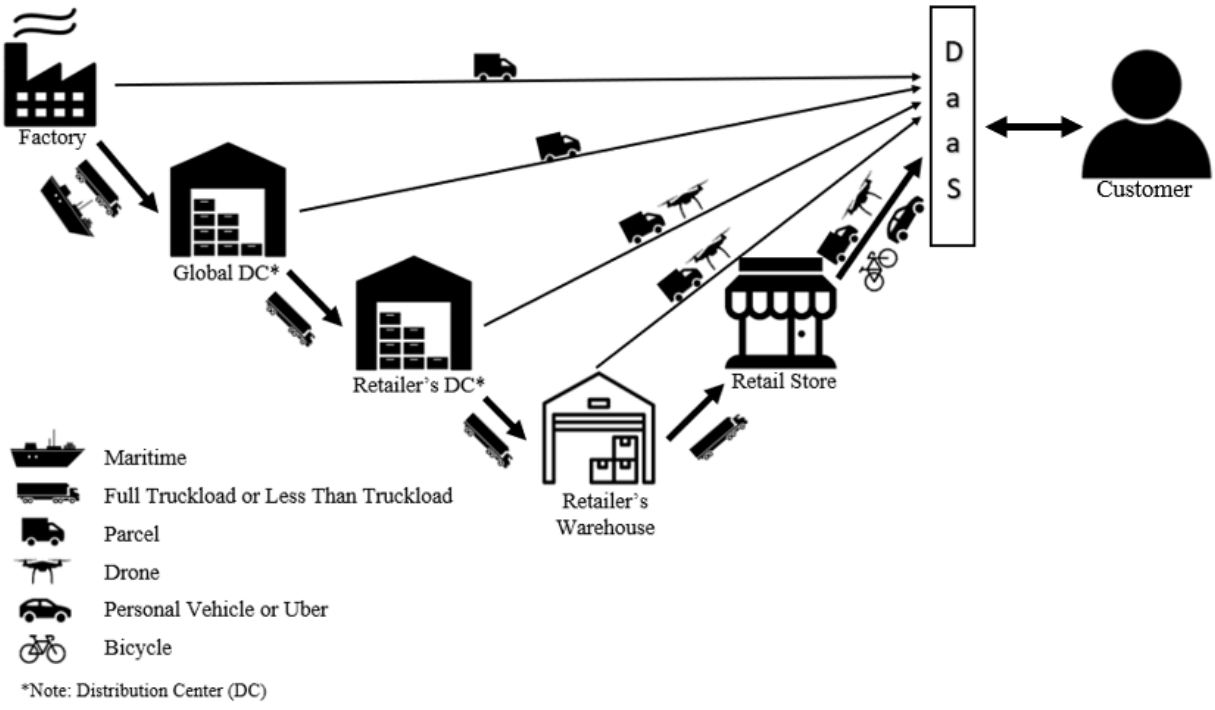


Figure 22: DaaS in the Omni-Channel Supply Chain, modified from Horvath (2020)

5.4.1 Omni-Channel Experience Dimensions

The literature review described Shi et al.'s (2020) five omni-channel experience dimensions: connectivity, integration, consistency, flexibility, and personalization (Table 2). Each experience dimension was defined to represent the customer's experience in the omni-channel supply chain. A successful DaaS model should improve each omni-channel experience dimension because the purpose of DaaS is to improve customer experience and enhance the omni-channel supply chain. A DaaS system inherently connects and integrates each channel in the supply chain. DaaS has the potential to increase the consistency that customers experience when ordering delivery because the DaaS platform should provide an efficient and accessible service across all channels. DaaS can also enhance flexibility because customers should be able to manage their delivery orders within the platform. DaaS should improve the customer experience of personalized attention because the DaaS platform improves connectivity between the user and each channel in the omni-channel supply chain. A DaaS model can enhance the overall omni-channel supply chain to the extent that it meets the customer's expectations defined by Shi et al. (2020).

5.5 Conclusion

A DaaS model improves the current state of practice and enhances the omni-channel supply chain by increasing the accessibility and efficiency of delivery. The potential for DaaS to reduce the cost significantly and increase the scale of delivery makes it more available to the greater population. In addition, integrating emerging delivery technologies to optimize the DaaS model can improve efficiency and deliver goods at a faster rate.

Emerging drone and autonomous vehicle technologies will make expanding on-demand DaaS services more feasible because they can improve efficiency and accessibility. For example, a drone can deliver a package within a shorter time frame than a traditional delivery vehicle that must make several stops in one trip. A DaaS model with a large variety of vehicles in its fleet can optimize the type of vehicle used for each delivery based on its constraints. For example, if there is a sudden influx of orders that must all be delivered within the same timeframe, it may be the most cost and time effective to deploy 20 drones rather than 20 vehicles. Alternatively, if there are many orders in a single suburban development, it may be most efficient to deploy a single autonomous vehicle.

The DaaS platform must also leave room for further scalability and optimization. DaaS can increase value for the user to a greater degree by adding new delivery options, expanding to other regions, and optimizing through emerging technology integration. Scalability not only includes increasing delivery options within a designated location but could entail expanding service to nearby towns and cities, for example. Scalability could also involve broadening the omni-channel supply chain, which could mean, for instance, that an item from a storefront in a different state, or even another country, if DaaS reaches a global scale, could be offered for delivery through the DaaS platform. Scaling the DaaS platform in a way that also optimizes it is imperative to providing a cost-effective and efficient service.

Chapter 6: Conclusion

6.1 Overview

This chapter summarizes the findings of this study and evaluates its potential impacts on the delivery industry. Conclusions about the survey results and the potential extent of DaaS' impact on the delivery ecosystem are also presented. To avoid complications during DaaS implementation, possible foreseen challenges DaaS could present will be explored as well. This study's limitations will be considered, and potential areas for future work will be discussed.

6.2 Summary

The COVID-19 pandemic created a greater need for service-based delivery models and accelerated delivery technology innovation. There is a growing need to improve delivery services to meet user's needs better because the delivery industry is growing at an unprecedented rate. A survey about delivery preferences in the NRV was conducted to determine where current delivery services failed to meet customer needs. The purpose of the survey was to investigate the validity of several hypotheses related to the following topics:

- Location and Delivery Frustrations
- Vehicle Ownership and Delivery Frequency
- Delivery Satisfaction
- Delivery Service Frequency of Use Before, During, and After the Pandemic
- Types of Food Delivery Frustrations
- Food Delivery Preferences
- Types of Package Delivery Frustrations
- Differences and Similarities between Food and Package Delivery Frustrations
- Reasons People Use Delivery Services

The survey established perceived delivery service quality in the NRV and validated customer preferences about delivery services by considering the impact of the COVID-19 pandemic. The survey also evaluated the degree to which individuals experienced frustrations when ordering food or package delivery. Levels of satisfaction with delivery services and how perceived service quality changed by location and vehicle ownership were examined. All the circumstances and opinions analyzed by the survey were used to identify what users ultimately wanted in a delivery service.

The purpose of the analysis was to test each hypothesis to evaluate customer perception of delivery services in the NRV and answer the following research questions: *What delivery characteristics do customers value and how can these characteristics be used to define DaaS MOEs and a DaaS framework that also enhances the omni-channel supply chain?* The survey data revealed that individuals desire more efficient and accessible delivery services that reduce late deliveries and increase convenience. One of the most notable conclusions from the survey analysis was that the use of delivery services not only increased during the pandemic but will likely experience a permanent increase in usage. Major findings from the survey are that people desire the following factors in an ideal delivery service:

- User-friendly and intuitive technology
- Reasonable cost
- Accessibility for everyone

- Efficiency to mitigate frustrations
- A convenient service
- Time savings

Increased delivery applications of innovative delivery technologies and a growth in demand for on-demand delivery services couple to cause existing delivery models to evolve. This study detailed a DaaS model and framework to show how the current state of delivery could be expanded to promote a user-centric service. The development of DaaS largely stems from the evolution of delivery services resulting from the COVID-19 pandemic. DaaS can increase the efficiency and accessibility of delivery services by integrating technologies such as apps, drones, and autonomous vehicles. This study also applied qualitative elements of a MaaS system to establish core characteristics of DaaS and to display how DaaS can integrate with the omni-channel supply chain. Existing MaaS structures inspired the overall DaaS construct, and methods for measuring a DaaS system's success were derived from survey conclusions. The customer perception survey's findings showed what people value in delivery services and how the pandemic influenced people's delivery service perceptions.

The purpose of DaaS is to mitigate delivery frustrations and provide a seamless service. Therefore, the survey conclusions were applied to determine what MOEs could be used for a DaaS business model to ensure DaaS meets user expectations. MOEs for DaaS were established to provide a basis for measuring if DaaS was meeting user expectations in future implementations. The DaaS system was designed to easily integrate with the existing omni-channel supply chain to enhance current delivery services. DaaS MOEs can later be used to measure customer's perceived service quality of a DaaS platform. Emerging technologies that can operate within the omni-channel supply chain present the potential to optimize DaaS and the overall supply chain further. DaaS looks at delivery from a flexible and more user-focused standpoint that will truly evolve the delivery industry.

6.3 Conclusions

The COVID-19 pandemic had an unprecedented impact on everyone's lives and created an environment where delivery became a necessary service for many. The pandemic created a need to provide a better delivery service to customers, which accelerated innovations within the delivery industry as demand grew exponentially. DaaS can provide an improved delivery service that will reduce the current frustrations that many people are experiencing. Through the acceleration of delivery advancements caused by the pandemic, there is a need for a customer-centric delivery service that can integrate with and enhance the existing omni-channel supply chain. DaaS has the potential to significantly change the current delivery ecosystem through increased delivery accessibility and efficiency. Goods can be brought to users at a faster rate and on a larger scale. Autonomous vehicle and drone delivery technologies can significantly reduce the cost while correspondingly reducing the time of delivery.

Delivery models are evolving in a parallel manner to how mobility models have progressed to integrate MaaS. DaaS-related ideas already appear in the market but are a new and disruptive concept that is still in its infancy and will grow and expand in an unprecedented way. Current examples of ideas correlated to DaaS include, but are not limited to, flat-rate subscription and third-party delivery models. While both provide user-centric delivery services, they should be further scaled and optimized to fit a DaaS model. Autonomous vehicle and drone delivery testing include DaaS characteristics like fast-delivery, user-centric platforms, and technology use.

However, they still lack full deployment and interoperability with other DaaS actors. While most of these autonomous and drone delivery examples are still stand-alone entities, it is only a matter of time until they become integrated with other delivery services to enhance the omni-channel supply chain. DaaS should improve the level of service for users, especially, but also for producers and deliverers. The DaaS framework was designed to seamlessly integrate into existing systems because DaaS is meant to enhance the supply chain by making information more accessible to all actors. DaaS was also intended to promote scaling and optimization, and easy integration with emerging transportation technologies. This study introduced a new delivery concept—DaaS—that can improve customer satisfaction with delivery services and enhance the omni-channel supply chain. DaaS is a concept that is needed for people to thrive in modern times and brings the opportunity to provide added benefits to all users.

6.3.1 Potential DaaS Challenges

Challenges are inherent in new concepts, and DaaS certainly is not an exception; however, the long-term positive outcomes outweigh current complexities. While it is still partly unknown is how DaaS will develop as market penetration expands, particular challenges can be predicted based on those presented in Hensher (2017) and Jittrapirom et al. (2017) for MaaS. One of the main challenges is DaaS's scalability and implications that can arise from a full-scale service. Since DaaS is based on providing on-demand delivery services, and society is not yet sure how emerging technologies will affect the delivery ecosystem, new challenges are presented. Traffic patterns could change once DaaS is available on a large scale, and more people order goods to their homes rather than going to the store. DaaS could create an increase in congestion on roadways, and it could also lead to new forms of congestion such as low altitude air traffic or sidewalk traffic from drones and SADR, respectively. DaaS creates questions such as: will people stop going to the store entirely, and could storefronts be re-zoned to warehouses? A risk that stems from scalability is the uncertainty of delivery demand and capacity. Since DaaS provides increased services, it risks the loss of users due to vast increases in cost. In other words, DaaS must have enough capacity to meet society's demand without exceeding a reasonable price for the service. Therefore, DaaS must consider the implications of the delivery of five packages per day versus 20 packages per hour are highly different and will likely be reflected in platform or delivery fees. The cost to use DaaS must be reasonable enough at the beginning of implementation so that users are willing to sign-up. Once the DaaS platform grows in scale, fees could be reduced, and service could be increased.

The nature of DaaS involving multiple actors within the omni-channel supply chain presents potential challenges in stakeholder collaboration. Delivery companies may feel the need to develop a DaaS model in-house, rather than outsourcing to technology companies, for example, to avoid revealing business secrets. Any reluctance for DaaS platforms to have full interoperability could also slow progress. This potential lack of willingness to work together could ultimately delay comprehensive DaaS model implementation. Another factor that could create DaaS deployment delays is an initial hesitation in investing in emerging delivery technologies due to novelty and high cost.

6.4 Limitations

This study has several limitations due to the nature of conducting a stated preference survey and developing the framework for a new concept. The survey was only conducted with people who reside in the NRV in Virginia. Therefore, similar results and conclusions may not be

found if the survey were to be conducted elsewhere, such as in a large city or an extremely rural area. Also, the population in the NRV largely consists of college and university students, which was reflected in the sample population distribution of survey respondents. The large proportion of respondents who were under the age of 30 could potentially skew the results. Another limitation in the analysis could be that the survey did not initially ask what delivery services respondents had access to. Therefore, the analyzed items could not be compared to what individuals could access depending on where they lived. If a future similar study were to be conducted, the survey should identify what delivery services individuals can access.

Limitations that pertain to DaaS mainly arise from the inherent difficulty of defining a concept that does not yet exist. DaaS is a service that has not yet been fully implemented, resulting in a shortage of knowledge as to how DaaS might interact with the existing delivery ecosystem. This study defined how the DaaS framework might interact with the omni-channel supply chain to the best of the current state of knowledge. However, technology is constantly changing and advancing, which could impact DaaS integration in an unforeseeable way. The best way to evaluate how DaaS will work with the existing delivery ecosystem is to implement DaaS in practice.

6.5 Future Work

There are several areas for future work, such as analyzing new challenges that DaaS presents to the vehicle routing problem. DaaS is designed to optimize delivery, but the challenges that it can present must be analyzed to determine methods to reduce potential negative impact. Another area for future research is modeling the optimal way to deliver a product depending on the transportation mode available and the user's location. In some cases, a drone might be best if the product is small or if the delivery needs to be made to a rural area. In other cases, a deliverer might be necessary, depending on the product that is being delivered. Researching how DaaS affects the vehicle routing problem and how DaaS can interact with the delivery ecosystem to deliver a product via the optimal transportation mode will help find the most advantageous ways to scale DaaS models.

Another area for future work could be researching users' delivery preferences and choices within a larger population. This study conducted the survey in the NRV, Virginia, which has a relatively small population. In addition, the demographic distribution in the NRV may not apply to other areas of the world. Therefore, a more extensive survey could further classify what people want to see in a delivery service. In this study, a stated preference survey was conducted. Conducting a revealed preference survey within a DaaS interface is an area for future work that could identify users' actual habits and preferences. This research provides the background knowledge to develop a DaaS business plan. A revealed preference study would highlight DaaS user acceptance, and then the findings could be modeled to show areas where DaaS could be further improved. While there is still much that is unknown about how DaaS will change the current delivery ecosystem, it is known that DaaS can solve many practical challenges.

References

Ackerman, E. (2020, April 3). *Zipline Wants to Bring Medical Drone Delivery to U.S. to Fight COVID-19*. IEEE Spectrum. https://spectrum.ieee.org/automaton/robotics/drones/zipline-medical-drone-delivery-covid19

Amazon Prime delivery experiencing big delays due to COVID-19 [WWW Document], 2020. www.retailcustomerexperience.com. URL https://www.retailcustomerexperience.com/news/amazon-prime-delivery-experiencing-big-delays-due-to-covid-19/ (accessed 4.18.20).

Amazon.com: Amazon Prime. (2020, April 18). https://www.amazon.com/amazonprime?_encoding=UTF8&ref_=nav_logo_prime_join

Blacksburg Transit. (2021, February 16). Blacksburg Transit. http://ridebt.org/

Bogaisky, J., 2020. In this City, Toilet Paper Comes from the Sky Thanks to Google's Drones [WWW Document]. Forbes. URL https://www.forbes.com/sites/jeremybogaisky/2020/04/09/toilet-paper-drone-google-wing-virginia/ (accessed 4.18.20).

Brunner, G., Szebedy, B., Tanner, S., & Wattenhofer, R. (2019). The Urban Last Mile Problem: Autonomous Drone Delivery to Your Balcony. *2019 International Conference on Unmanned Aircraft Systems (ICUAS), Atlanta, GA, USA*, 1005–1012. https://doi.org/10.1109/ICUAS.2019.8798337

CDC. (2020, April 13). *Coronavirus Disease 2019 (COVID-19) – Prevention & Treatment*. Centers for Disease Control and Prevention. https://www.cdc.gov/coronavirus/2019-ncov/prevent-getting-sick/prevention.html

Census profile: New River Valley Planning District Commission PUMA, VA. (2021). Census Reporter. http://censusreporter.org/profiles/79500US5151040-new-river-valley-planning-district-commission-puma-va/

Cohen, T., Jones, P., 2020. Technological advances relevant to transport – understanding what drives them. Transp. Res. Part A: Policy Pract. 135, 80–95. https://doi.org/10.1016/j.tra.2020.03.002

Dorling, K., Heinrichs, J., Messier, G. G., & Magierowski, S. (2017). Vehicle Routing Problems for Drone Delivery. *IEEE Transactions on Systems, Man, and Cybernetics: Systems*, *47*(1), 70–85. https://doi.org/10.1109/TSMC.2016.2582745

Fairchild, A. M. (2014). Extending the Network: Defining Product Delivery Partnering Preferences for Omni-channel Commerce. *Procedia Technology*, *16*, 447–451. https://doi.org/10.1016/j.protcy.2014.10.111

Fink, A. (2002). *How to Ask Survey Questions* (2nd ed.). SAGE.

Freytas-Tamura, K. de, & Singer, J. E. (2020, March 19). The Delivery Workers Who Risk Their Health to Bring You Food. *The New York Times*. https://www.nytimes.com/2020/03/19/nyregion/coronavirus-nyc-delivery-workers.html

Fromm, J., 2019. The Evolution of Third-Party Delivery [WWW Document]. Forbes. URL https://www.forbes.com/sites/jefffromm/2019/06/20/the-evolution-of-third-party-delivery/ (accessed 4.16.20).

Grashuis, J., Skevas, T., & Segovia, M. S. (2020). Grocery Shopping Preferences during the COVID-19 Pandemic. *Sustainability*, *12*(13), 5369. https://doi.org/10.3390/su12135369

Guglielmo, C. (2013). *Turns Out Amazon, Touting Drone Delivery, Does Sell Lots of Products That Weigh Less Than 5 Pounds*. Forbes.

https://www.forbes.com/sites/connieguglielmo/2013/12/02/turns-out-amazon-touting-drone-delivery-does-sell-lots-of-products-that-weigh-less-than-5-pounds/
Hensher, D.A., 2017. Future bus transport contracts under a mobility as a service (MaaS) regime in the digital age: Are they likely to change? Transp. Res. Part A: Policy Pract. 98, 86–96. https://doi.org/10.1016/j.tra.2017.02.006
Hirschberg, C., Rajko, A., Schumacher, T., & Wrulich, M. (2016). The changing market for food delivery. *McKinsey & Company*.
Horvath, L. (2020, November 18). *Tech on Tap: Signed, sealed, delivered: Package delivery during the age of COVID*.
Jennings, D., & Figliozzi, M. A. (2019). A Study of Sidewalk Autonomous Delivery Robots and Their Potential Impacts on Freight Efficiency and Travel. *Journal of the Transportation Research Board*, *2673*(6), 317–326.
Jennings, D., & Figliozzi, M. A. (2020). A Study of Road Autonomous Delivery Robots and Their Potential Impacts on Freight Efficiency and Travel. *Journal of the Transportation Research Board*, *2674*(9), 1019–1029.
Jittrapirom, P., Caiati, V., Feneri, A.-M., Ebrahimigharehbaghi, S., González, M. J. A., & Narayan, J. (2017). Mobility as a Service: A Critical Review of Definitions, Assessments of Schemes, and Key Challenges. *Urban Planning*, *2*(2), 13–25. https://doi.org/10.17645/up.v2i2.931
June 2020 Online Grocery Scorecard: Growth in Sales & HH penetration continues. (2020, July 6). Brick Meets Click. https://www.brickmeetsclick.com/june-2020-online-grocery-scorecard--growth-in-sales---hh-penetration-continues
Kamargianni, M., Li, W., Matyas, M., & Schäfer, A. (2016). A Critical Review of New Mobility Services for Urban Transport. *Transportation Research Procedia*, *14*, 3294–3303. https://doi.org/10.1016/j.trpro.2016.05.277
Kamargianni, M., & Matyas, M. (2017). The Business Ecosystem of Mobility-as-a-Service. *96th Transportation Research Board (TRB) Annual Meeting*, 8–12.
Li, Y., May, A., & Cook, S. (2019). Mobility-as-a-Service: A Critical Review and the Generalized Multi-modal Transport Experience. In P.-L. P. Rau (Ed.), *Cross-Cultural Design. Culture and Society* (Vol. 11577, pp. 186–206). Springer International Publishing.
Mann Whitney U Test (Wilcoxon Rank Sum Test). (2017, May 4). https://sphweb.bumc.bu.edu/otlt/mph-modules/bs/bs704_nonparametric/bs704_nonparametric4.html
Melacini, M., Perotti, S., Rasini, M., & Tappia, E. (2018). E-fulfilment and distribution in omni-channel retailing: A systematic literature review. *International Journal of Physical Distribution & Logistics Management*, *48*(4), 391–414. https://doi.org/10.1108/IJPDLM-02-2017-0101
Morganti, E., Seidel, S., Blanquart, C., Dablanc, L., & Lenz, B. (2014). The Impact of E-commerce on Final Deliveries: Alternative Parcel Delivery Services in France and Germany. *Transportation Research Procedia*, *4*, 178–190. https://doi.org/10.1016/j.trpro.2014.11.014
Mosquera, A., Olarte Pascual, C., & Juaneda Ayensa, E. (2017). Understanding the customer experience in the age of omni-channel shopping. *Icono14*, *15*(2), 166–185.

Nuro R2 Autonomous Delivery Vehicle Gets Green Light [WWW Document], 2020. Robot Rep. URL https://www.therobotreport.com/nuro-r2-autonomous-delivery-vehicle-gets-green-light/ (accessed 4.18.20).

Nuro — Product [WWW Document], 2020. Nuro. URL https://nuro.ai/product (accessed 4.18.20).

Parasuraman, A., Zeithaml, V., & Berry, L. (1985). A Conceptual Model of Service Quality and Its Implications for Future Research. *Journal of Marketing*, *49*, 41–50. https://doi.org/10.2307/1251430?uid=25404&uid=3737976&uid=2&uid=5910312&uid=3&uid=25392&uid=67&uid=62&sid=21103987774637ource=gbs_api

Parasuraman, A., Zeithaml, V., & Berry, L. (1988). Servqual: A Multiple-Item Scale For Measuring Consumer Perc. *Journal of Retailing*, *64*(1), 12.

Piotrowicz, W., & Cuthbertson, R. (2014). Introduction to the Special Issue Information Technology in Retail: Toward Omnichannel Retailing. *International Journal of Electronic Commerce*, *18*(4), 5–16. https://doi.org/10.2753/JEC1086-4415180400

Pishue, B. (2020). *COVID-19's Impact on Freight: An Analysis of Long-Haul Freight Movement During a Pandemic*. INRIX.

Pony.ai Raises $400 Million from Toyota to Accelerate Autonomous Driving Development [WWW Document], 2020. GlobeNewswire. URL http://www.globenewswire.com/news-release/2020/02/26/1990586/0/en/Pony-ai-Raises-400-Million-from-Toyota-to-Accelerate-Autonomous-Driving-Development.html (accessed 4.18.20).

Qualtrics XM - Experience Management Software. (2021). Qualtrics. https://www.qualtrics.com/

R: The R Project for Statistical Computing. (2021). https://www.r-project.org/

Radford Transit. (2021, February 16). Radford Transit. http://www.radfordtransit.com/

Sample Size Calculator: Understanding Sample Sizes. (2021). SurveyMonkey. https://www.surveymonkey.com/mp/sample-size-calculator/

Saskia, S., Mareï, N., & Blanquart, C. (2016). Innovations in e-grocery and Logistics Solutions for Cities. *Transportation Research Procedia*, *12*, 825–835. https://doi.org/10.1016/j.trpro.2016.02.035

Sawadsitang, S., Niyato, D., Tan, P.-S., Wang, P., 2019. Joint Ground and Aerial Package Delivery Services: A Stochastic Optimization Approach. IEEE Transactions on Intelligent Transp. Syst. 20, 6, 2241-2254. https://doi.org/10.1109/TITS.2018.2865893.

Shi, S., Wang, Y., Chen, X., & Zhang, Q. (2020). Conceptualization of omnichannel customer experience and its impact on shopping intention: A mixed-method approach. *International Journal of Information Management*, *50*, 325–336. https://doi.org/10.1016/j.ijinfomgt.2019.09.001

Singh, S., 2019. The Soon to Be $200B Online Food Delivery is Rapidly Changing the Global Food Industry [WWW Document]. Forbes. URL https://www.forbes.com/sites/sarwantsingh/2019/09/09/the-soon-to-be-200b-online-food-delivery-is-rapidly-changing-the-global-food-industry/ (accessed 4.16.20).

Szymkowski, S. (2020a, April 9). *Nuro Will Start Self-Driving Delivery Vehicle Services in California*. Roadshow. https://www.cnet.com/roadshow/news/nuro-test-self-driving-delivery-vehicles-coronavirus-california/

Szymkowski, S. (2020b, April 20). *Contactless Delivery Using Self-Driving Cars Coming to Irvine, CA Amid Coronavirus*. Roadshow. https://www.cnet.com/roadshow/news/autonomous-grocery-delivery-toyota-pony-ai-irvine-california-coronavirus/

Ulmer, M. W., & Streng, S. (2019). Same-Day delivery with pickup stations and autonomous vehicles. *Computers & Operations Research*, *108*, 1–19. https://doi.org/10.1016/j.cor.2019.03.017

What is MaaS?, 2020. MAAS-Alliance. URL https://maas-alliance.eu/homepage/what-is-maas/ (accessed 4.16.20).

Wing [WWW Document], 2020. Wing. URL https://wing.com/ (accessed 4.18.20).

Yeo, V. C. S., Goh, S.-K., & Rezaei, S. (2017). Consumer experiences, attitude and behavioral intention toward online food delivery (OFD) services. *Journal of Retailing and Consumer Services*, *35*, 150–162. https://doi.org/10.1016/j.jretconser.2016.12.013

Appendix A: Survey

The following questions will give you an opportunity to tell us more about your experience with delivery in the New River Valley (counties of Montgomery, Pulaski, Floyd, and Giles, and the independent city of Radford).

Please answer openly and truthfully.
This survey is intended for people located in the New River Valley of ages 18+.

Default Question Block

Q2 How many years have you lived in the New River Valley (counties of Montgomery, Pulaski, Floyd, and Giles, and the independent city of Radford)?

- ◯ Less than 1 year
- ◯ 1-2 years
- ◯ 2-4 years
- ◯ 4-6 years
- ◯ More than 6 years

Q3 What county do you live in?

- ◯ Montgomery
- ◯ Pulaski

- ○ Floyd
- ○ Giles
- ○ City of Radford

Q4 Do you live within town or city limits (Blacksburg, Christiansburg, Floyd, Pembroke, Pearisburg, Narrows, Radford)?

- ○ Yes
- ○ No

Q5 Which category includes your age?

- ○ 18-24
- ○ 25-29
- ○ 30-34
- ○ 35-39
- ○ 40-44
- ○ 45-49
- ○ 50-54
- ○ 55-59
- ○ 60-64
- ○ 65+
- ○ Prefer not to say

Q6 What is your gender?

- ○ Male
- ○ Female
- ○ Other (specify) _____

- ○ Prefer not to say

Q7 What is the highest degree or level of education you have completed?

- ○ Some High School
- ○ High School
- ○ Associates Degree
- ○ Bachelor's Degree
- ○ Master's Degree
- ○ Ph.D. or higher
- ○ Trade School
- ○ Prefer not to say

Q8 What is your annual income?

- ○ Less than $25,000
- ○ $25,000 - $50,000
- ○ $50,000 - $100,000
- ○ $100,000 - $200,000
- ○ More than $200,000
- ○ Prefer not to say

Q9 Are you married?

- ○ Yes
- ○ No
- ○ Prefer not to say

Q10 How many children do you have?

- ○ None
- ○ 1
- ○ 2-4
- ○ More than 4
- ○ Prefer not to say

Q11 Do you own or have access to a vehicle?

- ○ Yes
- ○ No

Q12 Are you a College or University student?

- ○ Yes
- ○ No

Q13 Are you an undergraduate or graduate student?

- ○ Undergraduate
- ○ Graduate

Q14 How often did you use the following delivery services before the COVID-19 pandemic began?

	Never	Once a year	Once every 6 months	Once every 3 months	Once a month	Once every 2 weeks	Once per week	More than once per week

		Never	Once a year	Once every 6 months	Once every 3 months	Once a month	Once every 2 weeks	Once per week	More than once per week
Q14-1	3rd Party Restaurant Delivery Apps (e.g. Grubhub, UberEats, etc)	○	○	○	○	○	○	○	○
Q14-2	Grocery Delivery	○	○	○	○	○	○	○	○
Q14-3	Package Delivery (e.g. Amazon, Online Retail, etc.)	○	○	○	○	○	○	○	○

Q15 How often have you been using the following delivery services during the COVID-19 pandemic?

		Never	Once a year	Once every 6 months	Once every 3 months	Once a month	Once every 2 weeks	Once per week	More than once per week
Q15-1	3rd Party Restaurant Delivery Apps (e.g. Grubhub, UberEats, etc)	○	○	○	○	○	○	○	○
Q15-2	Grocery Delivery	○	○	○	○	○	○	○	○
Q15-3	Package Delivery (e.g. Amazon, Online Retail, etc.)	○	○	○	○	○	○	○	○

Q16 How often do you think you will use the following delivery services after the COVID-19 pandemic ends?

	Never	Once a year	Once every 6 months	Once every 3 months	Once a month	Once every 2 weeks	Once per week	More than once per week
Q16-1 3rd Party Restaurant Delivery Apps (e.g. Grubhub, UberEats, etc)	○	○	○	○	○	○	○	○
Q16-2 Grocery Delivery	○	○	○	○	○	○	○	○
Q16-3 Package Delivery (e.g. Amazon, Online Retail, etc.)	○	○	○	○	○	○	○	○

Q17 Are you generally satisfied or unsatisfied with delivery services in the NRV? Please describe why.

- ○ Satisfied
- ○ Neutral
- ○ Unsatisfied

Q18 Do you prefer to order food for delivery directly from a restaurant or do you prefer using 3rd party apps (e.g. Grubhub, UberEats, etc.)

- ○ Directly from a restaurant
- ○ 3rd party apps
- ○ I do not order food delivery from restaurants

Q19 Do you ever get frustrated trying to make a food delivery order? Rank how often you are frustrated.

Never	Very Rarely	Rarely	Neutral	Occasionally	Frequently	Very Frequently

		Never	Very Rarely	Rarely	Neutral	Occasionally	Frequently	Very Frequently
Q19-1	App or website was difficult to use	○	○	○	○	○	○	○
Q19-2	Food was too cold or too warm	○	○	○	○	○	○	○
Q19-3	Delivery was late	○	○	○	○	○	○	○
Q19-4	Items were missing from your order	○	○	○	○	○	○	○
Q19-5	Fees were too high	○	○	○	○	○	○	○

Q20 Do you ever get frustrated trying to order a non-food item (e.g. a package from Amazon)? Rank how often you are frustrated.

		Never	Very Rarely	Rarely	Neutral	Occasionally	Frequently	Very Frequently
Q20-1	App or website was difficult to use	○	○	○	○	○	○	○
Q20-2	Item was damaged or broken	○	○	○	○	○	○	○
Q20-3	Delivery was late	○	○	○	○	○	○	○
Q20-4	Items were missing from your order	○	○	○	○	○	○	○
Q20-5	Shipping fees were too high	○	○	○	○	○	○	○

Q21 How comfortable are you with having items delivered to you via the following?

	Extremely uncomfortable	Moderately uncomfortable	Slightly uncomfortable	Neither comfortable nor uncomfortable	Slightly comfortable
Q21-1 Drone	O	O	O	O	O
Q21-2 Autonomous Vehicle	O	O	O	O	O
Q21-3 Sidewalk Robot	O	O	O	O	O

Q22 Rank the reasons (from most to least important to you) for why you used delivery services before the pandemic?

Convenience

Safety

Time Savings

Comfort

Cost

Accessibility

Q23 Rank the reasons (from most to least important to you) for why you use delivery services?

Convenience

Safety

Time Savings

Comfort

Cost

Accessibility

Appendix B: HRPP Memo

Division of Scholarly Integrity and Research Compliance
Institutional Review Board
North End Center, Suite 4120 (MC 0497)
300 Turner Street NW
Blacksburg, Virginia 24061
540/231-3732
irb@vt.edu
http://www.research.vt.edu/sirc/hrpp

MEMORANDUM

DATE: February 5, 2021

TO: Kevin Patrick Heaslip II, Marcella Kaplan

FROM: Virginia Tech Institutional Review Board (FWA00000572, expires October 29, 2024)

PROTOCOL TITLE: Delivery Survey

IRB NUMBER: **21-099**

Based on the submitted project description and items listed in the Special Instructions section found on Page 2, the Virginia Tech Human Research Protection Program (HRPP) has determined that the proposed activity is not research involving human subjects as defined by HHS and FDA regulations.

Further review and approval by the Virginia Tech Human Research Protection Program (HRPP) is not required because this is not human research. This determination applies only to the activities described in the submitted project description and does not apply should any changes be made. If changes are made you must immediately submit an Amendment to the HRPP for a new determination. Your amendment must include a description of the changes and you must upload all revised documents. At that time, the HRPP will review the submission activities to confirm the original "Not Research" decision or to advise if a new application must be made.

If there are additional undisclosed components that you feel merit a change in this initial determination, please contact our office for a consultation.

Please be aware that receiving a "Not Research" Determination is not the same as IRB review and approval of the activity. You are NOT to use IRB consent forms or templates for these activities. If you have any questions, please contact the Virginia Tech HRPP office at 540-231-3732 or irb@vt.edu.

PROTOCOL INFORMATION:

Determined As:	**Not Research**
Protocol Determination Date:	**February 5, 2021**

ASSOCIATED FUNDING:

The table on the following page indicates whether grant proposals are related to this protocol, and which of the listed proposals, if any, have been compared to this protocol, if required.

SPECIAL INSTRUCTIONS:

This activity does not meet the definition of research, as defined within the Federal Policy for the Protections of Human Subjects. The primary goal and activity is to administer a survey to collect responses from people in the New River Valley about their opinion of delivery services. This activity does not meet the federal definition of research, since information collected will focus on delivery services in the New River Valley, and will not be generalizable.

Date*	OSP Number	Sponsor	Grant Comparison Conducted?

* Date this proposal number was compared, assessed as not requiring comparison, or comparison information was revised.

If this protocol is to cover any other grant proposals, please contact the HRPP office (irb@vt.edu) immediately.

Appendix C: Correlation Table

	Q2	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q14-1	Q14-2	Q14-3	Q15-1	Q15-2	Q15-3	Q16-1	Q16-2	Q16-3	Q17	Q19-1	Q19-2	Q19-3	Q19-4	Q19-5	Q20-1	Q20-2	Q20-3	Q20-4
Q4	0.38																												
Q5	0.65	0.43																											
Q6	0.19	0.08	0.29																										
Q7	0.49	0.21	0.58	0.19																									
Q8	0.60	0.37	0.78	0.26	0.60																								
Q9	-0.54	-0.35	-0.75	-0.23	-0.44	-0.70																							
Q10	0.56	0.43	0.77	0.20	0.38	0.63	-0.68																						
Q11	-0.34	-0.14	-0.21	-0.13	-0.24	-0.21	0.21	-0.19																					
Q12	0.70	0.45	0.82	0.30	0.55	0.78	-0.70	0.68	-0.22																				
Q14-1	-0.17	-0.24	-0.27	-0.01	-0.02	-0.08	0.25	-0.28	0.07	-0.19																			
Q14-2	0.03	0.04	0.16	-0.03	0.10	0.16	-0.12	0.15	0.07	0.10	0.20																		
Q14-3	0.10	0.05	0.15	0.08	0.17	0.20	-0.09	0.12	-0.06	0.18	0.21	0.13																	
Q15-1	-0.34	-0.35	-0.37	0.01	-0.20	-0.24	0.36	-0.39	0.22*	-0.29	0.56*	0.12	0.08																
Q15-2	0.05	-0.07	0.15	0.05	0.10	0.16	-0.13	0.12	0.12*	0.08	0.19	0.61*	0.15	0.18															
Q15-3	0.15	0.08	0.22	0.07	0.20	0.27	-0.18	0.19	-0.06	0.25	0.09	0.12	0.77*	0.10	0.24														
Q16-1	-0.22	-0.28	-0.25	-0.01	-0.08	-0.09	0.31	-0.28	0.18*	-0.18	0.66*	0.15	0.17	0.79*	0.20	0.16													
Q16-2	0.08	0.01	0.16	0.03	0.05	0.16	-0.09	0.14	0.15*	0.13	0.10	0.53*	0.08	0.14	0.72	0.16	0.25												
Q16-3	0.10	0.03	0.15	-0.01	0.15	0.19	-0.10	0.11	-0.04	0.18	0.16	0.13	0.87	0.10	0.21	0.82*	0.20	0.13											
Q17	0.19	0.19*	0.19	0.18	0.12	0.13	-0.11	0.13	-0.05	0.18*	-0.06	-0.03	0.00	-0.16	-0.03	-0.01	-0.07	0.01	-0.03										
Q19-1	0.08	0.02	0.09	0.13	0.12	0.08	-0.05	0.01	0.00	0.06	0.01	0.06	0.10	0.04	0.16	0.13	0.07	0.13	0.10	0.15									
Q19-2	0.01	0.02	0.08	0.19	0.14	0.09	-0.06	-0.02	-0.09	0.08	-0.02	0.01	0.05	0.06	0.05	0.10	0.08	0.03	0.05	0.17	0.48								
Q19-3	-0.05	-0.11*	-0.07	0.13	0.02	-0.01	0.07	-0.10	0.07	-0.05	0.17	0.10	0.02	0.18	0.13	0.01	0.19	0.07	-0.01	0.17	0.34	0.55							
Q19-4	0.00	0.00	0.02	0.10	0.06	0.03	-0.04	0.00	0.00	0.01	0.06	0.08	0.11	0.02	0.15	0.11	0.10	0.12	0.08	0.16	0.34	0.51	0.53						
Q19-5	-0.12	-0.14*	-0.21	0.05	-0.09	-0.11	0.16	-0.17	0.06	-0.11	0.19	0.05	0.00	0.27	0.09	0.01	0.22	0.03	-0.03	0.11	0.13*	0.18*	0.36*	0.22*					
Q20-1	0.11	0.13*	0.11	0.06	0.07	0.12	-0.14	0.07	0.01	0.11	-0.02	0.13	0.01	-0.08	0.00	0.02	-0.04	0.06	-0.01	0.12	0.37*	0.29	0.14	0.21	-0.05				
Q20-2	0.07	-0.02	0.03	0.04	0.07	0.14	-0.10	0.00	-0.02	0.02	0.01	0.07	0.06	-0.05	0.04	0.08	-0.02	0.04	0.04	0.14	0.39	0.37	0.30	0.30	0.05	0.56			
Q20-3	-0.06	0.01	0.01	0.09	-0.02	-0.01	0.00	-0.01	0.01	-0.01	0.08	0.16	0.11	0.07	0.16	0.08	0.11	0.09	0.07	0.21	0.35	0.24	0.23	0.26	0.22	0.44*	0.41*		
Q20-4	0.10	0.00	0.11	0.06	0.10	0.17	-0.16	0.04	0.02	0.07	0.09	0.11	0.11	-0.03	0.07	0.12	-0.01	0.06	0.10	0.11	0.30	0.32	0.26	0.31*	0.01	0.51*	0.67*	0.39*	
Q20-5	0.06	0.07	0.03	0.05	0.00	0.04	-0.08	0.06	0.06	0.03	-0.02	0.07	-0.10	-0.09	-0.02	-0.11	-0.07	0.00	-0.12	0.10	0.23	0.17	0.14	0.22	0.11*	0.52*	0.36*	0.39*	0.45*

*P-Value < 0.05

Note: Values with a Correlation of +/- 0.40 are Highlighted