TRAVEL MODE SELECTION WHEN
AUTONOMOUS TRANSPORTATION ATTRIBUTES
ARE INCLUDED AS CRITERIA

By

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I would like to thank my wife for her never-ending patience though all my incarnations, especially diving into one more degree when already eligible for an AARP card. I love you dearly and look forward to finally spending some time together.

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Abstract: Technology is rapidly changing the options available for travelers and transportation provider's business models. Billions of dollars have been investing in autonomous automobiles, but deployment timelines vary widely. Simultaneously, airlines are facing a severe shortage of qualified pilots that is predicted to extend for 20 years. For shorter trips, travelers may opt for the autonomous vehicle which provides positive attributes commercial air travel does not; productivity, privacy and flexibility. This research is designed to determine if these attributes affect the traveler's mode choice, if one of them affects choice more than the others and how the attributes relate to price and total travel time. The survey was constructed using choice survey methods as described by the Transportation Research Board and the results collected from over 400 respondents. The analysis shows that when presented trip options, productivity influences the transportation mode selection, but flexibility and privacy did not. In the 500-mile driving range, over 40% of the trips selected used the Ground Based Autonomous Vehicle (GBAV) as the mode of choice. GBAV is used instead of autonomous automobile because future iterations will be free of current design constraints and may be considerably more appealing for travel.

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CHAPTER I

INTRODUCTION

The purpose of this dissertation is to begin to explore the potential impacts autonomous automobiles will have on the U.S. airline industry. The data collected will, hopefully, generate actionable information that can be used by airline strategic planners, consultants and investors to develop strategies to, if necessary, cope with specific changes in traveler's mode selection.

Transportation technology is evolving rapidly. Because of advances in automation and artificial intelligence (AI) this is true for both air and ground modes of travel. Elon Musk's statement regarding AI is equally true in reference to transportation technology:

> The hard part of standing on an exponential curve is: when you look backwards, it looks flat, and when you look forward, it looks vertical. And it's very hard to calibrate how much you are moving because it always looks the same. (Dowd, 2017, para. 24)

Genesis of Research Topic

Three years ago I was a full-time management consultant, part-time graduate student. I was working on a project that required travel from my home, Stillwater, OK to the client's facility in Southaven, MS each week. Southaven is essentially a suburb of Memphis, TN and is just South of the Memphis airport (KMEM). To fly commercially to work requires several steps, typical of most business travelers. In my case, the steps were:

1. Drive or get a ride to the airport
2. Check in, if a bag is to be checked

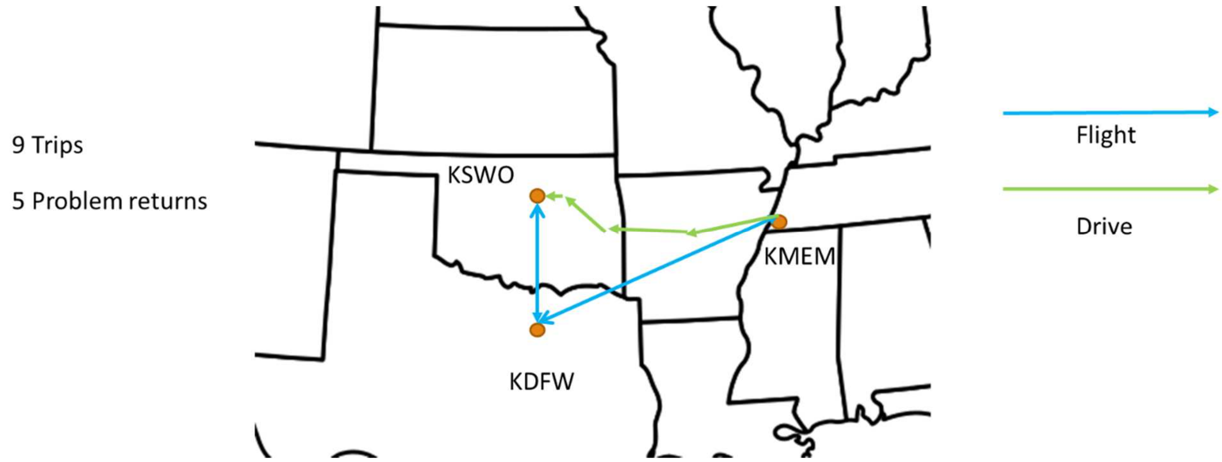
3. Go through security
4. Wait to board and board
5. Fly to the intermediate hub
6. Wait for next flight
7. Fly to destination
8. Retrieve bags
9. Secure transportation
10. Drive or ride to the hotel or work site

All of these are necessary steps, and although I am an experienced traveler, I was often frustrated at the lack of productive time in the process. For five to nine hours, I was largely unproductive, had little privacy and virtually no flexibility. To make matters worse, five times out of nine trips there were problems returning home, necessitating that I drive home rather than fly. The drive took nearly the same time, about seven hours, as shown in Figure 1.1. While that drive did give me tremendous flexibility and privacy, it was not particularly productive.

I had been planning on researching a timeline to autonomous commercial aircraft and as a byproduct of that work read extensively on autonomous automobiles and their potential. As I thought about that in context my travel, I recalled a study conducted for the National Business Aircraft Association (Krane & Orkis, 2009) regarding private aircraft that contained a brief section on productivity. In that study, the executives surveyed indicated their productivity is much higher in their aircraft than on a commercial flight or in their office. Putting all those pieces together, my travel frustration, my interest in autonomous vehicles and work in private aviation led to this study.

Figure 1. 1

Personal Travel Problem



History

A brief history will illustrate the exponential acceleration of transportation technology. The first known wheeled vehicle, a simple cart, dates from around 3,500 BCE (Anthony, 2007). To progress to a cart with an engine required another 5,200 years, when in 1779, Nicolas-Joseph Cugnot developed a steam-engine tractor that traveled at 2.5 miles per hour for the French army (Manwaring, 1966). Only 106 years later, Carl Benz began building what are now considered the first production automobiles with internal combustion engines ("Benz Auto," n.d.). Now, just 130 years later, we stand at the brink of an autonomous automobile revolution which will affect every other mode of transportation, including commercial passenger aviation (Lam, Taghia, & Katupitiya, 2017).

The developmental timeline of flight paralleled the development of surface transportation. From man's early vision of flying like a bird to the most rudimentary of gliders required thousands of years. In one of the first known attempts to build a glider, Brother

Elmer, in 1010 C.E., repeated Icarus' attempt by attaching a set of wings to his arms and jumping off the tower of Malmesbury Abbey ("Flying Monk," 2014). He was, in a word, unsuccessful. From this early attempt to fly the development of gliders to the first successful motorized flight took a millennium, however, from the Wright brothers first flight at Kitty Hawk to Neil Armstrong walking on the moon required less than seventy years (Bilstein, 2001).

Technology Development Directions

Technological advancements in ground and air transportation are leading directly to autonomous vehicles in both contexts. The goal is to reach level 5, which the Society for Automotive Engineers (SAE) defines as the full-time performance by an automated driving system of all aspects of the dynamic driving task under all roadway and environmental conditions that can be managed by a human driver (2004). Similar requirements will likely exist for autonomous aircraft. In 2014, Vance considered that pilotless aircraft must be able to fly in all conditions in which commercial aircraft with appropriately rated pilots could safely fly. Said another way, passenger aircraft, without a pilot onboard, must demonstrate the ability to meet or exceed current commercial aviation safety metrics. (Vance, 2014)

Autonomous automobiles receive much of the attention from the popular press and it is logical to assume that autonomous aircraft are more difficult to deploy. From a technical perspective, this is simply not true (Bellias, 2017). Designing a system to fly an aircraft from one airport to another is a simpler task than to guide a terrestrial vehicle across town. There are fewer objects to run into in the sky, navigation and communication systems are already in place and existing avionics and flight control systems are capable of controlling the aircraft from gate to gate without human intervention. The question that remains, on the ground and in the air, is can these systems at least meet, or preferentially exceed the existing commercial air transportation system's safety performance? To garner public acceptance, autonomous systems must be demonstrably safer that existing manned transportation systems (Vance & Malik, 2015).

Socially, autonomous flight is more challenging. Massachusetts Institute of Technology professor John Hansman pointed out that the technical challenges have never been the issue, the success of autonomous flight will depend on the willingness of the traveling public to board an airplane with no human pilot (Lerner, 2017, para. 2). The acceleration of air and ground transportation technology continues today.

Throughout the remainder of the document the term Ground-Based Autonomous Vehicle (GBAV) will be used rather than autonomous automobile. The logic for using this term is that many writers and researchers assume an autonomous version of a modern automobile in their writing. Level 5 autonomy will give engineers and designers a nearly blank canvas to design new or improved utility into the vehicles.

This rapid technical innovation increases the probability of transportation industry disruption. Disruption creates market uncertainty and challenges companies to plan for contingencies.

The definition of a disruptive technology can take several forms.   This study will use Danneels core definition of a disruptive technology (2004, p. 249):

> ...a technology that changes the bases of competition by changing the performance metrics along which firms compete. Customer needs drive customers to seek certain benefits in the products they use and form the basis for customer choices between competing products.

Regulatory Environment

Both air and ground mode's regulatory environments are evolving in an effort to improve safety, keep up with evolving technology and meet consumer demand. In the regulatory domain, GBAVs receive more active support. This is not surprising as changes to aviation regulations have historically been very measured and require a significant amount of time (Cleveland & Price, 2003). For GBAV's, there are recent news stories about state and federal legislative bodies improving the opportunities for companies to test their vehicles on state and federal roads (Hughes, 2017; Mitchell, 2017; Zanona, 2017).

Recent summarized studies indicate growing public acceptance of GBAVs (Kyriakidis, Happee, & de Winter, 2015). This research is supported by current popular press articles noting government progress in changing regulations that pave the way for GBAV testing. In October of 2017 a U.S. Senate panel unanimously approved to a bill aimed at speeding the use of self-driving cars without human controls, a measure that also bars states from imposing regulatory roadblocks (Shepardson, 2017).

Regulatory agencies for automobiles and trucking in the U.S. are actually promoting autonomous travel ("ITS accelerating," n.d.) in the interest of public safety and infrastructure use, while in aviation the FAA has a reputation for being unresponsive or slow to action (Cleveland & Price, 2003). With public acceptance of GBAV's rising and active promotion by the U.S. Department of Transportation (DOT), it is reasonable to expect that autonomous ground travel in the U.S. will occur before autonomous air travel.

Customer Preferences Today

Prior to 1978 air travel in the U.S. was tightly controlled by the Civil Aeronautics Board (CAB) and the cost of air travel was high (Kaps, 2000). The CAB controlled point-to-point routes, determined which airlines were allowed to fly them, how often and how much they could charge. Post-deregulation, prices decreased up to 50% as airlines began to compete with one another for passengers. Airline competition led a need for increased efficiency. As a result, airlines created a hub-and-spoke system where flights originate and return to centralized hubs which reduces the number of discrete routes and eliminates low-volume city pairs. To achieve more efficiency airlines reduced their expenses and created the commercial aviation environment we experience today.

In the U.S., all major domestic airlines serve city pairs in the continental United States using the hub-and-spoke system. This means that unless the flight originates and terminates at a hub the passenger will pass through a hub on their trip. For example, consider a passenger traveling from Oklahoma City, OK to Nashville, TN. In addition to the travel time to and from the airport, check-in and Transportation Security Administration (TSA) security checks, the passenger will travel through at least one intermediate airport, Dallas-Fort Worth for example, then disembark their aircraft, reposition to another gate, re-queue and board the next flight. This is not just time-consuming, the time spent is nearly completely unproductive. If you include the average travel time to and from the airport for travelers within the airport's customer area you must add an estimated 90 minutes to the beginning of a flight and up to 60 minutes or more at the end (Vance, 2013).

Contrast the commercial flight experience to the potential of fully autonomous ground-based vehicle systems. In this scenario, the traveler(s) request a vehicle to pick them up at their place of departure and transport them directly to their destination without requiring any of the intermediate steps that air travel requires. Additionally, the traveler can elect to delay, revise the destination, or stop for any reason, and do all of this on their own schedule. Conceivably, coworkers will be able to travel together and meet, work together and discuss private topics in a vehicle designed to support multiple passengers in a mobile workspace. In many ways, this may be comparable or superior to current passenger experience on corporate aircraft. In a survey conducted for the National Business Aircraft Association (NBAA) and General Aviation Manufacturers Association (GAMA), Harris Interactive found that when using working in their office as a reference, "passengers estimate that they are 20% more productive on the company aircraft than they are in the office. This contrast to being 40% less productive on commercial flights" (Krane & Orkis, 2009, p. 6).

Mode Choice Factors

Productivity or productive time as a mode selection decision criterion has been suggested (Clements & Kockelman, 2017) or estimated (LaMondia, Fagnant, Qu, Barrett, & Kockelman, 2016) in academic research and corporately researched when the traveler has access to corporate aircraft (Krane & Orkis, 2009). However, when modes of travel that provide increased productivity become available, the traveler may use productivity, or freedom to be productive, as a factor in their mode selection process. Comparing existing travel modes to future travel modes is difficult. There is one comparison in commercial research, a 2009 study Harris Interactive conducted on behalf of the NBAA and GAMA. The survey asked business travelers to rate their productivity in different modes of travel, including commercial airlines and private aircraft (Krane & Orkis, 2009). Business aircraft travelers reported being twice as productive on corporate aircraft as when traveling on commercial airlines. This measure of productive time is comparable because the traveler is isolated from the general public, does not require check-in or security processes and operates on their own schedule. For the purposes of this study the productivity rates of private aircraft travel will be used to represent that of autonomous GBAV travel.

Statement of the Problem

The commercial aviation industry is at the confluence of rapid technological advances and substantial economic growth. This growth is the primary driver of the demand for additional pilots, which is driving pilot wages up and inflating an already burdensome expense category. If this demand for pilots cannot be met it is in the best interest of the airframe manufacturers, airlines and cargo carriers to develop autonomous aircraft for commercial applications. There are two primary challenges to this, proving safety to the flying public and the Federal Aviation Administration (FAA). Proving safety that will match the current U.S. airline safety standard will be difficult. Likewise, proving and certifying a safety level acceptable to the FAA will be a challenging task.

However, autonomous automobiles and heavy trucks are being tested on public roads today ("More States Explore", 2017) and are being actively promoted by regulatory agencies and private companies. This creates opportunity for the GBAV manufacturers and systems development firms to reinvent transportation. This also creates very real risks for domestic airline service providers.

During this period of accelerated research and development for automated systems, the automotive and aviation segments of the larger travel industry appear to be succumbing to a variety of cognitive biases that keep them narrowly focused and unable to see potential strategic risks and potential outcomes (Steenblik, 2015). For example, airframe manufacturers, airlines and pilots appear to be focused on automating existing aircraft and keeping/removing pilots from the cockpit depending on which side of the labor equation they fall. They do not appear, at least from the outside, to consider the future possibility that customers may select another mode of travel entirely.

GBAV's hold the promise of convenience, comfort and productivity, not to mention more privacy and less personal intrusion by the TSA, for business and recreational travelers for destinations 500 miles or fewer away. Domestic airlines must plan for this eventuality to remain successful in a rapidly evolving environment.

Purpose of the Study

As applied research, this study is intended to be of direct and immediate relevance to practitioners and to address issues they see as important and is presented in ways they can understand and act upon (Saunders, Lewis, & Thornhill, 2012). As such, at a high level, the purpose is to improve understanding of a particular business or management problem. The purpose of this study is to test the importance of productivity and convenience as mode selection criteria for business travel.

Current research on travel model selection frequently focuses on factors such as trip time, costs and schedule or is focused on a narrow scope of modes, e.g., taxi vs. personal automobile (Bagloee, Tavana, Asadi, & Oliver, 2016; Bradley, 2015; de Lapparent & Ben-Akiva, 2014; Neely, 2016). The advent of GBAV's may change the mode selection process, therefore it is important to stakeholders in the commercial aviation sector to begin to identify and understand the potential impacts. Travelers from small to medium sized businesses (SMBs) represent the largest revenue base for most airlines (Kaps, 2000). The study will inform interested parties of the potential positive and negative impacts to current stakeholders in commercial passenger aviation. Any positive or negative impacts identified by this study can be used to mitigate strategic risks or be leveraged for change and increased corporate performance. The stakeholders to be considered are shareholders, employees, specifically pilots, the pilot's labor unions, airline managers, airframe manufacturers, avionics manufacturers, and air traffic control, the FAA, passengers and cargo customers.

Research Questions

The following questions will be answered by this study:

1. Does the addition of productivity as a criterion to selection of travel mode make a difference in traveler's choices?
2. Does the addition of flexibility as a criterion to selection of travel mode make a difference in traveler's choices?
3. Does the addition of privacy as a criterion to selection of travel mode make a difference in traveler's choices?
4. Do any of the discriminators productivity, flexibility or privacy influence the travel mode decision more than the other?

Significance of the Study

There is a growing body of research on autonomous transportation topics, much of which is specific to the mode, ground or air. Autonomous automobile research explores technical barriers and new technologies, the regulatory environment, networking and communication between vehicles, customer ownership patterns and preferences for ground-based travel. Likewise, research in air transportation is predominately concerned with technology development and the regulatory environment and is biased toward passenger carrying unmanned aircraft systems. None of this addresses the business impact of one of these developing modes on a segment of travelers. This study aims to provide an informed baseline for the commercial aviation industry to begin a strategic risk assessment for GBAV development and deployment.

Acronyms

ADS – Automated Driving System

AI - Artificial Intelligence

AV - Autonomous Vehicle

CAB - Civil Aeronautics Board

CAV - Connected Autonomous Vehicle

CV - Connected Vehicle

CROP - Common Relative Operational Picture

DCA – Discrete Choice Analysis

DOT - Department of Transportation

FAA - Federal Aviation Administration

GBAV - Ground-Based Autonomous Vehicle

HRI - Human Robot Interaction

ITS - Intelligent Transportation System, part of the U.S. DOT

NASA - National Aeronautics and Space Administration

NIST - National Institute of Standards and Technology

SAE – Society for Automotive Engineers

SP – Stated Preference

TSA - Transportation Security Administration

UMS - Unmanned Systems

V2V – Vehicle to Vehicle

V2X – Vehicle to anything

VMT – Vehicle Miles Traveled

WTP – Willingness to Pay

Definitions of Terms

Autonomous – Operations of an unmanned system (UMS) where the system receives its mission from humans and then accomplishes that mission with or without further human-robot interaction (HRI). The level of HRI, along with other factors such as mission complexity, and environmental difficulty, determine the level of autonomy for the system.

Collaboration or Cooperation - The process by which multiple manned or unmanned systems jointly work together by sharing data, such as coordinates, planned movements and local Common Relative Operational Picture (CROP), or by acquiring intelligence to perform a mission synergistically, i.e., learning to work cooperatively to accomplish missions more effectively.

Levels of Automation:

No Automation (Level 0): The driver is in complete and sole control of the primary vehicle controls—brakes, steering, throttle and motive power—at all times. No automation ("SAE autonomy level," 2016).

Driver Assistance (Level 1): Automation at this level involves at least one driving mode-specific driver assistance system. These systems assist either steering or acceleration/deceleration tasks using limited environmental information and with the human performing all remaining tasks of dynamic driving ("SAE autonomy level," 2016).

Partial Automation (Level 2): The driving mode-specific execution by one or more driver assistance systems of both steering and acceleration/deceleration using information about the driving environment with the anticipation that the driver performs all other dynamic driving tasks ("SAE autonomy level," 2016).

Conditional Automation (Level 3): The driving mode-specific functioning by an Automated Driving System (ADS) of all aspects of the active driving task with the anticipation that the driver will respond appropriately to a request to take action ("SAE Autonomy Standards," 2016).

High Automation (Level 4): The driving mode-specific execution by an ADS of all aspects of the dynamic driving task, even if a human driver does not respond correctly to a request to intercede ("SAE autonomy level," 2016). Therefore, this can be both occupied and unoccupied vehicles. While full Level 4 autonomous vehicle markets are still in the future, many manufacturers have indicated that they will have connected car features by 2020.

Full Automation (Level 5): The full-time functioning by an ADS of all facets of the dynamic driving task under all roadway and environmental conditions that can be managed by a human driver ("SAE autonomy level," 2016).

Assumptions

- The GBAV description in the survey is sufficient for the respondents to use in comparison to their current travel modes.
- Respondent's travel time to and from airports represent average business travelers
- The travel mode attributes assessed in the survey are important to business travelers. Those attributes and their definitions are:
    - Total travel time – door to door travel time
    - Travel cost – total cost of transportation to and from the destination
    - Productive time – amount of time during travel than can be use productively
    - Flexibility – the traveler's ability to alter plans during travel

    - Privacy – the traveler’s ability to work and communicate privately
    - Processing time - time spent standing in line or going through security, for example

Limitations

The limitations of this study are as follows:

- The GBAV in the survey is representative of a product that does not exist and is only described briefly, therefore respondent’s interpretation of the description or their imagination may limit their ability to consider the alternatives precisely.
- The sample size may affect the error margin.
- Biases against change, especially without experiencing the actual product, may negatively affect the survey results.

CHAPTER II

LITERATURE REVIEW

It is difficult to know what is happening in the boardrooms and research labs of commercial airlines and their supporting suppliers and manufacturers. Large public companies are generally loath to share their long-term concerns and strategies that are not already obvious in the public domain. That said, there is little external evidence that the major airline's strategic planners have identified GBAVs as a threat to the short-haul segment of their business. The review of literature for this study will inform the researcher on current trends in the development of GBAVs, commercial aviation firm's strategic direction and current concerns such as the well documented pilot shortage, and the rapidly changing regulatory environment. Transportation technology and AI are rapidly developing fields where academic publication lags behind the current state of the art, often by years. Therefore, to improve the utility to readers of this applied research, non-academic publications are included to provide supporting data to inform the reader and researcher of the current level of technology and interest at the time of writing.

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As applied research, this study is intended to be of direct and immediate relevance to practitioners and to address issues they see as important and is presented in ways they can understand and act upon (Saunders, Lewis, & Thornhill, 2012). As such, at a high level, the purpose is to improve understanding of a particular business or management problem. The purpose of this study is to test the importance of productivity and convenience as mode selection criteria for business travel.

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The following are the proposed documents to gather information, compare and contrast these sources, and inform the research data and findings

Autonomous vehicle research and planning is not new to academia or businesses. In a curatorial insight article for the Computer History Museum, Weber (2014) reminds us that airplanes received the first autopilots merely a decade after the Wright brothers. In the same article is a picture from a 1950s issue of the Saturday Evening Post of an advertisement purporting the “Driverless Car of the Future” for America’s Electric Light and Power Companies. The picture depicts a family of four playing a board game in their car as it drives down the highway. The drive toward increased automation is constant. It has been envisioned by authors in popular literature and researched for many years. In 2004, the National Institute of Standards and Technology (NIST) defined terms used to identify levels of autonomy for automobiles. The NIST document represents some of the early government work and set the baseline definitions for researcher to use in development and collaboration using a common vocabulary. These standards have been codified in the Society of Automotive Engineers (SAE) standard SAE J 3016-2018 which details the vocabulary, terms and standards for the five levels of autonomous automobiles.

Kaps (2000) observed that domestic airlines, historically report that 30 to 40 percent or more of operating expenses are labor costs, which include salaries and benefits. Pilots, mechanics, dispatchers and flight attendants all have specialized skills which command higher wages and benefits in the marketplace (Kaps, 2000). Reducing or eliminating labor costs is a significant incentive for commercial airlines to modify their operations and reduce the number of employees in all categories.

Although automating high labor costs out of the cockpit of commercial passenger and cargo aircraft makes financial sense, the flying public may not be prepared to adopt that strategy in the near future.

Technical progress

In 2017, the journal Research-Technology Management published in their R&D trends forecast that survey respondents are reporting significant research and development funding is directed at researching automation and robotics, artificial intelligence, unmanned flying and autonomous transportation systems. The progress is very measured and necessarily slow. Wing, Barmore, and Krishmamurthy. (2002) were conducting research in the early 2000's aircraft broadcasting intent to air traffic control systems and the application to ground-based vehicles. In the intervening 16 years, progress is being made, slowly.

Early research led by a NASA researcher on the application and use of vehicle intent in an air traffic control environment. The concept of broadcasting each vehicles intent in a movement management system can be utilized in an air or ground-based transportation network.

Contrast that to more recent corporate projections, for example United Technologies 2016 report where the company is designing "Advanced Algorithms for Perception and Management" to solve problems such as delivering supplies to a village and encountering unplanned surprises, for example hostile combatants.

Social/adaptation Progress

Vance and Malik. (2015) provided survey data and a statistical projection of passenger willingness to fly on an autonomous aircraft based on their analysis of factors that may be essential in the decision to fly on fully autonomous passenger airliners. Their findings provide a valuable comparison to the results of the survey in this research document. Their paper focuses on factors that travelers will consider before flying on autonomous aircraft. An excellent data set available to compare with current thinking and research on public acceptance and willingness to fly or drive in an autonomous vehicle.

Leicht, Chtourou, Ben Youssef (2018), modeled and measured the effect of consumer innovativeness on potential predictors of autonomous vehicle adoption and purchase. Their conclusions showed a positive relation with purchase intentions for performance expectancy, effort expectancy and social influence. One aspect of their methodology that raises concern when considering their results is that the more than half of their respondents work in the automotive industry, therefore their biases and expectations may project a result different than a more representative sample of the general population.

Benefits

Morgan Stanley Research's comprehensive report on autonomous automobiles (2013) includes projected significant potential societal benefits. For example, Morgan Stanley quoted a US Department of Transportation (DOT) report that states that in 2009 there were 10.8 million motor vehicle accidents resulting in 2,000,000 injuries. These led to 32,000 deaths – and this is just in the US. In the same report, the US DOT says the 90% of the accidents are a result of human error. All of this to say that in the automotive world, unlike commercial aviation, the barrier of safety performance that the autonomous automobiles must achieve to outperform current modes is very low. Morgan Stanley reports the accident savings, which includes injuries and fatalities could be as high as $488,000,000,000 per year. Additionally, Morgan Stanley sees the potential for productivity gains of over $500,000,000,000 per year, for a total of nearly a trillion dollars per year in benefit.

Public Opinion

After surveying 5,000 people around the world on automated driving, Kyriakidis, Happee, & de Winter (2015) found that "69% of respondents stated that fully automated driving will reach a 50% market share before 2050." Also, that "respondents were concerned about software hacking/misuse, legal issues, and safety." It is also interesting that "results showed that respondents, on average, found manual driving the most enjoyable mode of driving, yet they found the idea of fully automated driving fascinating" signaling a very real willingness of the public to experience the benefits of autonomous travel.

Influencing Factors

There are several factors influencing the advance of technology in the cockpit and on the ground. Airlines have two problems employing pilots: their employment costs are very high and they are struggling to find enough qualified pilots to meet the current demand (Everhart, 2017). This is true for U.S. domestic commercial airlines and the U.S. military. As the airlines continue to experience difficulty meeting pilot demand they must raise wages to attract new pilots. In their Long-term Market Outlook, Boeing (2016) reported demand for pilots increasing for the next 15 years. Airlines can alleviate all or some of this pressure by automating flying tasks, all or in part. This started years ago. Early commercial airliners required four cockpit crew members, the pilot, co-pilot, navigator and flight engineer. Upgrades in avionics and navigation technology replaced the navigator followed shortly by the flight engineer a few years later. Current practice, even for the largest commercial passenger aircraft the Airbus A380 is for two flight crew on duty.

The pressure created by expanding markets, the real pilot shortage and increasing wages creates a business environment favorable for disruption. This is especially true if transportation is viewed as a system rather than just looking at commercial airlines as the only viable alternative for moving people and goods between locations. Haines (2000) provides useful tools for framing the potential impacts of disruptive strategic risks that may be applied to airlines vis-a-vis ground-based autonomous vehicles

An article from the Economist (2016) points out the very real pilot shortage issue that is affecting and will continue to affect airlines and militaries around the world. The pilot shortage will drive development of automation as airlines and suppliers do not want to lose out on income or be burdened with assets and that are not being utilized and generating revenue because they do not have an adequate supply of qualified pilots.

The potential of disruptive technologies and business practices creates strategic risks for businesses. Therefore, the development of autonomous vehicles creates a significant level strategic risk for airframe and automobile manufacturers as well as airlines, rental car agencies and driving services. This paper is the early research to begin framing those risks correctly.

Technology Development and Integration Research

In a fundamental research paper Adner & Levinthal (2001) write on the power of the demand side of technology innovation's role in technology development speed and adoption. This concept is important to this paper in that ground-based autonomous vehicles are being 'pulled' by the end users and regulators and in the commercial air markets it is still very much in the exploration stages.

There is some healthy tension between the current research and application environment for autonomous ground-based vehicles. Bagloee, Tavana, Asadi, & Oliver (2016) presented the current state of transportation research for autonomous vehicles including the challengers, opportunities and future policy implications. They point out that one of the drivers of the autonomous vehicle trend, safety, is related to the aging population, especially in the United States. Meanwhile, commercial transportation companies are moving ahead with product development and on-road testing.

Bazzan, de Brito do Amarante, & Da Costa (2011) researched the management of customer demand models and routing in personal transportation. They believe that 'pods' and other autonomous vehicles will become ubiquitous, creating new challenges for traffic management and transportation systems. Their work validates the need for V2V (Vehicle to Vehicle) and V2X (Vehicle to anything) communications standards that are in development. The authors propose an agent-based approach, using agent-based modeling, first in a centralized model then exploring decentralization options.

Endsley, M. R. (2017) discusses the automation conundrum, which is that the more a system is automated and becomes reliable the less situationally aware the humans in the loop become. Unfortunately, this has been demonstrated in recent aviation accidents where pilots are less situationally aware because their flight navigation and control automation is reliable. Therefore, when something does go wrong, it takes the human a long time to catch up. The exact same issue is repeating itself in autonomous car testing, where accidents have occured precisely because the human became too comfortable with the car driving itself and the subsequent loss of situational awareness.

In contrast to this, Narayan & Dogramadzi (2013) concludes that enabling more autonomy on commercial aircraft will improve safety. While this paper is only targeting situations of pilot incapacitation, it does move us down the path towards full automation. The logical conclusion is that if the aircraft can recover from pilot incapacitation and land safely, the next step to full automation is relatively short.

Transportation Tomorrow – Ground and Air Mixed

Lawrence Burns, in his book, aptly titled Autonomy (2008), paints a picture of future personal transportation that represents the convergence of autonomy, electric power and the adoption of ride hailing apps like Uber and Lyft. In this scenario the average traveler, especially for local trips, will not own a car. Instead, the traveler will use an app on their phone or a computer to request transportation which will come to their location and pick them up. This view is reinforced by Dhawan, Hensley, Padhi & Tschiesner (2019) in their McKinsey Quarterly article. Once at the destination the 'car' does not need to remain and wait, unutilized and taking up space in a large heat sink (parking lot), as noted by Nourinejad, Bahrami and Roorda (2018).

As early as 2013, transportation researchers and consultants suggested that to remain competitive, automobile manufacturers must add services that increase value to the consumer beyond their traditional offerings. Their suggestions include multi-modal journey planning (Frost & Sullivan, 2013). This advice may hold true for airlines as well as departure and destination point distance from the airport may influence travel mode selection as other options develop. This is discussed in more detail in chapter five.

Transportation engineers are working to understand how GBAVs will affect traffic flow. Farmer (2016) wrote on these traffic flow issues, especially in urban environments, noting that the utility of the GBAVs may be decreased, especially in their initial deployments, while there is a mix of autonomous and human driven vehicles intermixing on the roads and in congested environments. Demand forecasting, the fundamentals of traffic flow and travel mobility will all have to be recast as the new vehicles emerge onto the roadways.

Lam, Taghia, & Katupitiya, (2017) add to Farmer's work by articulating the difficulty of using existing modeling for transportation systems for autonomous study. The authors propose their recommended method for modeling and simulation of autonomy in a transportation system.

Uber funded a white paper by Holden & Goel (2016) which outlines their research and belief in on-demand urban air transportation. The article establishes a data point in the progress of autonomous travel and demonstrates that the marketplace has a strong desire to see that autonomous vehicles make it to commercial service. It is important to understand that it is not just the military or researchers that are striving for autonomy in transportation. In this case, an existing company that is focused on customer service though ground transportation, is owned and operated by individuals, is studying and funding research on urban air travel in small, autonomous aircraft.

Automation and autonomy are viewed as cost drivers for businesses with heavy transportation needs. Hormozi (2013) notes that autonomy has the potential to transform supply chains through more consistent and reliable movement of goods. The point is well taken, the promise of autonomous delivery is that it overcomes some human weaknesses, notably the inability to operate 24-hours per day, without mandated rest periods and our safety record is not exceptional.

Lee & Kim's article (2017) is indicative of the depth of autonomous aviation research. The authors are not just exploring how to fly people or objects from point A to point B, but have moved beyond that into how to use articulated arms to lift unknown loads into or under an aircraft for transport. As progress is made from small drones to carrying humans, fault detection, isolation and even repair are crucial elements to reliability and public acceptance. Marzat, Piet-Lahanier, Damongeot & Walter were exploring this topic in 2012. This too, reinforces the challenge to autonomous flying, the customer wants perfection because the consequences of failure are perceived to be much higher than in a ground vehicle.

Moore's (2010) nearly nine-year-old presentation to the American Institute of Aeronautics and Astronautics (AIAA) on the progress toward on-demand aircraft is a vision of the future that is consistent with other predictions for on-demand automobiles. If both are true, the question becomes "which is likely to progress to implementation in the shortest amount of time?"

In the June 22, 2016 issue of the Economist, the authors reflect on the research and businesses initiatives to provide passenger transportation by small automated aircraft. They compare flying a helicopter, which can indeed be challenging, to flying a personal drone, which is much simpler. Drones are not currently required to go through any FAA certification processes, which will be required, at some level, to carry passengers, and may dampen the enthusiasm for upscaling drone technology for human travel.

Ryan (2014) ran a multi-agent safety and control simulation (MASCS) against Naval flight deck operations to explore the interaction between variables. This paper provides another data point marking progress towards an autonomous vehicle future, as researchers work on methods for vehicle to vehicle communications and one-to-many control of the vehicles, which by definition, makes them less autonomous. Another part of this research includes modeling the potential changes to travel behavior and patterns, such as the work of Vogt, Wang, Gregor & Bettinardi (2015). Their work is interesting in that they are looking at the relationships of factors and how changes my affect travel patterns. The authors present an innovative method, Fuzzy Cognitive Maps (FCM), for transportation planners to use to anticipate changes when quantitative data is not available.

Regulatory Environment - Ground

In an article for Government Technology, Descant (2017) provides an update on the number of states exploring truck-platooning technology and regulations. Descant demonstrates the progress made in the regulatory environment for ground-based autonomous and semi-autonomous vehicles. This is an area that is changing rapidly and academic research on the regulatory environment for autonomous is outdated by the time it is reviewed. At the time of publication, California, Arizona, New Mexico and Texas had formed the I-10 Connected Freight Corridor Coalition which allows for testing of truck platooning – a method of trailing semi-truck in what can be thought of as extreme tailgating.

Los Angeles Times writer Mitchell (2017) reported on California legislators drafting "a new set of streamlined regulations" to allow test vehicles on California roads. The driverless vehicles will not be allowed to charge for their services, but could be allowed on California roads by June 2018.

The U.S. Department of Transportation (DOT) Office of the Assistant Secretary for Research and Technology runs the Intelligent Transportation Systems Joint Program Office (ITS). The ITS produces research and standards for integrating systems and encouraging adoption, one of those, Accelerating Deployment (2019) documents the path of research and development, adoption and is focused on updates and communicating with stakeholders on interoperability, connectedness and automation. This work clearly articulates the government is encouraging the development and adoption of autonomous and semi-autonomous vehicles to the point of developing and proposing a path to meet those goals. The ITS report is primarily focused on ground-based vehicles.

Writing a regulatory commentary for the Manhattan Institutes Economics for the 21st Century group, Hughes (2017) points out new traffic fatality data that underscores need for autonomous vehicle legislation in support of developing GBAVs to improve safety. His paper describes the current legislative machinations to accelerate the adoption of autonomous vehicles to improve the estimated 37,500 motor vehicle traffic fatalities in 2016. Interestingly, Senator Inhofe submitted an amendment to remove weight restrictions which will allow for truck testing. Litman (2017) wrote a very well researched paper for the Victoria Transport Policy Institute concluding that the time timeline of having viable, reliable fully autonomous vehicles on the road by 2030 is possible, but not probable. One of his points that was of particular interest to me is chart from the Government Accounting Office in 2016 showing that a fully autonomous car will require 100 million lines of code to operate. This is in contrast to a Boeing 787 Dreamliner, which requires 6.5 million. Litman also stated “In contrast to the cautious predictions by experts, most optimistic predictions are made by people with financial interests in autonomous vehicle industries, based on experience with other types of technology” indicating the true timeline probably falls somewhere in the middle.

On the political commentary website The Hill, Zanona (2017) notes that driverless car investments top $80 billion, which is supported by the recent Accenture paper (2019) showing investment at $200 billion by early 2019.

In a Reuters news article Shepardson (2017) writes “A U.S. Senate panel on Wednesday unanimously gave the green light to a bill aimed at speeding the use of self-driving cars without human controls, a measure that also bars states from imposing regulatory road blocks.” Another clear demonstration that the automotive regulatory environment is progressing very quickly, Shepardson also stated “Within three years, the bill would allow automakers to each sell up to

80,000 self-driving vehicles annually if they could demonstrate they are as safe as current vehicles." This is a much lower bar than in aviation automation and demonstrates the regulatory environment for ground-based autonomous vehicles is progressing faster than in aviation. One view suggests people expect autonomous ground vehicles to be safer than the current automobile and it is difficult for aviation companies to make U.S. airline travel safer than it already is.

Regulatory Environment - Air

The negative side of the regulatory environment is articulated well by Cleveland & Price (2003) in a journal article used as a point of reference in describing the FAA slow-moving bureaucracy. The FAA, without either reorganization or better leadership, may be the biggest impediment to autonomous aircraft. In the intervening years since publication of this article the FAA has worked to reorganize and speed decision making and customer service, especially with respect to general aviation. They have been slow to react to unmanned vehicles and have appeared to waver on their approach to licensing and management.

Smith, Viken, Guerreiro, et al, (2012) projected potential number of small autonomous aircraft designed to transport individuals and small groups will place a tremendous burden on the national airspace system. System modernization has been slow and the additional autonomous aircraft system demand, combined with the FAA's slow response time and airline pilots fighting against autonomy will slow the progress of adoption for autonomous aircraft (Smith, et al, 2012).

Existing Mode Selection Research

Part of the genesis of this project, Krane & Orkis (2009) wrote a paper on behalf of the National Business Aircraft Association (NBAA) and the General Aviation Manufacturers Asosociation (GAMA). I initially read this report as part of a research project for a business client on the benefits of aircraft ownership and when it is reasonable to fly privately. The author's finding also communicate what they found motivated business travelers in 2009. In the NBAA report Krane & Orkis (2009) found that "the primary reason for using business aircraft, as reported by passengers, is to support business schedules that cannon be met solely with the use of the scheduled commercial airlines" (p. 22). When measured on a scale of 10, commercial airline travel productivity was rated a 3 while private airplane travel at a value of 6. What stood out was that this was the first and perhaps only time productivity was considered as a real benefit.

de Lapparent & Ben-Akiva (2014) provide a model for future research on this subject when more is known, suggesting that that the dual theory of choice under risk provides an attractive framework for the analysis of choice of travel mode for work trips of greater than 10 kilometers (p 202).

In this paper presented at the Transportation Research Board LaMondia, Fagnant, Qu, Barrett, & Kockelman (2016) discuss their very detailed work on automated vehicle travel over long distance. The see the inflection point at 500 miles where the users chose driving or flying almost equally. They also noted that as the travelers perceived travel time benefits from autonomous travel rise, the monetary costs become less important.

Li (2004) points out that intercity travel decision making includes a complex set of underlying decisions, such as when to travel, where to travel, which mode to choose, and others. Li's dissertation work provided a detailed engineering approach that is recommended for further study in this domain.

Air travel, while safe is often unreliable, especially when there are significant weather events. Combine that with infrequently serviced communities, and one small problem can confound business travel. Sweet & Chen (2011) asked the question of how unreliability affects the choice of travel mode. While their study was constrained to the Chicago area, but is still instructive to this report. They note that "Travel time unreliability is important, particularly to the workplace and an (arguably) realistic one-standard deviation change in travel time unreliability, on average, is associated with approximately a 23% reduction in the odds of using a car." Other modes may be affected similarly, however more work needs to be done to research how airline unreliability may affect user mode choice.

The Business of Travel

Adner & ZemskyP (2005) observe that new technologies are often brought to the market in a specialized areas. In their article establishing definitions of disruptive technologies in the marketplace. Their conclusion summarizes the implications for new entrants and existing or incumbent firms. They note (p.249) that for technology companies with new technology well-suited for a niche, in which the technology may still prove to be disruptive. Adner & Zemsky identify factors (costs, segment sizes, etc.) that must be considered and valued in assessing the potential of disruption. For new-technology firms, they demonstrate that the market leader does not necessarily have the greatest incentive to pursue disruptive strategies. Additionally, they show that new-technology firms blindly embracing disruption can lead to a decrease in their profits. Given the possibility of multiple contributing factors, both types of firms may benefit from actions to shape industry expectations to then coordinate activity on their preferred outcome. It is also possible that new-technology companies benefit from an anticipation of disruption because established-technology firms occasionally reduce output in anticipation. They conclude with an interesting observation, that mergers among established firms can increase industry rivalry if they alter competition boundaries.

Following along this line of thought, Danneels (2004) sought to build on the academic and popular work of Harvard Business School professor Clayton Christensen on disruptive technology. Danneels conclusions from his readings that the concept of "customer centricity" are quite interesting. They are not to be understood to say that firms should not listen to their customers, but that they should not listen too much. Danneels says "First, one needs to make a distinction between current and potential customers. Being customer□oriented does not imply an exclusive focus on current customers. In the worst case, a firm may become what Day (1999) has called "customer compelled"—essentially bending over backward to fulfill every whim of current customers, even at the expense of the company's short□term and long□term performance. This management journal article is used to help accurately frame the concept of market disruption and to be consistent in the use of vocabulary and terms. This is important for this paper because it spans different disciplines.

Clements & Kockelman (2017) studied the economic effects of automated vehicles across a variety of industries, with one notable exception for our purposes, air transportation. Their paper covered connected and fully automated or autonomous vehicles effect on the automotive industry, electronics and technology, trucking and freight movement, personal transport, medical, auto repair, insurance, legal, construction and infrastructure, land development, digital media, oil and gas, and law enforcement. To be fair, the implications in the personal transportation section do apply to airlines to a limited degree. They note that autonomous vehicles "might decrease the demand for fast transportation." The example provided is a 10 hour trip by car, where the traveler "may opt to make the trip overnight, sleeping while the care takes them to the destination instead of taking a flight." A 10-hour trip is outside the scope of this research, however the concept of using a GBAV for longer, overnight travel is an attractive subject to consider for future research. This paper was presented to the Transportation Research Board and presents one vision of the future of autonomous vehicles. The other is that while some individuals will own them, most will use a service to provide an appropriate vehicle as needed.

As a side note, I used Downes & Nunes (2014) book Big Bang Disruption: Strategy in the Age of Devastating Innovation primarily as a point of reference and as a popular book written by academics to keep the discussion and conclusion is this paper consistent with terminology in the management field.

CHAPTER III

METHODOLOGY

Introduction

As applied research, this exploratory study is intended to be of direct and immediate relevance to practitioners and to address issues they see as important and is presented in ways they can understand and act upon (Saunders, Lewis, & Thornhill, 2012). As such, at a high level, the purpose is to improve understanding of a particular business or management problem. The purpose of this study is to test the importance of productivity and convenience as mode selection criteria for business travel.

Current research on travel model selection frequently focuses on factors such as trip time, costs and schedule or is focused on a narrow scope of modes, e.g., taxi vs. personal automobile (Bagloee, Tavana, Asadi, & Oliver, 2016; Bradley, 2015; de Lapparent & Ben-Akiva, 2014; Neely, 2016). The advent of GBAV's may change the mode selection process, therefore it is important to stakeholders in the commercial aviation sector to begin to identify and understand the potential impacts. Travelers from small to medium sized businesses (SMBs) represent the largest revenue base for most airlines (Kaps, 2000, p. 222). The study will inform interested parties of the potential positive and negative impacts to current stakeholders in commercial passenger aviation. The stakeholders to be considered are shareholders, employees, specifically pilots and the pilot's labor unions, airline managers, airframe manufacturers, avionics manufacturers, air traffic control, the FAA, passengers and cargo customers.

Research Questions

The following questions will be answered by this study:

1. Does the addition of productivity as a criterion to selection of travel mode make a difference in traveler's choices?
2. Does the addition of flexibility as a criterion to selection of travel mode make a difference in traveler's choices?
3. Does the addition of privacy as a criterion to selection of travel mode make a difference in traveler's choices?
4. Do any of the discriminators productivity, flexibility or privacy influence the travel mode decision more than the other?

In this chapter the process and methods used are documented such that the work could be reproduced and further research could be conducted using the tools and data set gathered for this experiment.

Participants

The primary desired attribute of the research subjects is that they are frequent business travelers, defined as traveling a minimum of three to four times per year. Specifically, the trips of research interest are medium-length trips, defined in terms of travel time and distance; therefore, the transport mode options are reduced to three: automobiles, commercial air, and GBAVs. By using only three mode options, the researcher was able to simplify the complexity of the survey instrument. Geographic diversity was not specifically requested, however location data was provided and that data is reported in chapter 4 and will be useful in future analysis.

The sample size was calculated based the commonly used equation:

Necessary Sample Size – $(\text{Z-score})^2$ * StdDev*(1-StdDev)/$(\text{margin of error})^2$

In this case, we want a confidence level of 95% which equates to a Z-score of 1.96, a confidence interval of $\pm$5% and population of greater than 100,000. The manual sample size calculations were confirmed by using online sample size calculators from Qualtrics and Creative Research Systems (https://surveysystem.com). Based on the large number of business travelers in the US, a minimum of 383 qualified respondents were required for statistically valid results using Qualtrics sample size calculator. The researcher contracted Qualtrics with a requirement to supply a minimum of 400 completed surveys by qualified respondents.

The researcher requested that each respondent meet the following minimum requirements:

- Business travelers,
- Travel at least three times per year,
- On medium-length trips defined as being approximately 500 miles

Instrument

The purpose of the survey instrument is to capture the stated transportation mode preference of the respondents given descriptions of each mode and five attributes for each trip option. The context of the survey is business travel for medium length trips. The instrument for this survey was developed by the researcher specifically for this survey, however the development process for this type of survey is very well documented with many examples. The sources and process are detailed in the following paragraphs. The complete instrument for this survey can be found in Appendix A.

Instrument Validity

The validity of this type of survey instrument is addressed directly in the Transportation Research Board's (TRB) On-line Travel Survey Manual (OTSM) (2018). In section 21.3, the manual states:

> A concern often voiced about the use of SP data is that people do not necessarily do what they say they will do. Therefore, a key issue associated with SP data is validity. Pearmain, et al. (1991) have reviewed a number of studies in which the validity of predictions of choice behavior based on SP techniques was investigated, based on this review, they concluded that the results of most of these studies seemed encouraging, suggesting that SP techniques can predict choice behavior for the sample being studied with a reasonable degree of accuracy. However, they noted that most of the reported studies of validity had the following shortcomings:
>
> · The research was not done in a systematic way;
>
> · The research was carried out as a by-product of a practically-oriented study;
>
> · Some of the studies were based on incorrectly applied prediction methods; and
>
> · Typically the reported research only concerned the reproduction of existing behavior of the sample being studied; few studies deal with the generalization of predictions to entire populations, and very few look at the ability to predict behavioral changes in response to changed circumstances.

They continue that it is difficult to make statements about all SP surveys because each experiment is designed and executed differently. The manual goes on:

> This is partly a science, but also an art to some extent, and often there is no substitute for experience when it comes to surveys and market research. Therefore, it is very difficult to design and carry out meaningful SP research without obtaining at least some advice and input from persons and/or firms who have experience with this specific type of survey.

One of the criticisms of SP surveys is commitment bias, where the respondent chooses the new mode of transit, especially when cost and time factors are particularly advantageous. In this survey, I tried to remove this bias estimating travel time and costs for the GBAV as accurately as I could. It also helps that a GBAV is, in essence, an existing mode (automobile) and it therefore not an unrealistic, exotic alternative that offered substantial improvement in time and cost. Quite the contrary, the major improvements are in the new categories being measured. The OTSM recommend making the surveys as realistic as possible and that is what I have done here.

The OTSM continues:

> Even with the most realistic, customized surveys, however, it is likely that some potential for non-commitment bias still exists. Furthermore, combined analysis of SP data with RP data, while useful in many ways, does not address this particular issue, because the RP data does not provide any information about modes that do not already exist.

Instrument Reliability

For SP surveys, calculating instrument reliability is difficult and I found no literature on the subject. When researching Cronbach's Alpha, the suggested method, a post by Zaiontz (2014) stated that "The goal in designing a reliable instrument is for scores on similar items to be related (internally consistent), but for each to contribute some unique information as well". I was able to determine the Cronbach Alpha for the section of the survey that fit the tool, the section of the instrument where the respondents supplied their perceived value or measure of a specific activity, e.g. productivity while in a commercial airliner. All of these were answered on a scale of one to five, which tends to produce smaller values for Cronbach's Alpha since there are fewer items on the scale (Simon, 2004). Using the JMP Analyzer on this section of the instrument the calculated Cronbach's Alpha is 0.7772. There are widely differing opinions regarding the proper value for a Cronbach's Alpha. Simon writes that in social science applications 0.7 or higher is considered satisfactory, but other use 0.75 or 0.8 and in other case some are satisfied with 0.6, especially in exploratory studies.

Research Design & Procedure

Transportation is an often-researched field in public and private arenas. Transportation research methodologies and guidelines, and more specifically surveys to determine how travelers make choice selections, are detailed in the Transportation Research Board's (TRB) On-line Travel Survey Manual (OTSM) (2018), which is based on the work of Stopher et al. (2008) and Tierney et al. (1994). Transportation surveys are usually designed to capture the current behavior of the traveler, to reveal their preferences, which is known as a Revealed Preference (RP) surveys. For the research required for this study, Chapter 21 of the OTSM, Stated Preference (SP) Surveys, composed by Correia and Bradley (ND) describes the theory of SP Surveys in the context of transportation mode selections. SP surveys are a form of Stated Response (SR) survey that provide specific data on the way a choice decision is made. SP and SR surveys are a form of Discrete Choice Experiment (DCE) which are often used in marketing and many other fields to quantify subject's preferences. The TRB OTSM documentation provided the researcher a basis for experiment design that is accepted practice and encouraged by the Transportation Research Board as a standard methodology. For this reason, the researcher believes the instrument is very appropriate for measuring the intended variables.

The SP survey data collected in a properly constructed instrument is authoritative and is easy to understand. This allows analysis using descriptive and inferential statistics and allow the researcher to suggest reasons for relationships. Specifically, the survey will build on the work of Clements & Kockelman (2017) and LaMondia et al. (2016), who recommended that a SP survey could remove assumptions in the existing literature regarding the value of automated vehicle attributes.

Yang, Choudhury, Ben-Akiva, Abreu, & Carvalho (2009) describe in detail a SP survey project, including instrument design. Their work and the TRB manual is used as a foundation for this survey design. This SP survey was designed and implemented to provide data sufficient to address the four research questions articulated in earlier in this chapter. The initial step in designing the SP survey is to identify and design the important attributes used to make choice decisions for transport mode selection and the values of the attributes for each of the travel modes. The classical approach as defined in the TRB manual was used, therefore attribute values for the explanatory variables were determined using values that are realistic. In this study the researcher considers three travel mode alternatives, one of which, the GBAV, is not available to travelers as of date of the survey distribution. In general, this research evaluated public acceptance of GBAVs and quantified traveler sensitivity to level of service by varying values of travel time, travel cost, productivity, flexibility, privacy and processing time. The attributes productivity, flexibility and privacy are included specifically to provide answers to the research questions.

The selected travel mode alternatives have multiple common attributes. Subsequent SP surveys, may use a pilot survey to determine the attributes values most significant to the travelers. In this exploratory study, those attributes are included in the assumptions to minimize the complexity and size of the survey instrument to a range that can be reasonably accomplished given time and funding constraints.

Procedure

A pilot survey with two choice scenarios was designed and distributed to 30 associates of the researcher that are known frequent travelers. The responses were reviewed and feedback was sought and received via email and telephone calls. The primary purpose of this initial test survey and a subsequent smaller test was to ensure the respondents understood the capabilities of the conceptual GBAV and that the attribute values were perceived as reasonable.

Following the two test surveys, the final survey instrument was prepared for distribution to the contracted for respondents. The survey instrument used in this study is a survey designed for quantitative analysis through discrete choice modeling and logistic regression.

The survey was constructed, programmed and tested using Oklahoma State University's College of Education, Health and Aviation's license for Qualtrics, LLC Software as a Service (SaaS) survey building and distribution tool. During this survey period, Qualtrics was acquired by SAS. The resulting data was analyzed using SAS's JMP Pro, version 13.1 (JMP) statistical analysis software also provided by Oklahoma State University. This study will require the use of humans in a purposive sample of participants, and approval ED 17-159 from the Oklahoma State University Research Compliance Institutional Review Board (IRB) was be obtained prior to any interaction with the subjects. Once satisfied with the quality of the instrument and with IRB approval, Qualtrics distributed the survey to qualified respondents purchased by the researcher through Qualtrics. The subjects for this survey were selected and vetted by Qualtrics.

For the Qualtrics platform to collect the data as required by the choice models the researcher had to produce the JavaScript shown in Appendix B. The guidance for the coding design came from work by Dropp (2014), which specifically addresses implementing this type of analysis in Qualtrics.

Unlike quantitative statistical research methods, in the SP type of analysis, the concept of independent and dependent variables is not appropriate. We are not predicting the choice, but rather calculating the probability of the mode being selected as the desired option. The attribute levels in the choice models are explanatory and set constructs for the respondent's decision making. This is discussed in detail in the next section.

Attribute Definitions and Value Assumptions

In order to make the choice decisions realistic and to abide with the SP survey guidelines in the TRB OTSM, the following attributes and their values that the researcher used for the experiment were based on current, at the time of survey distribution, real pricing and experience. Each attribute is defined in the following list:

- Total Travel Time – time, in minutes, measured from door to door, from leaving home or office and arriving at the final destination, including driving time and ingress/egress times.
- Process Time – time, in minutes, waiting in line, ticketing, baggage check-in and pick-up and security.
- Privacy – a number from 1-5 representing the respondent's perception of privacy in a given range of possible privacy in each mode.
- Flexibility – a measure of the perceived flexibility of the travel mode given the constraints of the mode.
- Productivity – A measure of the respondent's perceived or estimated productivity in a range constrained by the mode.

- Flexibility – A measure of the respondent's perceived ability to modify travel plans during the trip.
- Cost – Estimated real costs based on airline trips that match the profile of the study, Internal Revenue Service (IRS) automobile reimbursement rates and sampled rental car rates for trips of this length or duration.

Table 3.1 displays the values selected for each of the attributes for each mode of travel. For some attributes there were five options, for others only three. The values for the attributes were based on current prices for airline travel for trips similar to those the research is intended to consider. For example, a flight the researcher used often from Stillwater, OK (KSWO) to Memphis, TN, (KMEM) was included. Automobile rates were based on a combination of rental car rates, standard reimbursement rates. Academic research on the productivity, flexibility and privacy of transportation modes is virtually non-existent. The only research found with respect of productivity was a single study conducted for the National Business Aircraft Association (Krane & Orkis, 2009).

Table 3. 1

Assumed Values of GBAV Attributes

Mode	Total Travel Time (Hours)	Round Trip Cost ($)	Productive Time (%)	Flexibility (1-least, 5-most)	Privacy (1-least, 5-most)
GBAV	5	400	100%	5.0	5.0
GBAV	6	500	90%	4.5	4.5
GBAV	7	600	80%	4.0	4.0
GBAV	8	700			
GBAV	9	800			
Commercial Air	4	400	30%	2.0	2.0
Commercial Air	5	500	20%	1.5	1.5
Commercial Air	6	600	10%	1.0	1.0
Commercial Air	7	700			
Commercial Air	8	800			
Automobile	6	450	20%	4.0	5.0
Automobile	6.5	500	15%	4.5	4.5
Automobile	7.0	550	10%	5.0	4.0
Automobile	7.5	600			
Automobile	8	650			

Experiment Design

Prior to gaining access to the choice selection section of the survey, respondents were asked screening questions intended to mask the purpose of the survey and to validate them with respect to their travel experience, by including a question regarding trip length to qualify the respondents and insure only qualified respondents completed the survey. Qualtrics then distributed the survey and collected fully completed survey data from 420 qualified respondents.

The SP survey instrument is divided into four sections:

1. Travel - typical trip information for the respondent
2. Respondent productivity estimates by mode
3. Perceived decision criteria importance

4. Stated preference choice scenarios

In the first section of the survey respondents were asked the qualifying questions mentioned above, then asked for information on the typical business trips they traveled in the last year. The qualifying questions ensured that the respondents provided by Qualtrics met the required standards. Respondents were asked to log the number of trips in each of five trip length categories (0-400 miles, 401-600 miles, 601-800 miles, 801-1,000 miles and 1,000+ miles), average total trip time in hours and estimated total driving time in hours for trips flown on commercial airlines. Respondents were then asked for the:

- Time spent, in minutes, when traveling through their primary airport for the drive to the airport,
- Time spent parking through check-in,
- Time from check-in through security,
- Time from security through boarding,
- Time deplaning through arriving airport and
- Time to travel from the arrival airport to the destination.

This information is to be used in analysis of traveler behavior and the identification of travelers likely to benefit from alternatives to commercial air travel for short to medium-length trips.

In the second section, the respondents were asked to rate their own productivity on a scale of one to five, one being completely non-productive and five being 100% productive, in the following contexts: in an automobile as the driver, in an automobile as a passenger, in a taxi or ride share, waiting to board a flight, on an airplane, or other.

In section three the respondents were given a brief explanation of one possible implementation of a GBAV and asked to rate, on a scale of one to five, the importance of the attributes that will be asked about later in the scenarios. Those attributes are: total door-to-door time, privacy, flexibility, productivity, cost and other. The result of their value perception of these attributes were then compared to their answers in the survey.

In each scenario, each presented attribute had one of three to five values. Those values vary by scenario, such that all combinations are seen by respondents. The attribute values communicated in the assumptions are based on the Travel Survey Manual's recommendation to set the values close to existing options or expected values for modes that have not been implemented. The goal is to make the attribute values as realistic as possible. For analysis, each descriptive attribute value is representative of a numerical value, e.g. Not private = 1, Semi-private = 2, Very private = 3.

Section four contains the choice scenarios. Each respondent was presented four choice scenarios. Each choice scenario included two variations of all three mode alternatives, each with varying attribute values. The respondent was asked to select their preferred trip for each scenario. For example, see Table 3.2.

Table 3. 2

Example Choice Table

	Mode	Travel Time	Travel Cost	Productive Time	Flexibility (1-5)	Privacy (1-5)
Trip 1	GBAV	5 hours	$400	90%	5	5
Trip 2	GBAV	7 hours	$500	100%	5	5
Trip 3	Automobile	6 hours	$300	20%	5	5
Trip 4	Automobile	8 hours	$200	10%	5	5
Trip 5	Commercial Air	5 hours	$500	30%	2	2
Trip 6	Commercial Air	7 hours	$700	20%	1	3

Each attribute can be represented by one of the available values in a choice scenario. For example, door to door time for a 500-mile trip could vary from five hours (best) to nine hours (worst) in two hour increments. Likewise, cost may vary from $400 (best) to $800 (worst) in $100 increments. The possible combinations are too numerous for any one respondent to answer; therefore, each respondent was presented four choice scenarios. Two attributes have five possible values and three with three values each, therefore there are 1,125 possible combinations for each of the three modes using a full factorial design (5 x 5 x 5 x 3 x 3 = 1,125). By using a minimum of 400 respondents, each completing four scenarios and therefore seeing 24 combinations, it was ensured that all possible permutations were seen, though not by one person. With a final count of 420 respondents, each possible set of values for the attributes was seen at least nine times in the survey.

Data Analysis

To transform the collected data into a useable format in JMP, it was downloaded from Qualtrics as a CSV file and then edited by removing columns containing data not required to answer the research questions. The complete data set has been retained, in accordance with the IRB proposal and approval, as it may be useful for continued analysis beyond the limited scope of the research questions. For example, Qualtrics collects the geographic location, recorded latitude and longitude coordinates, for all respondents. That data, provided not too many respondents use Virtual Private Networks (VPNs) may have value in determining regional differences in travel mode selection criteria. An example of one scenario in the data table used for analysis is in Table 3.3.

Table 3. 3

Formatted Data Table

ID	Scenario	Mode	Time	Cost	Prod	Flex	Priv	Choice
R_0wxQ0KHcjYoGh2N	1	GBAV	7	500	100	4.5	4.5	0
R_0wxQ0KHcjYoGh2N	1	GBAV	9	500	100	4	5	0
R_0wxQ0KHcjYoGh2N	1	Auto	7.5	450	20	4.5	4	1
R_0wxQ0KHcjYoGh2N	1	Auto	8	550	10	5	4	0
R_0wxQ0KHcjYoGh2N	1	ComAir	7	800	30	1.5	1.5	0
R_0wxQ0KHcjYoGh2N	1	ComAir	7	400	20	1.5	1.5	0

In Table 3.3 the ID field displays a unique code for each respondent, the Scenario field shows which of the four scenarios that particular row was presented in, the Time, Cost, Prod, Flex and Priv fields represent the door-to-door time of the trip, the cost in dollars, the productivity as a percentage and flexibility and privacy on a scale of one to five, respectively. Once the 10,080 data line file was complete analysis could begin with the JMP software.

The data file was opened in JMP and the proper analysis tools selected from the Analyze pull-down menu: Consumer Research -> Choice. The attribute fields, Mode, Time, Cost, Prod, Flex and Priv were added in the JMP Construct Profile Effects window. Choice was selected as the Response Indicator, ID as the Subject ID and Choice Set as the Choice Set ID. The combination of Subject ID and Choice set creates a unique set of presented attributes and the respondent's choice.

From JMP Run Model was selected which executes all analysis programs associated with choice model methods. The first test are measures of the statistical significance of each of the attributes. The first output is the Effect Summary, which shows the significance level of each of the attributes. The attributes are listed in order from most significant to least significant. Additionally, the JMP software calculates the LogWorth for each attribute. The LogWorth is calculated using the formula:

$$\text{LogWorth} = -\log_{10}(p - value)$$

Therefore, any LogWorth greater than 2 is significant at the 0.010 level. The Chi-square Likelihood Ratio Test calculates and provides Likelihood Ratio Chi Square value, degrees of freedom and P or (Prob > ChiSquare). JMP presents these values in a table formatted like Table 3.4

Table 3. 4

Likelihood Ratio Tests

Source	L-R ChiSquare	DF	Prob>ChiSq
Mode	0.000	2	1.0000
Time	73.938	7	<.0001
Cost	102.130	7	<.0001
Prod	13.752	6	0.0325
Flex	3.625	5	0.6046
Priv	7.398	5	01927

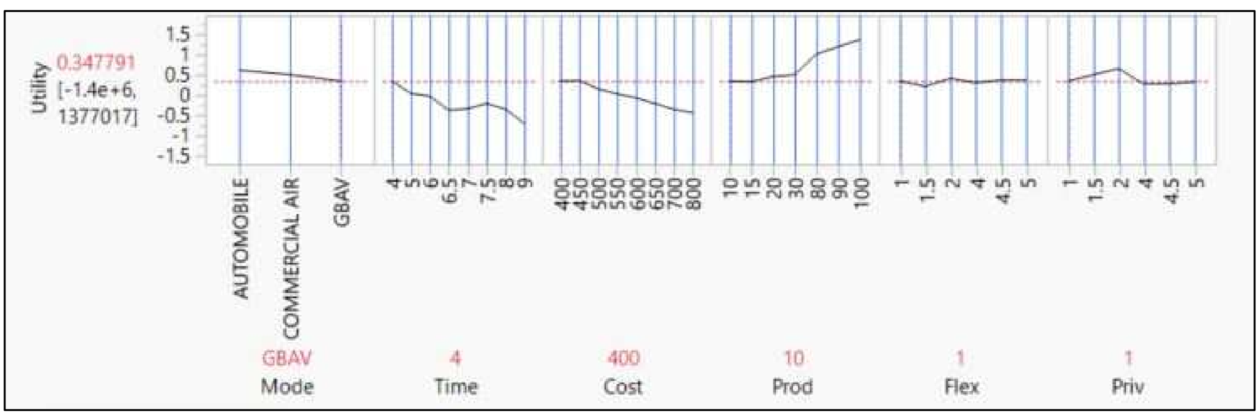
The likelihood ratios test begins to answer all four of the research questions, do any of the individual factors make a difference to travelers and are any of them more impactful than the others. Following the significance testing the JMP software executes consumer utility and probability calculations that calculates the level of satisfaction consumers receive or believe they will receive with the attributes presented to them.

The output of the utility profiler out is data and graph similar to Figure 3.1, however the utility profiler is a dynamic tool, which the researcher can use it to optimize utility and desirability for the attribute values based on the data (Consumer, 2017). This tool is used to discover traveler's perceived utility of the different attribute relative to the others and will be exploited in the findings section of this paper.

The utility profiler is also an important tool in seeking answers to the research questions. Using this tool, we can measure the perceived utility or relative importance of each of the attributes for the transportation modes. We will have measured which have a significant impact and those can then be ranked. The y-axis scale, from -1.5 to 1.5 is arbitrary, indicating relative importance.

Figure 3. 1

Utility Profiler Output

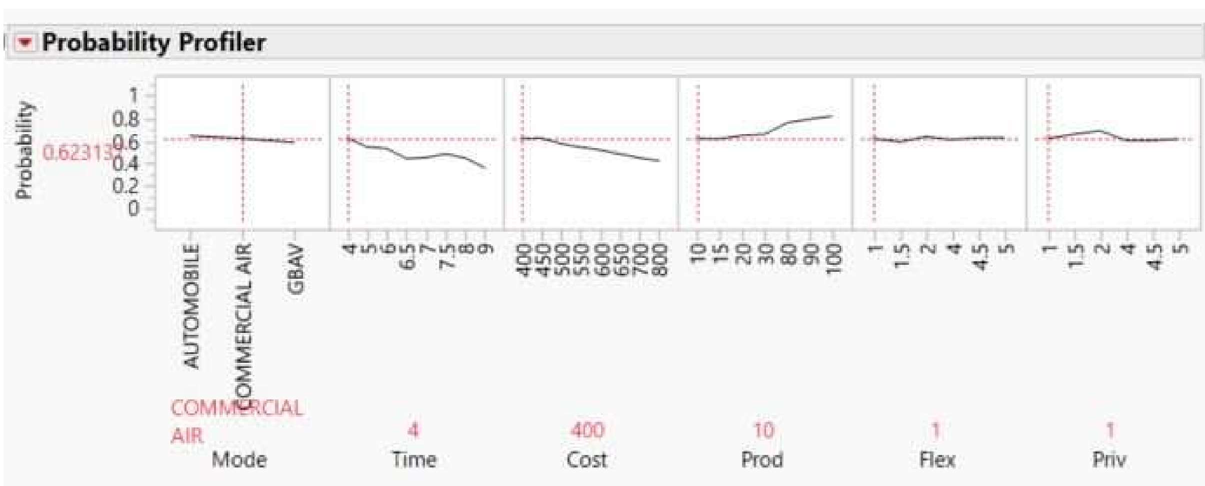


The Probability Profiler, shown in Figure 3.2, is similar to the Utility Profiler, except the output allows you to compare choice probabilities among a number of potential products. This predicted probability is defined as $(\exp(U))/(\exp(U)+\exp(U_b))$, where U is the utility for the current settings and U_b is the utility for the baseline settings. This implies that the probability for the baseline settings is 0.5. In the example below, commercial air is set as the baseline and the relative importance of each attribute/value pair can be interpreted visually.

Like the utility profiler, the probability profiler also shows the traveler state preference by indicating which attribute is likely to influence the decision which will contribute to answering the survey questions. The scale on the probability profiler is different than the utility profiler. The y-axis is 0 to 1, indicating the percent probability this item or trip will be selected. For example in Figure 3.2, the probability that this trip will be selected is 62.3%.

Figure 3. 2

Probability Profiler Output



Finally, the most important output for the research questions is the Effect Marginals. The Effect Marginals shows the marginal probabilities and marginal utilities for each main effect in the model (Consumer). The marginal probability is the probability that an individual selects attribute A over attribute B with all other attributes at the mean or default levels (Consumer, 2017). Figure 3.3 shows an example from the JMP 13.1 Consumer Research manual (2017). In this example from the JMP Consumer research manual, the marginal probability of any subject choosing a pizza with mozzarella cheese, thick crust and pepperoni, over that same pizza with Monterey Jack cheese instead of mozzarella, is 0.9470. This analysis will provide the most insight into the expected consumer behavior given the attribute values the respondents were provided. The combination of the effect marginals, the utility profiler and the probability profiler will answer all of the research questions.

Extending the value of the probability profiler, JMP includes a multiple choice profiler. The multiple choice profiler brings clarity to the data and insight in to how the respondents compare specific choices.

Figure 3. 3

Effect Marginals Example

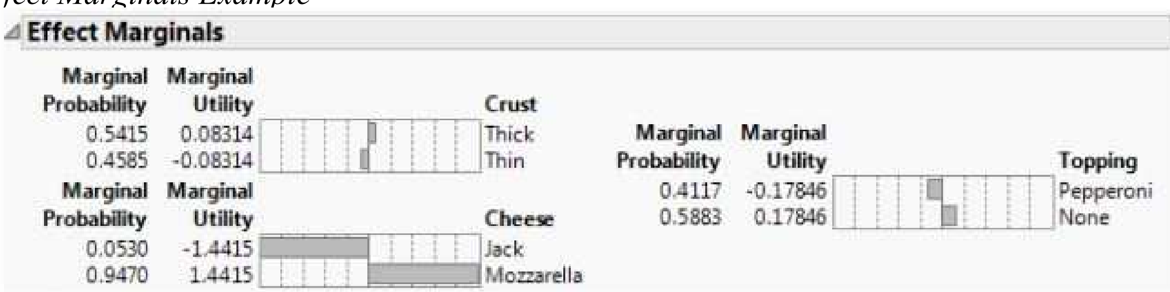
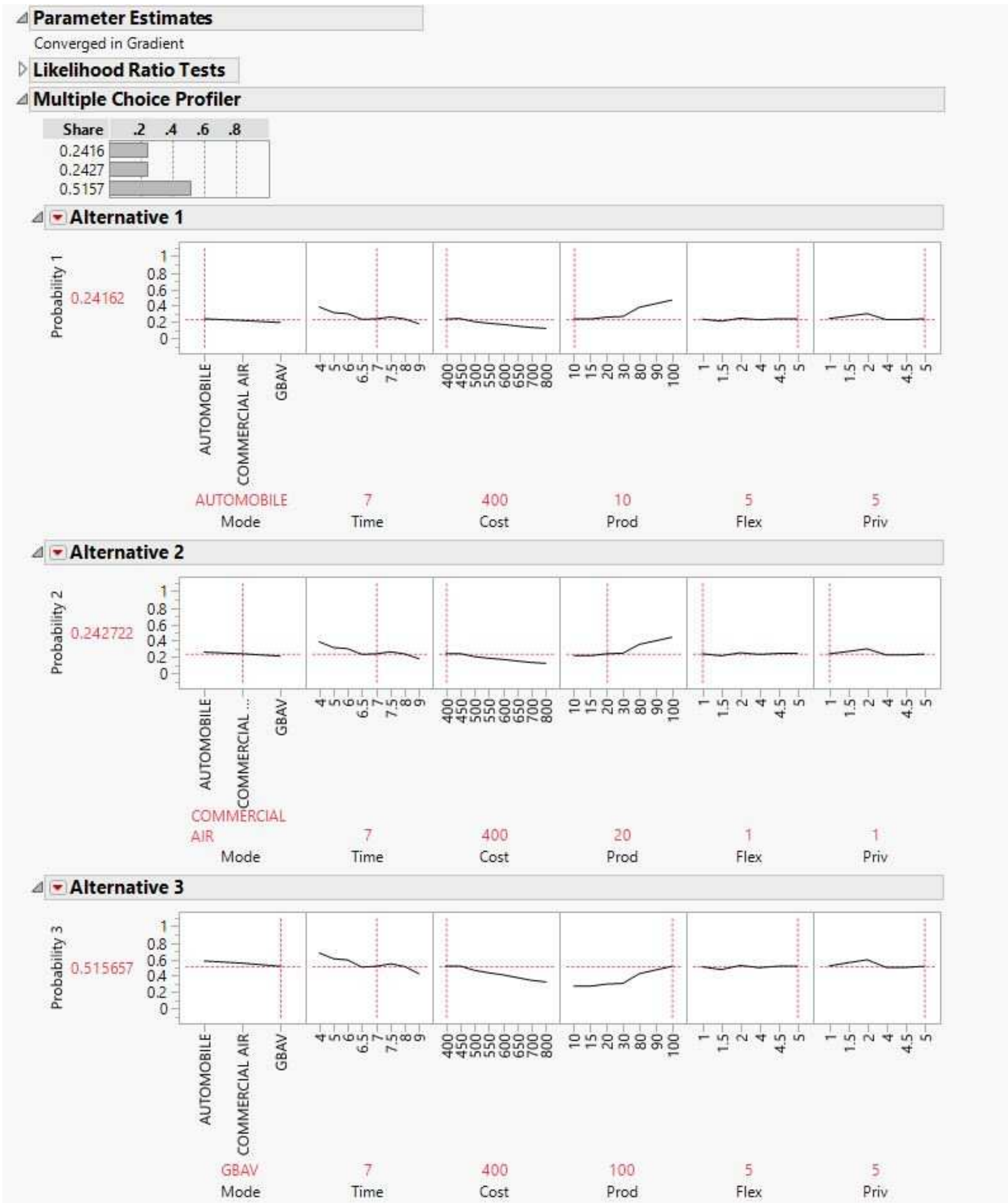


Figure 3. 4

Multiple Choice Profiler



The multiple choice profiler gives us the opportunity to see how one individual trip attribute affects the traveler’s choice. In Figure 3.3, three alternatives, one for each mode, are compared directly. In all three alternatives the total trip time is seven hours and the cost is $400. The variation, aside from mode, is in productivity, flexibility and privacy. For the automobile, productivity is set a 10%, Flexibility is set at 5 of 5 and privacy is 5 of 5. For Commercial Air, the productivity is set at 20%, flexibility at 1 of 5 and privacy at 1 of 5. For the GBAV, productivity is set at 100%, flexibility at 5 of 5 and privacy at 5 of 5. Given those parameters, the probability of selection for each mode is shown on the left in red numerals. The probability of the automobile being selected is 24.162%, for the commercial air the probability is 24.272% and for the GBAV 51.5%

Appendix D contains additional examples of this output to supplement the findings in Chapter 4.

CHAPTER IV

ANALYSIS AND FINDINGS

The purpose of this research was to measure if, and how, including the attributes of potential future autonomous vehicles affects business traveler's mode choice when selecting a method of transportation. Traditionally, the primary considerations for decision making are Time and Cost when it comes to medium-length trips, which for this research is in the 500-mile range, plus or minus 200 miles. Medium length trips can be casually defined as trips where the time domain of traveling by commercial air or of driving an automobile are comparable. For very short trips it is likely air travel does not make sense and for very long trips often driving is impractical. Previous research does not include factors such a s flexibility, privacy and productivity and of which become readily available in an autonomous vehicle. In this chapter we will show the research findings, how the findings correspond with the research questions and what we found and answers to the research questions. Those research questions are:

1. Does the addition of Productivity as a criterion to selection of travel mode make a difference in traveler's choices?
2. Does the addition of Flexibility as a criterion to selection of travel mode make a difference in traveler's choices?
3. Does the addition of Privacy as a criterion to selection of travel mode make a difference in traveler's choices?

4. Do any of the discriminators Productivity, Flexibility or Privacy influence the travel mode decision more than the other?

For this survey, the researcher contracted Qualtrics to provide a minimum of 400 qualified respondents and received data from 418 completed surveys. The respondents were geographically diverse with 43 U.S. states represented. Table 4.1 shows the number of respondents from each U.S. state.

With simple analysis, the data indicates that U.S. business travelers are receptive GBAVs and willing to choose GBAVs as a potential travel mode. Using a simple count of the mode of travel each respondent chose for 1,672 trips evaluated, which included 10,032 choice alternatives, Figure 4.1 shows the percentage of each mode selected. Given the attribute values selected for this research, the respondents chose the GBAV in 40% of the scenarios, a higher percentage than either automobiles or commercial air travel. Preliminarily, this provides an affirmative answer to the fourth research question: Do any of the discriminators (attributes), Productivity, Flexibility or Privacy influence the travel mode decision more than the other. For 40% of these respondents, the answer is yes. It does not tell us however, which of the attributes affect traveler mode choice decisions.

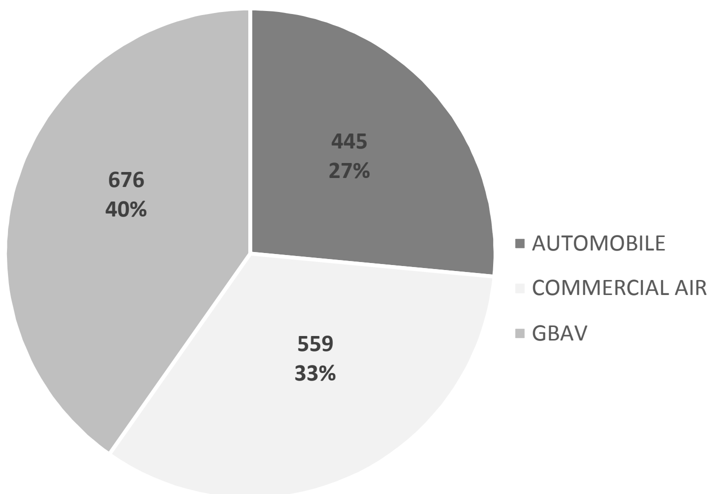
Table 4.1

State Survey Representation

State	Number of Respondents
Alabama	5
Arkansas	3
Arizona	6
California	46
Colorado	6
Connecticut	9
Delaware	1
Washington DC	3
Florida	44
Georgia	12
Hawaii	1
Iowa	2
Idaho	2
Illinois	12
Indiana	7
Kansas	8
Kentucky	4
Louisiana	3
Massachusetts	5
Maryland	11
Michigan	12
Minnesota	6
Missouri	5
Mississippi	3
North Carolina	15
North Dakota	1
Nebraska	3
New Hampshire	1
New Jersey	19
New Mexico	2
Nevada	1
New York	27
Ohio	16
Oklahoma	5
Oregon	1
Pennsylvania	19
Rhode Island	1
South Carolina	12
Tennessee	16
Texas	33
Utah	2
Virginia	6
Washington	10
Wisconsin	6
West Virginia	5

Figure 4. 1

Travel Modes Selected as a percentage



Clearly, the business traveler is willing to choose the GBAV as a mode of travel often. This, very simply and clearly, answers the fourth research question. The following sections contain a review of the survey respondents travel experience and their pre-survey perceptions of the importance of the attributes presented in the survey and their perceived productivity during selected activities required typically for commercial airline travel. Following that is the statistical information produced from the survey data: statistical signification of the attributes, utility profiles and marginal probabilities of selection, all of which will contribute to answer the research questions.

Respondent Travel Profiles and Perceptions

The respondents reported a total of 3,429 business trips of all lengths in the last year, an average of 8.2 trips per year per respondent. 1,371 of those trips were in the 400 to 800-mile range which is the focus of this research. That is an average of 3.3 business trips per year in the focus range for each respondent. For those trips in the 400 to 800-mile range, the average estimated driving time was 10.2 hours.

When asked about their experience with commercial air the respondents were asked to estimate the time required for each phase of the process. Understanding the time in these, largely unproductive phases help to demonstrate the capacity to recapture productive time in the travel process. The respondent's averages are show in Table 4.2.

Table 4.2

Airport Travel Estimates

Phase	Mean (min)	Median (min)	High (min)	Low (min)
Drive to Airport	31.90	75.00	150.00	1.00
Parking through Check-in	14.40	32.50	65.00	1.00
After check-in through Security	18.20	29.50	60.00	1.00
After Security through Boarding	20.66	74.50	150.00	1.00
Deplaning through leaving the Airport	20.40	44.50	90.00	1.00
Travel from airport to Destination	48.10	199.50	400.0	1.0

Table 4.2 also shows that on an average medium-length trip using commercial airlines, the travelers spend on average 154 minutes (2 hours, 34 minutes) either traveling to the airport, processing or waiting at the airport, or traveling to their destination.

Table 4.3 shows the mean values of the respondents when asked about their perceived productivity in each aspect of airline travel. In this case the respondents did not believe there is much difference in productivity between any of these activities. On the low end, in the automobile as a driver, at a mean value of 2.75 is only considered 12.6% less productive (on the scale of 5) than being on the airplane, at 3.38, which presumably they are not flying.

Table 4.3

Perceived Productivity

Section or Mode of Travel	Mean Perceived productivity (1-5, 1 = Low, 5 = Very High)
Automobile as Driver	2.75
Automobile as Passenger	3.05
In a Taxi or Ride Share	2.88
Waiting to board a flight	3.20
On the Airplane	3.38

Table 4.4 shows the mean of the respondent value of importance for each attribute. These fall into a very narrow range, 3.12 to 3.59, and represent only 11.75% of the possible range of values, one as the minimum value and 5 as the maximum.

Table 4.4

Attribute Importance

Attribute	Mean Importance (1-5, 1 = Low, 5 = Very High)
Total door-to-door time	3.12
Privacy	3.32
Flexibility	3.45
Productivity	3.43
Cost	3.59

The data from Table 4.4 also indicates that in the pre-survey questions the travelers did not have a strong feeling regarding the importance of any of the attributes. Cost is the most important at 3.59, however Time was regarded as least important, which the research data will indicate is not in alignment with the traveler's decision-making. Flexibility, at 3.45 is reported to be moderately important, and the data will suggest it is of little concern to the travelers.

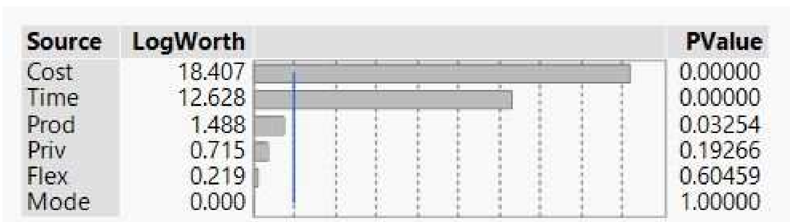
Effect Summary

The JMP Effect Summary shows the significance of each of the attributes in the collected data. The effect, or significance, is expressed through the calculated p-value. Figure 4.2 shows the JMP calculated p-value for each of the attributes, with time, cost and productivity at less than 0.05, indicating significance. The Effect Summary also contributes to answering the research questions by identifying the statistically significant attributes in this survey data. Comparing the p-values of the attributes, Cost and Time have the lowest p-values and the p-value for Productivity is also below the 0.05 threshold indicating, again, an affirmative answer to research question one, the addition of Productivity does make a difference in traveler's choices. It also provides an affirmative answer to question four: Do any of the discriminators, Productivity, Flexibility or Privacy, influence the travel mode decision more than the other. Conversely,

Figure 4.2 also shows that Flexibility and Privacy make nearly no difference with p-values of 0.60 and 0.19 respectively. If there were a null hypothesis that none of these attributes have a significant effect on the traveler's mode choice, we would have to reject the null hypotheses on the basis of the Productivity result.

Figure 4.2

Effect Summary



Likelihood Ratio Test

The Likelihood Ratio test, shown in Table 4.5, shows the Chi Square, degrees of freedom and probability > Chi Squared (p-value) in a single table, which supports the values from Figure 4.2.

Table 4.5

Likelihood Ratio Tests

Source	ChiSquare	DF	Prob>ChiSq
Time	73.938	7	<0.0001
Cost	102.130	7	<0.0001
Productivity	13.752	6	0.0325
Flexibility	3.625	5	0.6046
Privacy	7.398	5	0.1927

Utility Profiles

The Utility Profiler in JMP is an interactive tool, which in this research, helps the researcher and readers to visualize how changes in any or all of the attribute values (on the x-axis) affect the mode choice, which is the response or choice variable for this analysis. The steeper the slope on an individual attribute chart in Figure 4.3 indicates the relative influence of that attribute value on the perceived utility by the respondent. In this data, the attributes of Flexibility and Privacy show very little slope, which indicates very little influence on the traveler's mode selection relative to the influence of the attributes with steeper slopes. Figure 4.3. also shows a utility value of 1.14 for GBAVs when each of the red dashed lines representing the selected value each attribute is maximized for the selected mode in the Mode utility graph on the left side of the figure. You may notice that in the second graph, Time, the value selected is not the maximum on the chart, it is however, at the maximum point available to the GBAV and shown in Table 3.1. By varying selected attribute values in the Utility Profiler we can view the effect of changing any of the attribute values and see the implied changes by looking at the slope of each attribute line.

In the discussion for the Utility Profiler output, the concept of maximized attribute values refers to maximizing the perceived value not the actual numerical value. Using figure 4.3, for example, when referring the cost attribute, the maximize value is $400, the least expensive option not $800 the highest numerical value. Rational travelers will choose the less expensive trip when all other attributes are equal. Likewise, time values range from four hours to nine hours. A trip with a duration of four hours is more valuable to a traveler than a trip of nine hours, therefore the four-hour trip is the maximized value.

Figure 4. 2

GBAV Utility with Maximized Attribute Values

By switching the selected mode to automobile, even if time is reduced from seven and a half hours to four hours, which is neither possible or legal, even if physically possible for a 500-mile road trip, and we reduce productivity to 20% the overall utility decreases to 1.055 as Figure 4.4 reflects. Using these two outputs we can see that the respondents project the GBAV as having greater utility than the automobile even with the trip taking longer and having the same cost with flexibility and privacy unchanged.

Figure 4. 3

Automobile Utility, Maximized Except for Productivity

Figure 4. 4

Commercial Air, Maximum Utility

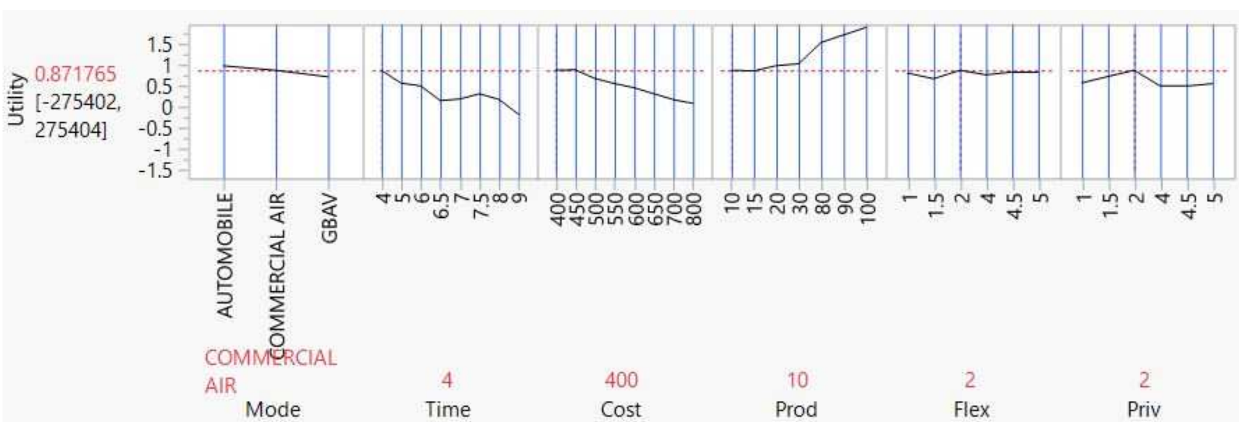


Figure 4.5 indicates that the maximum utility for commercial air as a mode of transport occurs when the time and cost attributes are at their minimum values. As soon as the trip begins to take longer or the cost of the trip rises, the utility begins to drop. In Figure 4.5 the utility is shown as 0.87 with the trip time at four hours.

Note also that figure 4.5 provides a visual representation of how the respondents regard each of the attributes. Flexibility and Privacy responses are nearly flat lines, indicating very little influence on the mode selection process.

By incrementing the time attribute value by one hour to five hours, the utility value of the trip drops to 0.56 as represented in Figure 4.6. This finding shows that for the business traveler, time is a very sensitive and therefore important factor. This finding conflicts with the traveler's responses to the question of importance of each of the attributes in Table 4.4, where trip time total had the lowest value, although those values were all very close.

Figure 4. 5

Commercial Air, maximum utility plus 1-hour

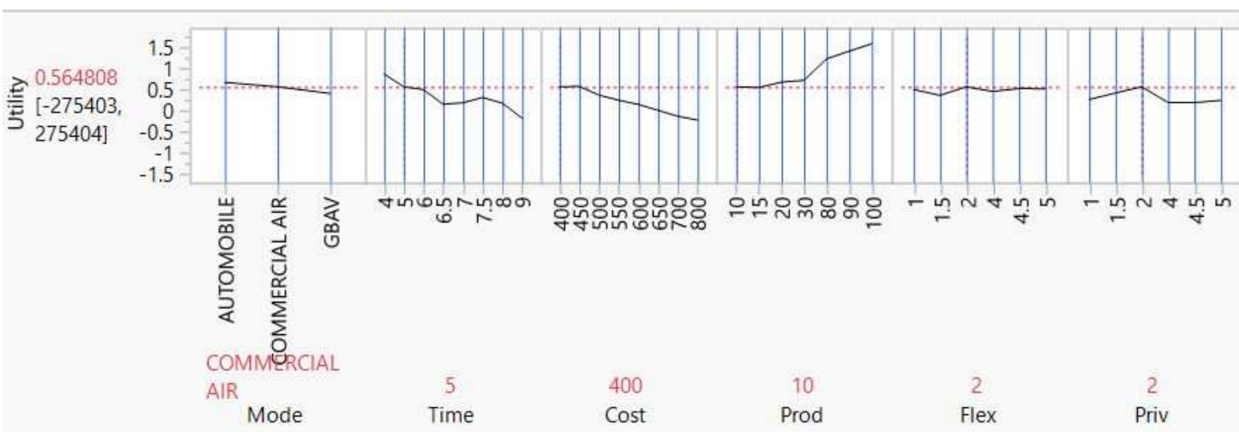
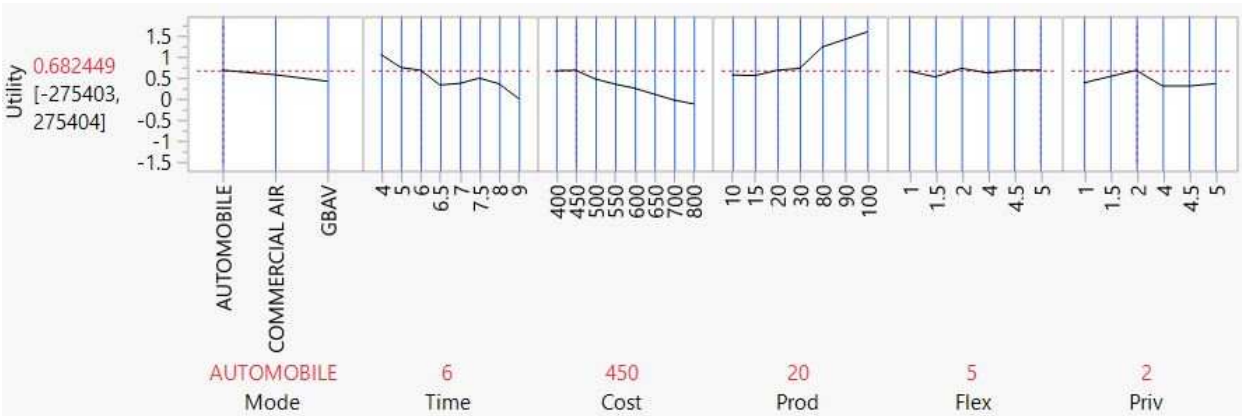


Figure 4. 6

Automobile, maximum utility value



In Figure 4.7, all attributes are set to their highest values base on the data, yielding a utility value of 068. Figure 4.4 expresses the maximum utility value for commercial air travel is 0.87. When GBAV is selected as the transportation mode and attribute values are maximized in terms of perceived value, the utility value is 1.06, much higher than commercial air or automobile. Table 4.6 shows the maximum possible utility value for each mode.

Table 4.6

Maximum utility values

Mode	Maxium Utility
Commercial Air	0.87
Automobile	0.68
GBAV	1.06

Figure 4. 7

GBAV, maximum utility value

Another analysis the JMP software performs is shown in the Effect Marginals charts that begin in figure 4.9. The Effect Marginals chart for each attribute displays two calculated values for each given attribute value. The Marginal Probability value is the calculated probability that a mode with that attribute value will be selected when all the other attribute values are at their default or mean values. Continuing to use Figure 4.9 as the example, and looking at the Marginal Probability column on the far left a range of values. These probability values can also be expressed as percentages. For example, at a Time of four hours the Marginal Probability value is 0.2070 or 20.7%. Note also that the sum of all the values in the Marginal Probability column is equal to 1.0.

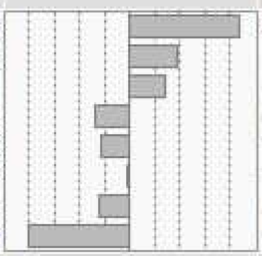
We can learn two facts from these charts, the probability a traveler will make a selection based on this attribute, all other things being equal, and the relative value or importance of that particular attribute to the travelers. This information also contributes to answering the research questions. The remainder of this section will discuss each attribute individually and the implications of the output.

Figure 4.9, rather unsurprisingly, presents that the most desirable value of the Time attribute, in the context of travel, is the smallest value, that is, the shortest time. With all other attributes at their mean values, the highest probability is 20.7% at the 4-hour value. If you combine the three lowest time value's Marginal Probabilities, the probability of one of the three trips being selected is 50.2% with all other attributes at their mean values.

Figure 4. 8

Marginal Probabilities, Time

Marginal Probability	Marginal Utility	Time
0.2070	0.54974	4
0.1523	0.24278	5
0.1425	0.17681	6
0.1004	-0.17383	6.5
0.1043	-0.13558	7
0.1182	-0.01050	7.5
0.1031	-0.14687	8
0.0723	-0.50254	9



For the Cost attribute, much like the Time attribute, low values equate to traveler desirability and therefore higher Marginal Probability of selection. Referring to figure 4.10, the highest Marginal Probabilities are the lowest cost alternatives, $400, $450 and $500. These three represent a total probability of 49.33%. The lowest cost does not have a probability of 100% or even 50%, demonstrating other factors are considered to as, or more, important to travelers than cost. Figures 4.9 and 4.10 show that travel time and cost are important to traveler's mode choice decision, which has been established by economic theory, experience and previous research.

Figure 4. 9

Marginal Probabilities, Cost

Marginal Probability	Marginal Utility	Cost
0.1741	0.37066	400
0.1762	0.38264	450
0.1430	0.17394	500
0.1267	0.05330	550
0.1147	-0.04671	600
0.0997	-0.18692	650
0.0865	-0.32850	700
0.0791	-0.41841	800

In Figure 4.11, Productivity stands out with the highest Marginal Probabilities of any of the attributes at any value. The highest value for the traveler is achieved at the highest productivity values. At a Productivity value of 100%, meaning 100% of the trip has the potential to be productive time, the Marginal Probability is 24.5%, the highest single value of any of the five attribute's total of 35 possible attribute values. With all other attributes at their mean values, nearly 25% of the time travelers will select the GBAV, as it is the only one with the potential of 100% productivity. Given the top three productivity values, the GBAV has a total selection probability of 62.3%, much higher than either the cost or time attributes. This result also provides an affirmative response to the first research question, the addition of productivity does make a difference in traveler's choice of mode. Figures 4.12 and 4.13 show that for the attributes Flexibility and privacy, the result is negligible or not as strong.

Figure 4. 10

Marginal Probabilities, Productivity

Marginal Probability	Marginal Utility	Prod
0.0884	-0.39642	10
0.0870	-0.41270	15
0.0988	-0.28563	20
0.1031	-0.24263	30
0.1715	0.26584	80
0.2057	0.44738	90
0.2454	0.62416	100

The data in Figure 4.12 is different than the previous attribute result in that while the other showed a clear preference for high performance, represented by low cost, short travel times or high productivity, when it comes to flexibility the traveler responses indicate less priority or interest. The Marginal Probability result highest value is 17.2% and the lowest value is 14.7%. The spread from highest (most desirable) to lowest (least desirable) is only 2.5% indicating that flexibility is not very important to the travelers. Looking at this table the traveler's ambiguity is apparent with the Marginal Probability fluctuating from high to low flexibility values.

Figure 4. 11

Marginal Probabilities, Flexibility

Marginal Probability	Marginal Utility	Flex
0.1682	0.01130	1
0.1468	-0.12491	1.5
0.1797	0.07736	2
0.1611	-0.03193	4
0.1723	0.03543	4.5
0.1719	0.03276	5

The Marginal Probabilities for Privacy (Figure 4.13) are similar to Flexibility in that they fluctuate from high to low Privacy values. Oddly, the highest marginal probability for Privacy is reached a value of two out of a possible five. It is reasonable to believe that business travelers do not value less Privacy or less Flexibility over more, therefore these results also indicate travelers place less importance on privacy and flexibility than on the other three attributes, time, cost and productivity.

Figure 4. 12

Marginal Probabilities, Privacy

Marginal Probability	Marginal Utility	Priv
0.1574	-0.04763	1
0.1834	0.10539	1.5
0.2126	0.25322	2
0.1462	-0.12117	4
0.1462	-0.12152	4.5
0.1542	-0.06829	5

The values from the Marginal Probability tables reinforce the findings of Effect Summary Table (p-value), the Likeliness Ratio table and the Utility Profiles and answer the research questions succinctly and emphatically.

1. Does the addition of productivity as a criterion to selection of travel mode make a difference in traveler's choices? *Yes, with a p-value that demonstrates statistical significance and the highest Marginal Probability, Productivity does influence traveler's mode selection.*
2. Does the addition of flexibility as a criterion to selection of travel mode make a difference in traveler's choices? *No, Flexibility was neither statistically significant nor influential in traveler's mode selection.*

3. Does the addition of privacy as a criterion to selection of travel mode make a difference in traveler's choices? *No, Privacy was neither statistically significant nor influential in traveler's mode selection.*
4. Do any of the discriminators productivity, flexibility or privacy influence the travel mode decision more than the other? *Yes, Productivity as an attribute is more influential than either Flexibility or Privacy.*

CHAPTER V

CONCLUSIONS

The first four chapters of this document provided an in depth introduction to the research study and the four research questions, a review of topical academic research with current readings from corporate documents, popular press, and news sources to insure topical currency, the research methodology and tools used to evaluate the data and my finding and analysis from the data.

This chapter provides an overview of the work, reiterates the answers to the research questions and then concludes with three parts. What risks does this imply for the U.S. commercial airline industry and its stakeholders, what opportunities does this create for the U.S. commercial airline industry and its stakeholders, and what are the next steps or further research that can be accomplished to clarify these findings.

Research Concept Origin

The genesis of the research came from my experience traveling as a consultant, specifically to and from consulting projects at medium length distances, and often from airports that are not hubs for any U.S. airline. These trips were not unusual in any way and required the normal airline travel components: drive to the airport, park, check bags if necessary, go through security, wait, and then board the flight. More often than not, there is an intermediate stop an airline hub and a change of planes, then the process happens again, essentially in reverse, board the second plane, disembark at the destination, gather baggage and secure transportation to the destination. Ensuring timely transportation on the destination end is often non-trivial and requires pre-planning to avoid delays or inconvenience. Only during the waiting times at the airport and while on the airplane is there much hope of productivity. And while some individuals can focus in a busy, loud and bustling environment, many cannot. Airline seat space is not growing, so unless you are traveling in first or business class, space is constrained and productivity is difficult to achieve.

Driving these medium length trips often takes about the same amount of time and unless you spend some of that time conducting business on the phone, that time is not productive. The primary advantages of driving are privacy and flexibility. No one is reading your laptop screen or notes over your shoulder or listening to your conversations, and you have the freedom to change your destination without having to pay a change fee, buy a new ticket and wait for another flight. You can also stop any time you wish for food, rest or to attend to biological needs.

Research Questions and Answers

This research project was designed to answer four questions regarding factors that influence business traveler's transportation mode choice for medium length business trips.

1. Does the addition of productivity as a criterion to selection of travel mode make a difference in traveler's choices? *Yes, with a p-value that demonstrates statistical significance and the highest Marginal Probability, Productivity does influence traveler's mode selection.*
2. Does the addition of flexibility as a criterion to selection of travel mode make a difference in traveler's choices? *No, Flexibility was neither statistically significant nor influential in traveler's mode selection.*

3. Does the addition of privacy as a criterion to selection of travel mode make a difference in traveler's choices? *No, Privacy was neither statistically significant nor influential in traveler's mode selection.*
4. Do any of the discriminators productivity, flexibility or privacy influence the travel mode decision more than the other? Yes, Productivity as an attribute is more influential that either Flexibility or Privacy.

Approach

I have a background in management consulting. Much of that work begins with discovery work consisting of research, interviews and gathering of information and then presenting findings, conclusions, recommendations and next steps to the client. As this is applied research, I am taking the same approach with this chapter. This chapter is written similar to a summary report provided to a client. In this case the presumed client would be a major domestic airline.

General Conclusions

To begin to quantify the risk GBAVs pose to commercial airlines we must first gather what we know and what we do not know. We know that a tremendous amount of money has been and is being invested in associated technologies. There is more detail on that subject later in this chapter. We also know, or can reasonable infer, some of the attributes of these vehicles. These are items to categorize as assumptions used to draw conclusions and plan actions. These assumptions are:

- GBAVs for medium distance or longer travel will approximate the speed of current automobiles on the highway. It is likely that when all or most of the vehicles on the road are GBAVs the speed will go up without loss of safety.

- GBAVs will accommodate one to many passengers and can be configured for work or relaxation.
- GBAV's will be connected vehicles with access to one or more forms of wireless communications and therefore capable of internet access, entertainment, video conferencing, etc.

These general findings have been validated in recent reports from Accenture (2018), McKinsey (2019) and Ford Motor Company via McKinsey (2019). While strictly aimed at the automotive industry, these reports all agree on the direction and development of autonomous automobiles. McKinsey believes we are at the beginning of "Mobility's second great inflection point", the first coming in the early twentieth century with the Ford Model-T providing affordability, convenience and a better travel experience. This model hasn't changed for over 100 years, but the McKinsey analyst believe significant changes are coming.

The next step, which is much of the work done to date is to determine the attractiveness of the GBAV to the traveler. This is the origin of the four research questions, we know the experience of travel today and we can conceive the possible travel experience of the future. After conducting a survey to answer the four research questions, I find that the approaching changes in the transportation marketplace provide risk and opportunity for the domestic airlines and airframe manufacturers, leasing firms and pilot and flight attendant's unions should begin paying attention if they are not already.

It is worth emphasizing here that the travelers surveyed were willing to select a mode of transportation that they *have never actually seen and that they know is not technically feasible yet, for 40% of the trips they were presented*. This single statement articulates the risk to the status quo very clearly.

Recently industry reports and popular news stories have stated that autonomous automobiles are more difficult to implement than originally thought. Mayersohn (2018) reported that although Waymo, for example, has already tested autonomous vehicles through 10 million miles, the work is not complete or really, even close to full Level 5 automation. That is true, but it does not change the reality that autonomous vehicles are coming, it does however make the time horizon unclear.

Yet, none of that has stopped companies and investors from placing large bets in the race to be the first to produce fully autonomous vehicles. In the same article, Mayersohn also reported that Ford invested $1 billion in a single company, Argo AI, in 2017. Other automotive and non-automotive firms are also investing at high levels, including Aurora Innovation, Baidu (the Chinese search company), Bear Flag Robotics, Didi Labs, Drive.AI, May Mobility, Roadstar.AI, Starsky Robotics and Zoox. Zoox is especially interesting, they are a single-purpose, full-vehicle design company that started from the ground up to design a complete GBAV not based on an existing vehicle.

On the investing web site Seeking Alpha, Raisinghani reported (2019) that Cruise Automation, the autonomous development arm of General Motors (GM) is currently valued at $14.6 billion and was holding $6 billion in cash. That is over 35% of GM's market capitalization. The same report quotes Allied Market Research (2019) as predicting that by 2026 the self-driving vehicle market could be expanding at a rate of nearly 40% annually and reach over a half a trillion dollars. Aurora, another autonomous startup raised $530 million, at a valuation of over $2 billion, in their most recent investment round, from Sequoia Capital and Amazon, among others. Amazon sees potential value in reducing delivery costs. Amazon spent more than $27 billion in 2018 on delivery costs, so they have sufficient incentive to innovate and reduce the cost and increase the speed of delivering products to your door. According to the Brookings Institution's Kerry & Karsten (2017) as of early 2017, over $80 billion had been invested in autonomous cars through more than 160 separate deals. That is an average investment of over $500 million.

These deals range from simple financial investments to strategic partnerships or acquisitions. The interest autonomous automobiles is high, partly because AI development and autonomous vehicle development go hand in hand, making the potential returns enormous. The rate of investment has not slowed in the last 18 months. That this rate of investment continues to increase leads to the conclusion that although the development and deployment timeline is not clear, autonomous cars will happen. Investors see a significant opportunity to profit or otherwise benefit from the technology. There are too many benefits to slow the efforts to get there.

This amount of investment, which is funding basic and applied research, innovation and state sanctioned trials, therefore, creates risks and opportunities for stakeholders in the U.S. airline industry and for third parties interested in profiting from disruption in the travel industry.

For most industry watchers there are two obvious, but very different, drivers of autonomous automobiles. The first is safety and its primary contributors aging, alcohol, and stupidity. The second is efficiency, comprised of speed, cost, and consistent performance. Given just these two things, the risk for airlines is clearly coming, if not present today.

Strategic and Business Risks

For airlines management, the most basic risk is clearly identified by the research data, that is, that some number of current passengers will opt to travel by GBAV rather than take their current airline flights. The number of people choose to do that will vary from airline to airline based on the demographics of that airline's customer base and how those passengers perceive the benefits of the GBAV. In this scenario of this study, given the constraints and attribute values provided the respondents, 40% of the time, the traveler would have traveled by GBAV.

To estimate the market impact airlines may experience, airline analysts or consultants will begin by analyzing their existing customer data in detail. Each airline will likely see differing levels of disruption based other their route structure, customer base and customer perceived performance with respect to ease of travel, delays, cancelations and timeliness. An outline of this type study follows later in this chapter. The airline-specific analysis will be very interesting and I am anxious to see what the calculated magnitude of potential impact is after applying the risk of losing travelers to actual airline customer travel data. A good candidate for the GBAV trip is a traveler that taking the GBAV from home, or other departure point, to their final destination takes approximately the same amount of time as it would if they were flying commercial or driving their own car.

It may be that only five percent of trips meet the criteria to be a good candidate for GBAVs. Even though that appears to be a small percentage, it has a significant negative financial impact for the affected airline. Using five percent as a starting place, and based on this study, a 40% GBAV selection rate of that five percent means that two percent of the airlines current load factor disappears. Logically, those seats will be on shorter haul flights (<500 miles) and therefore concentrated on certain routes. Therefore, one implication is that this may force the airlines to reduce the number of flights from airports on those routes, which will further hasten the problem by reducing the availability of convenient flights.

We can illustrate this with a simple example based recent publicly available airline data. Example Airlines carried 35 million passengers in the fourth quarter of 2018. Total operating revenue for Q4 is shown as $6.0 billion and net income as $600 million. Extrapolating from these numbers:

- 2% of $6.0 billion = $120,000,000 in *lost* revenue
- Or, $120,000,000 / $600,000,000 = 20% in *lost* net income

In any business, the potential loss of 20% of net income requires a serious reallocation of resources and reduction of expenses to reduce costs in an attempt to maintain or improve the net income to revenue ratio, which for Example Airlines is 10.0%. This is especially true in a business with historically low margins. These significant adjustments will necessitate layoffs, reducing assets or terminating aircraft leases, and reallocation of other resources. Knowing now that this is a possibility, airlines and airline-consulting firms can begin by taking two actions.

Recommended Action One

Since the timeline for deployment of fully autonomous vehicles is unclear, airlines need to first begin to actively monitor the development of GBAVs and maintain an estimate of the implementation timeline and the potential impact on their operations.

The National Highway Traffic Safety Administration (NHTSA) published a Notice of Proposed Rulemaking (NPRM) in 2017 on proposed standards for vehicle-to-vehicle (V2V). As these rules develop, they will apply to fully autonomous and partially autonomous automobiles. Many newer automobiles today are partially autonomous, with features like automatic braking systems, adaptive cruise control and lane correction. In the future, fully autonomous vehicles will be able to communicate intention. For example, the vehicle will broadcast its destination, path, and actions so that nearby vehicles can coordinate with them or act accordingly. As of yet, the V2V and V2X (vehicle-to-anything) communications standards are still in development and single standard had not emerged.

Monitoring the technology and regulatory development progress can be done relatively inexpensively, however finding current information is often difficult as the researchers and investors in private companies are loath to publicly share their progress. One method to mitigate that risk is to invest in one or more of the more promising ventures in order to keep an accurate measure of their progress. This also creates an opportunity for a researcher or consultant to provide monitoring and information sharing services to all types of travel and hospitality companies. Several people are doing this in the form of a blog. The best I have found of those is Marc Hoag's Autonomous Cars with Marc Hoag.

As standards emerge and manufacturers begin to produce mission-specific vehicles, GBAVs designed for individuals or teams to work in, or for families or other groups to travel together, the pressure will begin to mount on airlines to compete, partner with other transportation modes or assimilate them into a larger, wholly owned model.

Recommended Action Two

Therefore, the second action is to begin development of a plan to mitigate the effects of GBAVs encroachment on their business. This will be a slower process that needs to begin soon to help the airline adapt their strategy as the capabilities and rollout of GBAV's begins. Action one and action two go hand-in-hand. As information is gathered in the action one process, the details of GBAV development become clearer and plans and mitigations can begin to develop. As more information is gathered, the picture will continue to become clearer and the response plans become more specific.

Once an airline has begun to estimate how their passenger travel patterns affect their level of risk, they can begin to analyze the implications and actions required to mitigate the potential negative outcomes. The negative outcome may affect many areas of commercial aviation. Some of the potential negative outcomes are:

- A resulting overcapacity seats, and therefore overcapacity of:
    - Aircraft
    - Pilots
    - Flight attendants
    - Mechanics
    - Airport staff (ticket counter, baggage, gate)
    - Air side equipment
- For the labor unions, shrinking labor requirements means shrinking unions and therefore shrinking dues income and shrinking union power.
- For airline investors, less opportunity for return and increased risk and in the near term, decreasing stock values
- For airframe manufacturers, reduced sales of aircraft and parts
    - Shifting part and service capabilities to geographic areas less conducive to GBAV travel and are still expanding markets
- For aircraft leasing companies, defaults on leases and the return of aircraft. While there may be opportunities to expand into emerging and/or growing markets, growth opportunities may be reduced.
- For airport managers and supporting municipalities, shrinking numbers of passengers may slow planned growth, especially if financing is from passenger

fees. This could be especially difficult for defined aerotropolis like Denver International.

Each of these parties should be working together or independently to seek solutions or mitigation.

Strategic and Business Opportunities

In addition to the strategic risks created, GBAVs are, or will be, a disruptive technology. Any disruptive technology creates opportunity. In the midst of the potential negative outcomes for airlines and their stakeholders, there is opportunity. In the scope of this research, one opportunity is to integrate airlines and GBAVs into traveler's plans, maximizing the utility of the airlines existing investment in aircraft, people and infrastructure while providing high-value customer service to business and pleasure travelers. Think of it as mobility as a service. It applies to all transportation. Accenture (2018), in a note from their automotive lead, validated these conclusions saying that the mobility services revenue is predicted to climb to almost €1.2 trillion. Of Accenture's three recommendations to the automotive industry, two hold true for the airlines. They are customer centricity and ecosystem strategies. Both of these are discussed in the remainder of this chapter.

Airlines have always focused on their core competencies. Safety, logistics, operations, maintenance, customer service and increasingly data analytics to drive marketing efforts. Airlines stick to this partly due to regulatory requirements and partly market driven. In any highly regulated industry, if there is a negative outcome and the regulators believe it is because the organization had been distracted by non-core activities, the repercussions can be more difficult than otherwise necessary. To become effective integrators of multiple travel modes, an airline will need to go beyond their current business relationship structures with other travel vendors. Their opportunity is to create a fully integrated platform for travel planning in a way that best balances the traveler's time, resources and the priorities of the traveler across more dimensions than are currently provided and includes GBAVs.

One method to accomplish this is to acquire, merge with or partner with one of the automobile companies that is investing heavily in autonomous automobiles. These manufacturers are working hard to displace the airlines on the shorter trips and there might be opportunity to operationally merge into a vertically integrated unit. This would allow both the airline and the GBAV manufacturer the chance to meet customer needs in a single transaction.

The opportunity to innovate is nearly limitless. It will require starting with a blank page and engaging customers, using a disciplined methodology, to discover needs, wants, and pain points in their travel experiences. That, in short is the primary recommendation, to act like entrepreneurs, and begin with customer discovery, in two parts. First, get in front of the customers, and find out what they want, what they need and what they are willing to pay for, not what you have. This is going to require a lot creativity, in part because current traveler's only experience is 70-plus years of the same travel options: planes, trains and automobiles. Customer discovery is a defined process that is recommended practice for startup and new product innovation in existing companies. This process is best done with one-on-one interviews done by someone with trained in the methodology. It is easy for the interviewer to lead the customer to answers the interview wants, rather than discovering actual customer needs or frustrations. In this context, appropriate questions similar to:

- When you travel, how do you define too costly? Does time mean time? Money? Effort?

- When you travel, where do you experience frustration, or what makes you feel bad?
- When you travel, what are the main challenges you face? Do you understand how things work, or perhaps more importantly, how to get things done?
- When you travel, what risks do you experience? Not in terms of safety, but in terms of time or financial?

The responses to these questions and others from 100 travelers will help to inform the structure of the service offering and the marketing approach. This qualitative approach will yield a database of responses where patterns will emerge that will help in solution discovery. The service should strive to overcome traveler's frequent obstacles and headaches.

Second, utilize existing customer travel data or work from the customer supplied trip data to develop algorithms, based on customer preferences and what was learned in step one, to assist the customer in selecting the travel components that deliver the most customer value for that specific trip and then provide the best possible solution for the customer based on departure and destination addresses. The survey responses associated with this study, for example, clearly show that the business travelers surveyed are most sensitive to time and price factors when choosing a mode of travel. Time is certainly important, especially when that time cannot be used productively. Most travelers are also price sensitive, even when a third party such as a client or employer are funding the travel.

Customer Data Analysis

Either in parallel with the customer discovery or after, the airline can begin to estimate the potential effects on their customer base by looking at their known travelers, which is those with airline affinity accounts such as American Airlines AAdvantage or Southwest Airlines

Rapid Rewards program. Those travelers have already provided data that in conjunction with their trip history, will help determine which customers are at risk for selecting the GBAV for some trips. The basic data to collect is as follows:

- Departure point (home address)
    - The interviewers in the customer discovery step can ask how often the customer travels from home or work. Those that ratio can be applied to all trips.
- Departure point (office address)
- Departure airport
- Connecting city
- Arrival airport
- Destination (if hotel also booked)
- Transportation time - this is more difficult and may have to be estimated
- Transportation time
- Trip duration – total

Using this data and travel databases analysts can determine driving distance and time and for each trip. This will be accomplished using existing or custom software tools. The result will be used ascertain the number of *at risk* trips, and then, using the initial results– calculate the impact of losing 40% of those trips to GBAV's

If with continue with the proposition that an airline will acquire or partner with a GBAV company to provide seamless travel that best responds to the travelers preferences, then the next step is to determine what will be offered to the traveler in response to their trip planning. It is useful to consider the factors that may affect traveler's value for business or personal travel. For this research with started with five:

- Time
- Cost
- Productivity
- Flexibility
- Privacy

There are other factors we should consider:

- Aggregate time (multi-mode)
- Availability by mode – limited access
- Total cost
- Comfort/amenities
- Priorities
- Social status

Using custom algorithms, the new company could weigh the factors appropriately and come up with a recommendation for the traveler. The recommendation can be as inclusive as the new company is ready to integrate into their processes. Consider the scenario in Figure 5.1

Figure 5.1

Trip 1

Trip Example 1	
Number of travelers:	1
Departure Address:	Oklahoma City
Distance from KOKC:	12 miles or 20 minutes
Destination Address:	Hilton Garden Inn, Southaven, MS (Memphis area)
Estimated GBAV time:	7h 14m
Estimated Airline Travel time:	5h 14m
Estimated Airline Add (drive/wait/drive):	1h 45
Total Trip time Air:	6h 59m
Productivity value:	1-10
Flexibility value:	1-10
Airline Cost:	
GBAV Cost:	
Recommendation based on Priorities:	

In this first example, we see two modes of travel to the same destination with nearly identical total travel times. The big differences in productivity, flexibility and cost. Depending on what the customer's priorities are, either option could be recommended. Example two, in figure 2 is quite different. Driving time is five times longer than flying and unless the traveler suffers aviophobia, flying the trip provides for much less travel time and nearly identical opportunities for productivity.

Figure 5.2

Trip Two

Scenario 2 – DFW to San Diego

Trip Example 2	
Number of travelers:	1
Departure Address:	Plano, TX
Distance from KDFW:	30 miles or 40 minutes
Destination Address:	San Diego State University
Estimated GBAV time:	20h 15m
Estimated Airline Travel time:	3h 10m
Estimated Airline Add (drive/wait/drive):	2h 35
Total Trip time Air:	5h 45m
Productivity value:	1-10
Flexibility value:	1-10
Airline Cost:	
GBAV Cost:	
Recommendation based on Priorities:	

Final Notes

There is still a long ways to go before level 5 autonomous vehicles are commonly used. The challenges come on two fronts, technology and customer acceptance. Customer acceptance will be the easiest to overcome. While many people are reluctant to accept that GBAVs are coming or more often than that, express a reluctance to give up driving, when they actually experience autonomous travel, they will be more accepting. The vehicles will be safer than human drivers, will stay sober, and will not lose their response times as they age and will be able to travel faster and more efficiently. Autonomous vehicles will actually give passengers autonomy. The autonomy to do what they want, when they want and not have to pretend they can multi-task while driving.

The technology piece will take more time. In my opinion, the most difficult period of time will be the transition from all human drivers to level 5 GBAVs. Aside from the technical integration of drivers and driverless on the same roads (more opportunity!) there is also the economic considerations. Not everyone will be able to afford autonomy at the outset. What do you do with existing vehicle? Recycle? Reequip? There is much to do in engineering, the regulatory environment and manage social implications.

While not directly related, Vance and Malik (2105) found in their research on the essential factors that may influence traveler's decision to fly on a fully autonomous aircraft that given choice information, they acceptance rate improved over a 10-year period between 2001 and 2013. Their findings are encouraging as GBAV's may be easier for travelers to conceive and consider. I believe the GBAV will be the precursor to fully autonomous aircraft.

Additional Practical Application

There are many possibilities to consider to put these finding in to practice. The first recommendation is to build on this research by using customer data and geographic determination of the likelihood of benefitting from GBAVs. This also carries a considerable amount of commercialization potential.

I recommended that airlines use their user data from their affinity programs to determine the percentage of trips that they are at risk of losing to autonomous vehicles, ground or air. That recommendation uses the home address and the known airport they fly out of along with the destination airport. An improvement on that is to use customer data from hotel affinity programs. I see this as an improvement because it includes both the starting point and the destination (hotel) and airport information can be derived from those two points.

What needs to be measured is how the distance, in time, from the departure and/or arrival airport affects the traveler's decision making with respect to the mode of transportation. Very simply drawing a 500-mile ring, representing the at-risk trips, around the departure address provides a rough answer, but i suspect the size and shape of that ring is affected by the distance from the airport. As an example, if we used my data from Marriott over the last five years, it would show domestic trips to: Boston, Chattanooga, Chicago, Dallas, Denver, Durango, El Paso, Kansas City, Las Vegas, Los Angeles (multiple airports), Memphis, Minneapolis, Mobile, Newark, New Orleans, Pensacola, Phoenix, Portland, St. Louis, San Diego, San Francisco, Seattle, Tallahassee, Tampa and Washington, D.C. Before American began service in 2016, I was flying out of OK or TUL. Conceivably, trips at risk include Dallas, Kansas City, and Memphis. As GBAV speed, comfort, range and reliability improve that might bring other cities into range, such as New Orleans or Denver. Perhaps even Chicago, which is an 11-hour drive today will be attractive as an overnight, sleeper car trip.

By digging deeper into the customer's current travel patterns and their perceptions of autonomous vehicles we can better plan for a future where the questions is not should we drive or fly, but what is the answer for me, on this trip.

Additionally, if data from both airlines and hotels is available, they can be compared and a clearer image can emerge of customer travel patterns. This research will naturally provide baseline data and algorithms to support the development of the beta version of the commercial mobility application mentioned previously.

Some other future research projects to consider:

- A survey of literature on the current state of the regulatory environment. This is a moving target and has many variations on the local, state and national level. I receive updates containing news articles nearly every day.
- Customer and product validation research to determine what travelers really need. Most of us that travel or have travel a lot have grown to accept the system we have. Efficient air travel is a miracle, a time machine that can move you to the other side of the country in just a few hours, and yet people still hate the process. By executing a disciplined customer discovery project we can, through a combination of survey and interviews, develop a real understanding of what people really want out of the travel process. Most importantly, we can understand where their real pain points are and begin to develop and response (product) to meet the unmet needs that they are willing pay resolve.

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APPENDICES

APPENDIX A

IRB APPROVAL LETTER

Oklahoma State University Institutional Review Board

Date:	Friday, January 12, 2018
IRB Application No	ED17159
Proposal Title:	An exploration of travel mode selection changes resulting form autonomous vehicles
Reviewed and Processed as:	Exempt

Status Recommended by Reviewer(s): Approved Protocol Expires: 1/11/2021

Principal Investigator(s):

Marc Tower	Jon Michael Loffi
Stillwater, OK 74078	Stillwater, OK 74076

The IRB application referenced above has been approved. It is the judgment of the reviewers that the rights and welfare of individuals who may be asked to participate in this study will be respected, and that the research will be conducted in a manner consistent with the IRB requirements as outlined in section 45 CFR 46.

☐ The final versions of any printed recruitment, consent and assent documents bearing the IRB approval stamp are attached to this letter. These are the versions that must be used during the study.

As Principal Investigator, it is your responsibility to do the following:

1. Conduct this study exactly as it has been approved. Any modifications to the research protocol must be submitted with the appropriate signatures for IRB approval. Protocol modifications requiring approval may include changes to the title, PI advisor, funding status or sponsor, subject population composition or size, recruitment, inclusion/exclusion criteria, research site, research procedures and consent/assent process or forms.
2. Submit a request for continuation if the study extends beyond the approval period. This continuation must receive IRB review and approval before the research can continue.
3. Report any adverse events to the IRB Chair promptly. Adverse events are those which are unanticipated and impact the subjects during the course of the research; and
4. Notify the IRB office in writing when your research project is complete.

Please note that approved protocols are subject to monitoring by the IRB and that the IRB office has the authority to inspect research records associated with this protocol at any time. If you have questions about the IRB procedures or need any assistance from the Board, please contact Dawnett Watkins 219 Scott Hall (phone: 405-744-5700, dawnett.watkins@okstate.edu).

Sincerely,

Hugh Crethar, Chair
Institutional Review Board

APPENDIX B

SURVEY INSTRUMENT

These are qualifying questions.

Welcome
Q1

Which types of activities does your work expect of you? Select all that apply.

- ☐ Deliver presentations
- ☐ Meet with customers face-to-face
- ☐ Travel
- ☐ Develop training

Q2
How often does your work expect you to travel?

- ☐ 1 time per year
- ☐ 2 times per year
- ☐ 3 times per year
- ☐ 4 or more times per year

Entry page to the official survey after the qualifying questions.

Title: Travel Mode Selection Criteria Survey

Investigator: Marc A. Tower, College of Education, Health and Aviation

Purpose: To explore the affects autonomous vehicles will have on travel mode choices. The survey will take approximately 15 minutes.

Risks: There are no risks associated with this project which are expected to be greater than those ordinarily encountered in daily life.

Benefits & Compensation: There are no direct benefits or compensation for participation.

Your Rights: Your participation in this research is voluntary. There is no penalty for refusal to participate, and you are free to withdraw your consent and participation in this project at any time.

Confidentiality: The records of this study will be kept private. Any written results will discuss group findings and will not include information that will identify you. Research records will be stored on a password protected computer in a locked office and only researchers and individuals responsible for research oversight will have access to the records. Data will be destroyed three years after the study has been completed.

Contacts: You may contact the researcher at the following address and phone number, should you desire to discuss your participation in the study and/or request information about the results of the study: Marc Tower, BUS 130AH, Riata Center for Entrepreneurship, Oklahoma State University, Stillwater, OK 74078, 405-744-7307. If you have questions about your rights as a research volunteer, you may contact the IRB Office at 223 Scott Hall, Stillwater, OK 74078, 405-744-3377 or irb@okstate.edu

If you choose to participate: Please, click NEXT if you choose to participate. By clicking NEXT, you are indicating that you freely and voluntarily and agree to participate in this study and you also acknowledge that you are at least 18 years of age.

It is recommended that you print a copy of this consent page for your records before you begin the study by clicking below.

Introduction and explanation from the researcher.

Dear Respondent,

The Aviation and Space Program of the School of Educational Foundations, Leadership and Aviation at Oklahoma State University is conducting a research study to explore travel mode choices, under various existing and future transportation technologies.

The transportation environment is changing rapidly and travelers will have new options in the future. This research project seeks to better understand the relative importance of selection criteria for **business travelers** when choosing a mode of travel for medium length trips (500-700 driving miles).

- The survey will take approximately 15 minutes to complete.
- The survey will ask questions about you, your current travel frequency and preferences, and future preferences.
- No names or other identifying information will be used in preparing the data for analysis.
- There are no risks involved in participation in this study and no direct benefits.
- You are not obligated to participate in the survey and you can stop at any time.
- Your input and opinions are **very important**, since is it is critical that all perspectives and types of business travelers be represented in the survey.

Thank you very much for your time and cooperation.

Sincerely,

Marc A. Tower
Interim Director, Riata Center for Entrepreneurship
Oklahoma State University

Section 1 – Travel

Information on Typical Trips
For the questions below:
· Consider the distance to be the departure point to destination driving distance. For example, the distance from your home or office to the hotel at your destination.
· The Average Total Trip Time is the total time from the departure point to the destination, e.g. from you home to the hotel in the destination city.
· The Estimated Total Driving Time is your estimate if the trip had been taken by automobile.

1. For each distance category below, how many business trips ***by air*** did you make in the last year?

	0-400 miles	401-600 miles	601- 800 miles	801 – 1,000 miles	Over 1,000 miles
Number of trips					
Average Total Trip time (in hours)					
Estimated Total Driving Time (in hours)					

Q7
2. When you travel to and through your primary airport:

	Drive to the airport	Parking though check-in	Check-in through security	Security through boarding	Deplaning through leaving airport	Travel time from airport to destination
Time (in minute s)						

Q8
Section 2 – Productivity

Perception of Productivity

1. On a scale of 1 to 5, 1 being non-productive and 5 being 100% productive, rate your personal productivity in mode or phase of travel listed below:

	01	2	3	4	5
In an automobile as driver					
In an automobile as a passenger					
In a taxi or ride share					
Waiting to board a flight					
On the airplane					
Other(explain)					

Q9
Section 3 – Travel Mode Selection

Decision Criteria Importance

There is a lot of research and engineering being done to bring autonomous vehicles to the market in the U.S. At some point in the future you may be able to choose a Ground-Based Autonomous Vehicle (GBAV) as a travel mode to take you to your destination. The term GBAV is used rather than autonomous car because designers will have flexibility to design the vehicles for specific tasks, such as allowing you to work while you are being transported.

In that case, the vehicle will be a moving workstation allowing the passenger to work on their computer, participate in a video conference, talk on the phone or participate in personal activities such as reading, watching a movie or resting. Conceivably, small groups could travel together in a larger vehicle set-up for collaborative work while en route.

These vehicles could also allow the passengers the flexibility to change destination, stop for rest, food or biological needs, and resume when the passenger chooses.

Q10
1. Considering the information above and your experience as a business traveler, rate on a scale of 1 to 5, 1 being not important and 5 being very important, the importance of each of the criteria below when selecting how you travel.

	Total door-to-door time	Privacy	Flexibility	Productivity	Cost	Other (explain)
Importance						

Section 4 – Trip Selection (example)

Definition of Terms

Ground-based Autonomous Vehicle (GBAV) – A future vehicle designed to travel on public roads without requiring input from passengers. Conceivably, the passenger will schedule the GBAV similar to ride hailing services such as Uber or Lyft, and pick you up at home or work and take you to your final destination. While traveling, the passenger could work, have internet access, read, rest or play a game or watch video. Rest stops and food breaks will be at your discretion.

Commercial Air – Commercial air travel as you know it today. For a medium length trip (500-700 ground miles) the time will include transport to the airport, possibly baggage and/or check-in, going through security and boarding. There may be an intermediate stop to change planes and then at the destination retrieve bags and transportation to the workplace or hotel.

Travel Cost – The cost in dollars ($) of a round trip.

Productive Time – The time available during the trip to work without distraction or interruption, displayed as a % of the trip time.

Flexibility - A measure of your ability to alter plans such as change destination, detour, make stops anytime you wish.

Privacy – Simply the ability to work without concern for others looking over your shoulder, or reading your screens or documents.

On the following pages you will see 6 options for a trip. For each table, select the one you would prefer of the six options.

In each scenario, Qualtrics was programmed to display two trips each for GBAVs, commercial air and automobile and to randomize and vary the values for each of the attributes.

Scenario 1 out of 4

	Mode	Travel Time	Travel Cost	Productive Time (%)	Flexibility (1-5)	Privacy (1-5)
Trip 1						
Trip 2						
Trip 3						
Trip 4						
Trip 5						
Trip 6						

Select the box for the trip you would select:

Trip 1	Trip 2	Trip 3	Trip 4	Tip 5	Trip 6
☐	☐	☐	☐	☐	☐

Scenario 2 out of 4

	Mode	Travel Time	Travel Cost	Productive Time (%)	Flexibility (1-5)	Privacy (1-5)
Trip 1						
Trip 2						
Trip 3						
Trip 4						
Trip 5						
Trip 6						

Select the box for the trip you would select:

Trip 1	Trip 2	Trip 3	Trip 4	Tip 5	Trip 6
☐	☐	☐	☐	☐	☐

Scenario 3 out of 4

	Mode	Travel Time	Travel Cost	Productive Time (%)	Flexibility (1-5)	Privacy (1-5)
Trip 1						
Trip 2						
Trip 3						
Trip 4						
Trip 5						
Trip 6						

Select the box for the trip you would select:

Trip 1	Trip 2	Trip 3	Trip 4	Tip 5	Trip 6
☐	☐	☐	☐	☐	☐

Scenario 4 out of 4

	Mode	Travel Time	Travel Cost	Productive Time (%)	Flexibility (1-5)	Privacy (1-5)
Trip 1						
Trip 2						
Trip 3						
Trip 4						
Trip 5						
Trip 6						

Select the box for the trip you would select:

Trip 1	Trip 2	Trip 3	Trip 4	Tip 5	Trip 6
☐	☐	☐	☐	☐	☐

APPENDIX C

QUALTRICS CUSTOMIZATION JAVASCRIPT

```
Qualtrics.SurveyEngine.addOnload(function()
{
    /*Place your JavaScript here to run when the page loads*/

var MODE_GBAV = ["GBAV"];
var MODE_AIR = ["COMMERCIAL AIR"];
var MODE_CAR = ["AUTOMOBILE"];
var TIME_GBAV = ["5","6", "7", "8", "9"];
var TIME_AIR = ["4","5","6", "7", "8"];
var TIME_CAR = ["6","6.5", "7","7.5", "8"];
var COST_GBAV = ["$400","$500","$600","$700","$800"];
var COST_AIR = ["$400","$500","$600","$700","$800"];
var COST_CAR = ["$450","$500","$550","$600","$650"];
var PROD_GBAV = ["100%", "90%","80%"];
var PROD_AIR = ["30%", "20%", "10%"];
var PROD_CAR = ["20%","15%", "10%"];
var FLEX_GBAV = ["5","4.5","4"];
var FLEX_AIR = ["2","1.5","1"];
var FLEX_CAR = ["5","4.5"];
var PRIV_GBAV = ["5","4.5","4"];
var PRIV_AIR = ["2","1.5","1"];
var PRIV_CAR = ["5","4.5","4"];


var MODE_a1 = MODE_GBAV[Math.floor(Math.random()*MODE_GBAV.length)];
var TIME_a1 = TIME_GBAV[Math.floor(Math.random()*TIME_GBAV.length)];
var COST_a1 = COST_GBAV[Math.floor(Math.random()*COST_GBAV.length)];
var PROD_a1 = PROD_GBAV[Math.floor(Math.random()*PROD_GBAV.length)];
var FLEX_a1 = FLEX_GBAV[Math.floor(Math.random()*FLEX_GBAV.length)];
var PRIV_a1 = PRIV_GBAV[Math.floor(Math.random()*PRIV_GBAV.length)];


var MODE_b1 = MODE_GBAV[Math.floor(Math.random()*MODE_GBAV.length)];
var TIME_b1 = TIME_GBAV[Math.floor(Math.random()*TIME_GBAV.length)];
var COST_b1 = COST_GBAV[Math.floor(Math.random()*COST_GBAV.length)];
var PROD_b1 = PROD_GBAV[Math.floor(Math.random()*PROD_GBAV.length)];
var FLEX_b1 = FLEX_GBAV[Math.floor(Math.random()*FLEX_GBAV.length)];
var PRIV_b1 = PRIV_GBAV[Math.floor(Math.random()*PRIV_GBAV.length)];
```

```
var MODE_c1 = MODE_CAR[Math.floor(Math.random()*MODE_CAR.length)];
var TIME_c1 = TIME_CAR[Math.floor(Math.random()*TIME_CAR.length)];
var COST_c1 = COST_CAR[Math.floor(Math.random()*COST_CAR.length)];
var PROD_c1 = PROD_CAR[Math.floor(Math.random()*PROD_CAR.length)];
var FLEX_c1 = FLEX_CAR[Math.floor(Math.random()*FLEX_CAR.length)];
var PRIV_c1 = PRIV_CAR[Math.floor(Math.random()*PRIV_CAR.length)];

var MODE_d1 = MODE_CAR[Math.floor(Math.random()*MODE_CAR.length)];
var TIME_d1 = TIME_CAR[Math.floor(Math.random()*TIME_CAR.length)];
var COST_d1 = COST_CAR[Math.floor(Math.random()*COST_CAR.length)];
var PROD_d1 = PROD_CAR[Math.floor(Math.random()*PROD_CAR.length)];
var FLEX_d1 = FLEX_CAR[Math.floor(Math.random()*FLEX_CAR.length)];
var PRIV_d1 = PRIV_CAR[Math.floor(Math.random()*PRIV_CAR.length)];

var MODE_e1 = MODE_AIR[Math.floor(Math.random()*MODE_AIR.length)];
var TIME_e1 = TIME_AIR[Math.floor(Math.random()*TIME_AIR.length)];
var COST_e1 = COST_AIR[Math.floor(Math.random()*COST_AIR.length)];
var PROD_e1 = PROD_AIR[Math.floor(Math.random()*PROD_AIR.length)];
var FLEX_e1 = FLEX_AIR[Math.floor(Math.random()*FLEX_AIR.length)];
var PRIV_e1 = PRIV_AIR[Math.floor(Math.random()*PRIV_AIR.length)];

var MODE_f1 = MODE_AIR[Math.floor(Math.random()*MODE_AIR.length)];
var TIME_f1 = TIME_AIR[Math.floor(Math.random()*TIME_AIR.length)];
var COST_f1 = COST_AIR[Math.floor(Math.random()*COST_AIR.length)];
var PROD_f1 = PROD_AIR[Math.floor(Math.random()*PROD_AIR.length)];
var FLEX_f1= FLEX_AIR[Math.floor(Math.random()*FLEX_AIR.length)];
var PRIV_f1 = PRIV_AIR[Math.floor(Math.random()*PRIV_AIR.length)];


var att_a_traits = [1,2,3,4,5,6];
var att_b_traits = [1,2,3,4,5,6];
var att_c_traits = [1,2,3,4,5,6];
var att_d_traits = [1,2,3,4,5,6];
var att_e_traits = [1,2,3,4,5,6];
var att_f_traits = [1,2,3,4,5,6];

att_a_traits[1] = TIME_a1;
att_a_traits[2] = COST_a1;
att_a_traits[3] = PROD_a1;
att_a_traits[4] = FLEX_a1;
att_a_traits[5] = PRIV_a1;


att_b_traits[1] = TIME_b1;
att_b_traits[2] = COST_b1;
```

```
att_b_traits[3] = PROD_b1;
att_b_traits[4] = FLEX_b1;
att_b_traits[5] = PRIV_b1;

att_c_traits[1] = TIME_c1;
att_c_traits[2] = COST_c1;
att_c_traits[3] = PROD_c1;
att_c_traits[4] = FLEX_c1;
att_c_traits[5] = PRIV_c1;

att_d_traits[1] = TIME_d1;
att_d_traits[2] = COST_d1;
att_d_traits[3] = PROD_d1;
att_d_traits[4] = FLEX_d1;
att_d_traits[5] = PRIV_d1;

att_e_traits[1] = TIME_e1;
att_e_traits[2] = COST_e1;
att_e_traits[3] = PROD_e1;
att_e_traits[4] = FLEX_e1;
att_e_traits[5] = PRIV_e1;

att_f_traits[1] = TIME_f1;
att_f_traits[2] = COST_f1;
att_f_traits[3] = PROD_f1;
att_f_traits[4] = FLEX_f1;
att_f_traits[5] = PRIV_f1;

a_list = ["a1","b1","c1","d1","e1","f1"];
b_list = ["a2","b2","c2","d2","e2","f2"];
c_list = ["a3","b3","c3","d3","e3","f3"];
d_list = ["a4","b4","c4","d4","e4","f4"];
e_list = ["a5","b5","c5","d5","e5","f5"];
f_list = ["a6","b6","c6","d6","e6","f6"];


document.getElementById(a_list[0]).innerHTML= "GBAV";
document.getElementById(b_list[0]).innerHTML= "GBAV";
document.getElementById(c_list[0]).innerHTML= "AUTOMOBILE";
document.getElementById(d_list[0]).innerHTML= "AUTOMOBILE";
document.getElementById(e_list[0]).innerHTML= "COMMERCIAL AIR";
document.getElementById(f_list[0]).innerHTML= "COMMERCIAL AIR";

    for(i=1;i<6;i++){
  document.getElementById(a_list[i]).innerHTML= att_a_traits[i];
  document.getElementById(b_list[i]).innerHTML= att_b_traits[i] ;
```

```
   document.getElementById(c_list[i]).innerHTML= att_c_traits[i] ;
   document.getElementById(d_list[i]).innerHTML= att_d_traits[i] ;
   document.getElementById(e_list[i]).innerHTML= att_e_traits[i] ;
   document.getElementById(f_list[i]).innerHTML= att_f_traits[i] ;
    }

Qualtrics.SurveyEngine.setEmbeddedData('Mode1', MODE_a1);
Qualtrics.SurveyEngine.getEmbeddedData('Mode1');

Qualtrics.SurveyEngine.setEmbeddedData('Time1', TIME_a1);
Qualtrics.SurveyEngine.getEmbeddedData('Time1');

Qualtrics.SurveyEngine.setEmbeddedData('Cost1', COST_a1);
Qualtrics.SurveyEngine.getEmbeddedData('Cost1');

Qualtrics.SurveyEngine.setEmbeddedData('Prod1', PROD_a1);
Qualtrics.SurveyEngine.getEmbeddedData('Prod1');

Qualtrics.SurveyEngine.setEmbeddedData('Flex1', FLEX_a1);
Qualtrics.SurveyEngine.getEmbeddedData('Flex1');

Qualtrics.SurveyEngine.setEmbeddedData('Priv1', PRIV_a1);
Qualtrics.SurveyEngine.getEmbeddedData('Priv1');

     Qualtrics.SurveyEngine.setEmbeddedData('Mode2', MODE_b1);
Qualtrics.SurveyEngine.getEmbeddedData('Mode2');

     Qualtrics.SurveyEngine.setEmbeddedData('Time2', TIME_b1);
Qualtrics.SurveyEngine.getEmbeddedData('Time2');

Qualtrics.SurveyEngine.setEmbeddedData('Cost2', COST_b1);
Qualtrics.SurveyEngine.getEmbeddedData('Cost2');

Qualtrics.SurveyEngine.setEmbeddedData('Prod2', PROD_b1);
Qualtrics.SurveyEngine.getEmbeddedData('Prod2');

Qualtrics.SurveyEngine.setEmbeddedData('Flex2', FLEX_b1);
Qualtrics.SurveyEngine.getEmbeddedData('Flex2');

Qualtrics.SurveyEngine.setEmbeddedData('Priv2', PRIV_b1);
Qualtrics.SurveyEngine.getEmbeddedData('Priv2');

     Qualtrics.SurveyEngine.setEmbeddedData('Mode3', MODE_c1);
Qualtrics.SurveyEngine.getEmbeddedData('Mode3');

Qualtrics.SurveyEngine.setEmbeddedData('Time3', TIME_c1);
```

```
Qualtrics.SurveyEngine.getEmbeddedData('Time3');

Qualtrics.SurveyEngine.setEmbeddedData('Cost3', COST_c1);
Qualtrics.SurveyEngine.getEmbeddedData('Cost3');

Qualtrics.SurveyEngine.setEmbeddedData('Prod3', PROD_c1);
Qualtrics.SurveyEngine.getEmbeddedData('Prod3');

Qualtrics.SurveyEngine.setEmbeddedData('Flex3', FLEX_c1);
Qualtrics.SurveyEngine.getEmbeddedData('Flex3');

Qualtrics.SurveyEngine.setEmbeddedData('Priv3', PRIV_c1);
Qualtrics.SurveyEngine.getEmbeddedData('Priv3');

    Qualtrics.SurveyEngine.setEmbeddedData('Mode4', MODE_d1);
Qualtrics.SurveyEngine.getEmbeddedData('Mode4');

Qualtrics.SurveyEngine.setEmbeddedData('Time4', TIME_d1);
Qualtrics.SurveyEngine.getEmbeddedData('Time4');

Qualtrics.SurveyEngine.setEmbeddedData('Cost4', COST_d1);
Qualtrics.SurveyEngine.getEmbeddedData('Cost4');

Qualtrics.SurveyEngine.setEmbeddedData('Prod4', PROD_d1);
Qualtrics.SurveyEngine.getEmbeddedData('Prod4');

Qualtrics.SurveyEngine.setEmbeddedData('Flex4', FLEX_d1);
Qualtrics.SurveyEngine.getEmbeddedData('Flex4');

Qualtrics.SurveyEngine.setEmbeddedData('Priv4', PRIV_d1);
Qualtrics.SurveyEngine.getEmbeddedData('Priv4');


Qualtrics.SurveyEngine.setEmbeddedData('Mode5', MODE_e1);
Qualtrics.SurveyEngine.getEmbeddedData('Mode5');

Qualtrics.SurveyEngine.setEmbeddedData('Time5', TIME_e1);
Qualtrics.SurveyEngine.getEmbeddedData('Time5');

Qualtrics.SurveyEngine.setEmbeddedData('Cost5', COST_e1);
Qualtrics.SurveyEngine.getEmbeddedData('Cost5');

Qualtrics.SurveyEngine.setEmbeddedData('Prod5', PROD_e1);
Qualtrics.SurveyEngine.getEmbeddedData('Prod5');

Qualtrics.SurveyEngine.setEmbeddedData('Flex5', FLEX_e1);
```

```
Qualtrics.SurveyEngine.getEmbeddedData('Flex5');

Qualtrics.SurveyEngine.setEmbeddedData('Priv5', PRIV_e1);
Qualtrics.SurveyEngine.getEmbeddedData('Priv5');

Qualtrics.SurveyEngine.setEmbeddedData('Mode6', MODE_f1);
Qualtrics.SurveyEngine.getEmbeddedData('Mode6');

Qualtrics.SurveyEngine.setEmbeddedData('Time6', TIME_f1);
Qualtrics.SurveyEngine.getEmbeddedData('Time6');

Qualtrics.SurveyEngine.setEmbeddedData('Cost6', COST_f1);
Qualtrics.SurveyEngine.getEmbeddedData('Cost6');

Qualtrics.SurveyEngine.setEmbeddedData('Prod6', PROD_f1);
Qualtrics.SurveyEngine.getEmbeddedData('Prod6');

Qualtrics.SurveyEngine.setEmbeddedData('Flex6', FLEX_f1);
Qualtrics.SurveyEngine.getEmbeddedData('Flex6');

Qualtrics.SurveyEngine.setEmbeddedData('Priv6', PRIV_f1);
Qualtrics.SurveyEngine.getEmbeddedData('Priv6');.....................................................



});

Qualtrics.SurveyEngine.addOnReady(function()
{



});

Qualtrics.SurveyEngine.addOnUnload(function()
{
    /*Place your JavaScript here to run when the page is unloaded*/

});
```

APPENDIX D

SUPPLEMENTAL MODE COMPARISONS

As referred to in chapter 3, the following pages contain supplemental information in the form of Multiple Choice Profiler output from JMP that clarifies how the value of the travel mode attributes affects the respondent's choices when selecting the travel mode. In Figure D.1, the example is the same as Figure 3.3, three alternatives, one for each mode, are compared directly. In all three alternatives the total trip time is seven hours and the cost is $400. The variation, aside from mode, is in productivity, flexibility and privacy. For the automobile, productivity is set a 10%, Flexibility is set at 5 of 5 and privacy is 5 of 5. For Commercial Air, the productivity is set at 20%, flexibility at 1 of 5 and privacy at 1 of 5. For the GBAV, productivity is set at 100%, flexibility at 5 of 5 and privacy at 5 of 5. Given those parameters, the probability of selection for each mode is shown on the left in red numerals. The probability of the automobile being selected is 24.162%, for the commercial air the probability is 24.272% and for the GBAV 51.5%

In Figure D.2, only one attribute value is changed, the productivity attribute of the GBAV. In this one, the productivity value of the GBAV is reduced to match that of the commercial airline. As a result of that one change, GBAV becomes marginally less desirable that the other two option. In the resulting tables, the automobile alternative is a 34.45 probability, the commercial air option is a 35.3% probability and the GBAV has dropped to a 30.2% probability. Clearly, including productivity as a factors available to travelers in their decision making affects their choices.

In Figure D.3 we see the effect of increasing the price of the GBAV trip from $400 to $600 when all other factors remain the same as in Figure D.1. The probability of the GBAV being selected is reduced from 51.6% to 41.5% while the commercial air and automobile alternatives each increase about 5% to 29.6% and 28.9% respectively. The result shows that travelers are price sensitive, however even a 50% increase in cost ($400 to $600) only made the probability of selection of the GBAV drop approximately 20% from 51.6% to 41.5%.

Figure D. 1

Multiple Choice Profiler example

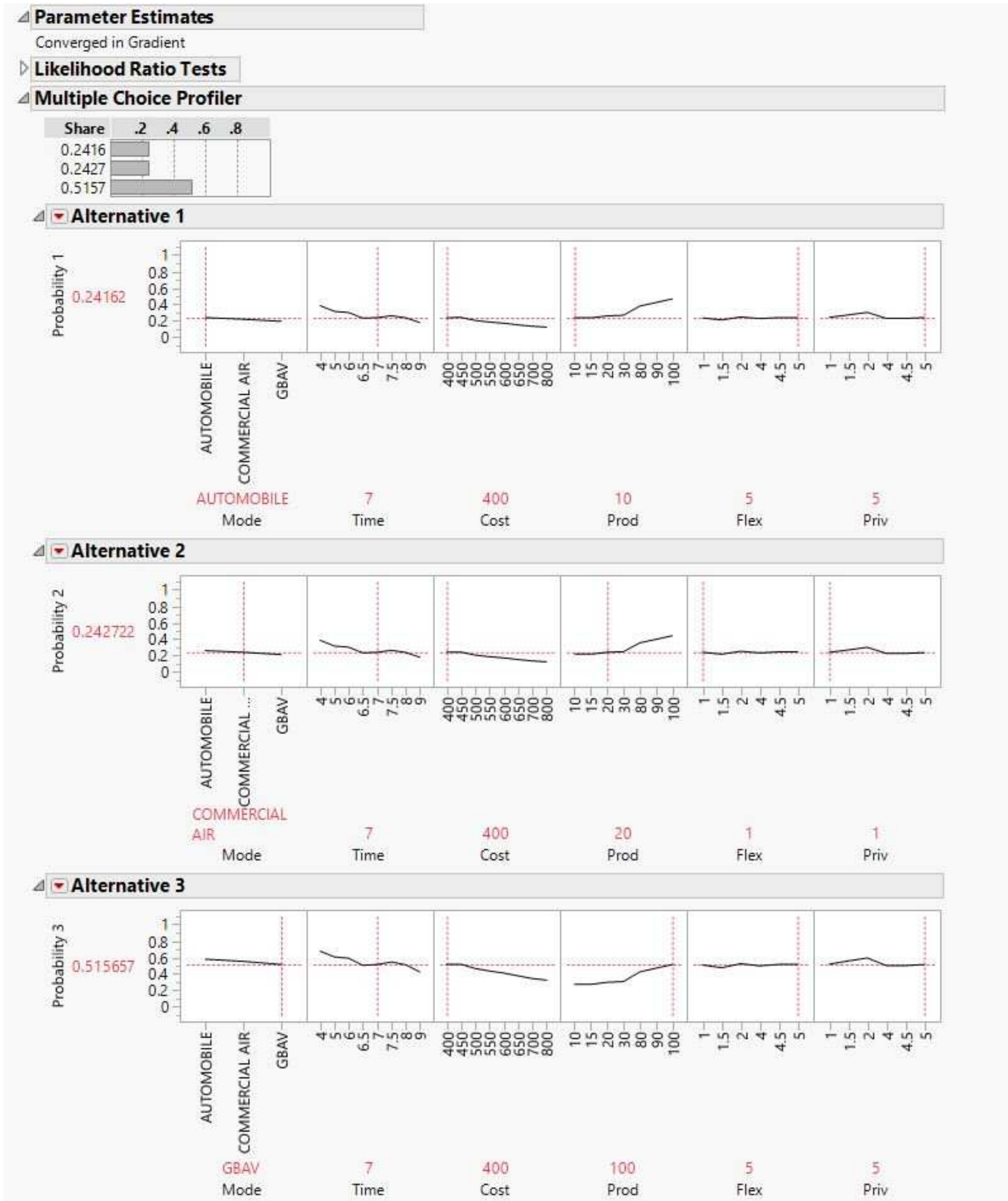


Figure D. 2

Reduced GBAV Productivity

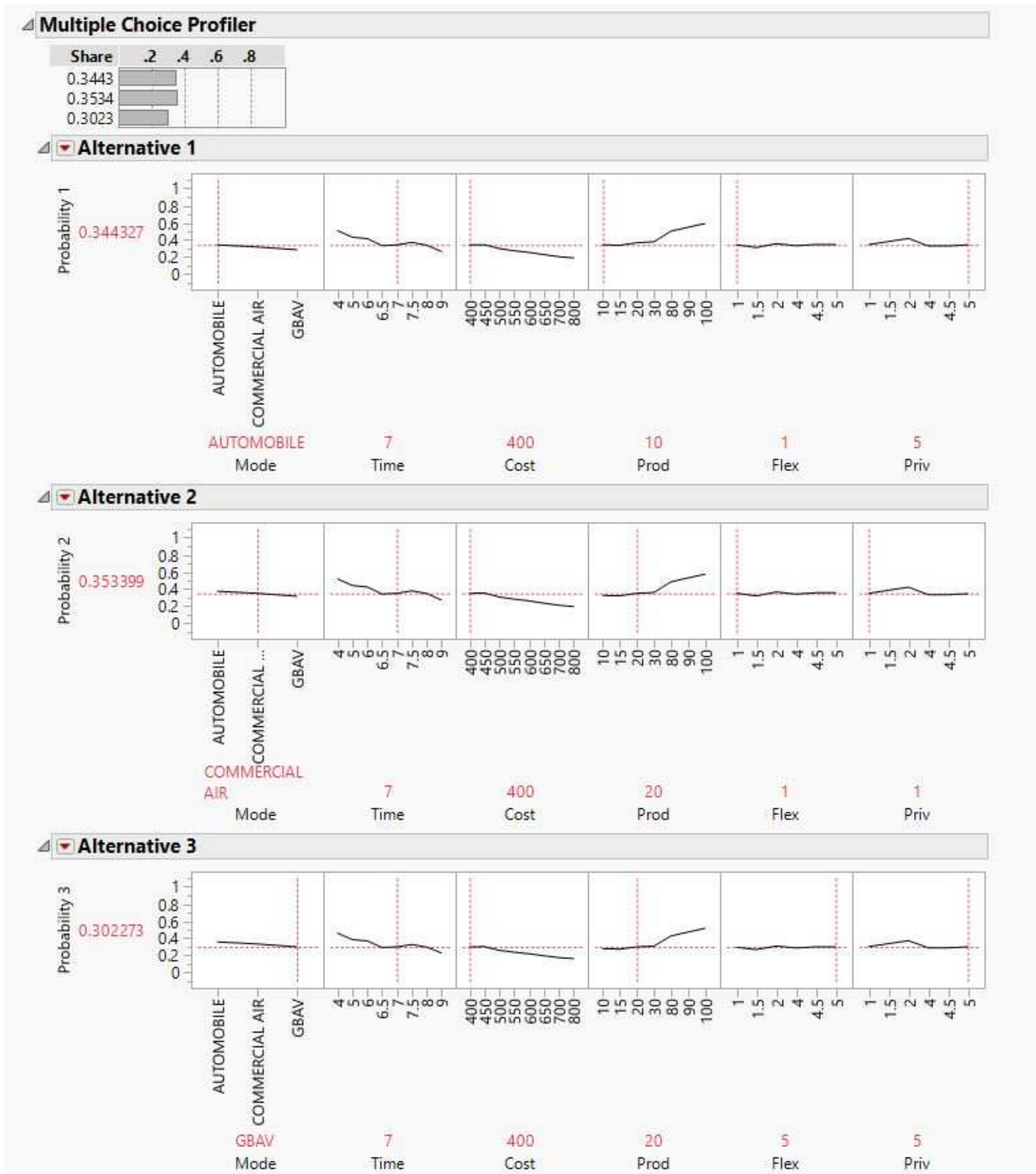
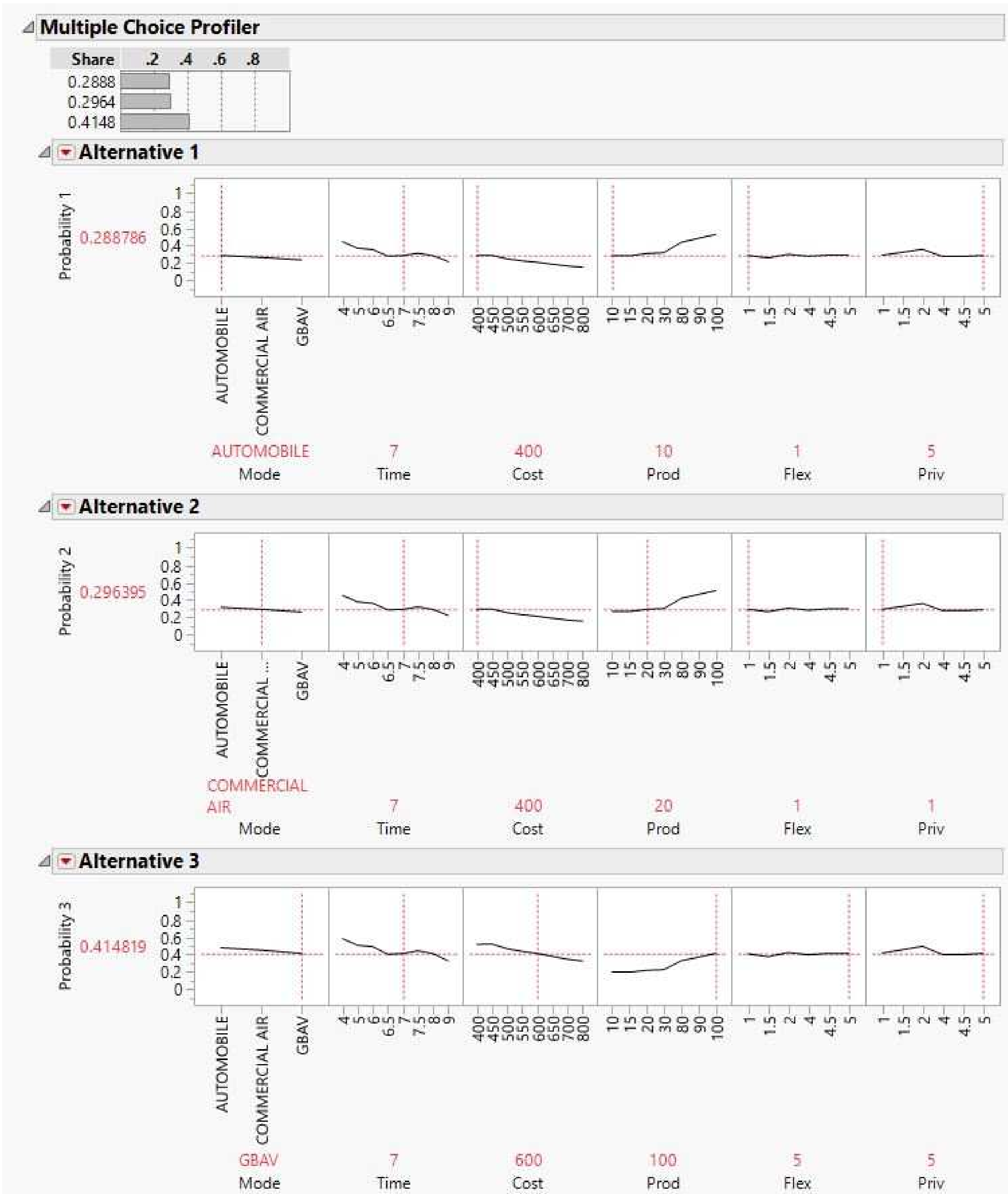


Figure D. 3

Price Effect



VITA

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Doctor of Education

Dissertation:: TRAVEL MODE SELECTION WHEN AUTONOMOUS TRANSPORTATION ATTRIBUTES ARE INCLUDED AS CRITERIA

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Completed the requirements for the Doctor of Education in Educational Studies at Oklahoma State University, Stillwater, Oklahoma in May, 2019.

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Aircraft Owners and Pilots Association
Experimental Aircraft Association