A BIRD IN THE HAND IS WORTH TWO ON THE BUS: SOCIAL MEDIA AND ITS ABILITY TO INFLUENCE PERCEPTIONS OF AUTONOMOUS PUBLIC TRANSPORT

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ABSTRACT

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Autonomous public transit (APT) is quickly gaining traction as a means to efficiently and economically strengthen, enhance, and extend public transportation networks, while at the same time boosting mobility for disadvantaged groups. Autonomous shuttles are already operating in several cities around the world; generally, APT receives high praise from riders after they interact with the technology. However, perceptions of APT among the general population are understudied. This study examines sentiment expressed by users on Twitter as a means to better understand their perception, and how it can be influenced. Sentiments among tweeters are slightly more negative, 53 percent in opposed to APT and 47 percent in favor. Safety concerns are by far and away the leading cause of negative perceptions. Moreover, safety incidents have a significant influence on the online discourse surrounding APT. Exactly 75 percent of days with ten or more tweets were as a result of a safety incident; though, notably, these incidents involved human error, as opposed to a technological fault with APT. This however did not dissuade tweeters from blaming APT. Finally, the study finds that influential tweeters also significantly influence discourse, though potentially for the negative. Influential tweeters were 36 percent more likely to tweet about safety concerns as opposed to the average tweeter. Changing the online discourse surrounding APT may drastically boost acceptance and positive sentiments towards the technology.

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Chapter 1. Introduction

Autonomous vehicles (AVs) and autonomous public transit (APT) are emerging as a legitimate means to increase mobility and save money, while at the same time having the potential to dramatically change transportation, both personal and public (Hall, Palsson, and Price, 2018; Litman, 2017a; Litman, 2017b; Harper et al., 2016). These technologies are incredibly important, not only could they improve road safety (Doecke, Grant, and Anderson, 2015), reducing fatalities, they could also lead to greater mobility for disadvantaged groups and the elderly (Litman, 2017a), as well as even lower carbon emissions (Thomopoulos and Givoni, 2015). Public transit could be made both cheaper, and have perhaps see service areas expanded (Salonen and Haavisto, 2019; Wicki and Bernauer, 2019). Though, there is significant debate as to whether or not all of these potential changes will benefit society (Krueger, Rashidi, and Rose, 2016; Ohnemus and Perl 2016). Sentiments towards and perception of AVs and APT are both largely negative, people are extremely concerned with both personal safety and the costs associated with the technology (Gkartzonikas, Christos, and Gkritza, 2019; Haboucha, Ishaq, and Shiftan, 2017; Bansal et al., 2016; Choi, and Yong, 2015). Though, when people finally interact with APT, they generally begin to express more positive sentiments towards it (Wicki and Bernauer, 2019; Salonen and Haavisto, 2019). However, perception of APT is understudied within the literature; if the goal is to promote the technology as a viable means to increase mobility, then changing public opinions is of paramount importance, and studying how perceptions are formed, and opinions changed by social media, may go a long way towards furthering that goal.

This study seeks to better understand perceptions of and sentiment towards AVs and APT, as well as how and to what extent social media influences perception. AVs are often a part

of APT, though the two are conceptually distinct ideas. However, on social media, tweeters often use the terms interchangeably. Using data collected from Twitter, which includes tweets, usernames, followers, retweets, and in some cases geodata, an analysis is conducted using both thematic and emergent coding (Braun et al., 2019; Charmaz, 2005). Tweets are simply a user voicing their opinion on the platform, similar to a message board, these are limited to 280 characters, though images can be attached as well. A retweet is when another user simply copies a tweet from a different user, and posts it on their own page. A reader can identify an author of a retweet simply by looking at it, regardless of whose page it is currently on.

In total 1422 tweets, e.g. units of data, were collected between January 1st, 2016 and December 31st, 2019 that specifically mention APT. It is hypothesized that the general sentiment on Twitter will match other sentiment analysis found within the literature; that is that around half of people will view the technology negatively, and half will view it positively (Kassens-Noor, Kotval, and Cai, 2019; Schoettle and Sivak, 2014). Additionally, it is hypothesized that some tweeters will be far more influential than others, and their tweets will receive a significant amount of attention relative to the standard tweeter. Important because opinions can be and are influenced by social media (Stieglitz and Dang-Xuan, 2012; Gupta, Ripberger, and Wehde, 2018).

The analysis found that sentiments and perception were in line with the literature, 53 percent of tweeters expressed negative sentiments towards AVs and APT, whereas 43 percent were positive, and spoke to benefits (positive expressions). Though, general announcements and mentions of automotive companies were the most common tweet topic. One category that emerged from coding was tweeters who viewed investments in APT as a negative, and would prefer money be spent on upgrading existing transit networks. These tweets, coded as public

transit preferred, comprised 10 percent of all tweets that expressed sentiment. Further, the analysis found that negative incidents involving AVs or APT had a tendency to dominate the online discourse for multiple days, 75 percent of major tweet days (those with more than ten tweets mentioning APT) were as a result of negative incidents. These tweets were almost always negatively themed, irrespective of the details of the incident, e.g. a human driver was at fault. Finally, the analysis found that influential tweeters have a significant impact on perception, and these tweeters have a tendency to focus on negative narratives, in particular safety concerns. Influential tweeters were 36 percent more likely to tweet about safety concerns than the average tweeter.

This study is one of the first to analyze the topic of AVs and APT using data from Twitter, specifically for sentiment and topic. Though Twitter data has been used in the past to study the discourse surrounding AVs (Kohl et al., 2018), how smart cities are perceived (Yigitcanlar, Kankanamge, and Vella, 2020), and how public transit is perceived (Schweitzer, 2014). All of which provide valuable insights, especially for planners working in these arenas. Previous studies primarily consisted of surveys, both in person and online, or interviews. Moreover, it is the first to examine the role that social media influence plays on the perception of AVs and APT. This is accomplished by analyzing major trends, how narratives emerge, and the role that influential tweeters have on the narrative surrounding AVs and APT. Additionally, it also employs emergent coding to identify unique categories/themes present in tweets that may not be represented elsewhere in the literature. Giving further insight into precisely how AVs and APT are viewed on social media, how narratives are formed around them, and how opinions are influenced by others.

Ultimately, concluding by providing recommendations to advocates of AVs and APT as to how best persuade people to interact with the technology, breed trust, and foster positive sentiment. Negative incidents have a profound effect on social media perceptions and conversations. When negative incidents occur, advocates would do well to quickly provide relevant information about the event, and highlight that APT may actually increase safety and accessibility. This goal can be furthered if influential tweeters were to actively promote the technology, instead of actively tweeting against it. Finally, the literature shows that once people interact with APT, their sentiments change significantly in favor of the technology, getting people to both ride on and tweet about APT would go a long way towards increasing trust and changing discourse.

1.1. Structure and Key Notes

This thesis uses social media data in an effort to better understand the perception that tweeters have on AVs and APT. While reading this thesis, key notes are needed to better understand some of the core concepts, methods, and arguments herein, and as a means to avoid confusion:

Foremost, it should be noted as to exactly what the difference between APT and AVs are, and what they represent within this thesis. AVs are specifically passenger vehicles operating autonomously and APT specifically refers to the automation of an entire transit system, or part thereof. AVs can be a part of APT, though APT could also exist without AVs (at least passenger vehicles, not counting shuttles or busses). On Twitter, people rarely distinguish between the two acronyms and often use them interchangeably. AVs serving as APT may operate similarly to rideshare services such as Uber or Lyft, in that a user would "summon" one to their doorstep, get taken to their destination, and then that AV would continue on providing transportation to other

individuals. Generally, when speaking about APT on its own, this thesis is referring to autonomous shuttles, busses, or rail, as these technologies are inherently devoted to mass transit. It should also be noted that a fleet of AVs may provide transit via a private company, whereas APT would almost always involve some level of government financing, control, or partnerships, as the networks would be far too complex and expensive to operate independently. Data collected from Twitter used both the search terms "autonomous vehicle" and "autonomous public transit".

Twitter is a popular social media platform that allows users to post messages limited to 140 characters, though that was increased to 280, it is not the largest social media website, but around 20 percent of internet users frequent the platform (Murthy and Pensavalle, 2016; Duggan and Brenner, 2013). Twitter is generally used by younger people, though it is also the most popular social media tool for socioeconomically disadvantaged people and minorities (Murthy and Pensavalle, 2016); these population groups stand to benefit the most from APT (Litman, 2017a). Though, Twitter data is not often accompanied by demographic data, so analyzing the characteristics of tweeters is not possible; thus, only their collective perceptions are analyzed within this thesis.

Users on Twitter can become "verified", this means that their account is known to Twitter to be the account of a celebrity, influential person, unit of government, or other person/entity with a significant following. Other tweeters are able to see if an account is verified simply by looking at a tweet. Verified tweeters are often given more attention than regular tweeters (Philander and Zhong, 2016). Because social media data is limited in scope, and because this thesis argues that APT will increase the quality of life for disadvantaged people, it also argues that the family members of those who do not participate in social media can in turn

be influenced by those who do. (Febrero, et al., 2018; Naumanen and Tukiainen, 2007; Campbell and Nolfi, 2005; Persson, 1993; Donelan, et al., 2002).

The data analyzed in this thesis was mined from Twitter via a Twitter developer account. Which is a special account with an arduous creation process that allows a person to access large data files. Twitter wants to ensure that their data is not being misused. As mentioned, this data lacks demographic information, but some users do include their geographic locations either in their profile information or via geolocation; those who do so are included in a geographic analysis herein. The data also includes dates and times of tweets. This thesis categorizes days with more than ten tweets about APT or AVs as "major tweet days", a proprietary term not used elsewhere.

After data was collected it was then coded. Coding is a process wherein a person reads each individual tweet and assigns them a "code", in the case of this thesis it was a number between 1 and 7. Categories for codes included: positive expressions s (1), safety concerns (2), cost concerns (3), public transit preferred (4), other (5), political (6), and automotive & mobility tech references (7). In some instances, the wording of tweets better highlighted the underlying sentiment. For example, tweets that used the words "fear", "scary", "risk" or "do not trust" were categorized as safety concerns. Whereas tweets that use the words "Excited", "helpful", or "futuristic" were categorized as positive expressions.

Categories were coded via thematic coding; this means that these categories are topics well discussed within the literature (Braun, et al, 2019). Additionally, emergent coding was employed, this means that some topics were so common within the data that they necessitated the creation of their own category; this was the case for tweeters who preferred public transit over the development of APT (Charmaz, 2005). Tweets were then broken down into positive and

negative sentiment. Notably, neutralized tweets were extremely rare within the data, people almost never analyzed the pros and cons of AVs or APT on Twitter, though, this may have to do with the relatively short character limit on the website. There simply was not enough space for a person to voice complex thoughts or opinions.

Some tweets were incomprehensible, playful, silly, or impossible to discern meaning from, these tweets were struck from the analysis. Additionally, the environmental impact of AVs is well discussed within the literature, and occasionally tweeters mentioned this fact as well (Gkartzonikas, Christos, and Gkritza, 2019; Ohnemus, and Perl 2016). Those tweets were blended into the "cost concerns" category, along with economic and social impacts that the emerging technology may pose.

Finally, it should be noted that the perceptions people have towards AVs is a moderately well studied, though just now emerging, topic within the literature. Other research has analyzed sentiment and perception using different tools. Some researchers use surveys, others use personal interviews, and some use data from social media or other online sources. This thesis is the first, to the authors knowledge, that specifically looks at sentiment on Twitter via a large data source.

Chapter 2. Literature Review

The literature concerning AVs has largely focused on the technology from an engineering point of view. That is not to say that the social sciences however have completed forgone discussion of AVs, though relative to engineering, the literature is severely lacking. Furthermore, the social science literature focusing on perception and sentiment of AVs and APT is just now developing. As new technology emerges, our homes, cities, and lives may all be affected and permanently changed; the potential for benefits is staggering, but concerns regarding safety, privacy, and job loss are abundant (Litman, 2017a; Chen and Lee, 2019). These concerns influence perception, but so too do social and traditional media (Stieglitz and Dang-Xuan, 2012; Gupta, Ripberger, and Wehde, 2018). The role these platforms play in the discourse surrounding AVs and APT is similarly understudied.

The sections below begin by examining attitudes towards and perception of AVs by various demographics, highlighting the perceived benefits and concerns of the technology. Followed by how people perceive APT, again by demographics while noting benefits and concerns. These perceptions are sometimes influenced by both traditional and social media. The literature review concludes by examining how and to what extent attitudes can be shaped by social media, and how narratives surrounding technology are both born and reinforced.

2.1. Public Attitudes Towards Autonomous Vehicles

Public attitudes in regard to AVs are not static, they are constantly changing and evolving as people interact with the technology, learn from it, and better understand its challenges and benefits. Planners and policy makers have limited information as to how people perceive AVs,

and those perceptions vary by geography and demographics. Perceptions, sentiment, and opinions are key in making informed planning and policy decisions going forward.

Numerous surveys, collected from around the world, have tested perceptions towards AVs (Haboucha, Ishaq, and Shiftan, 2017; Hudson, Orviska, and Hunady, 2019; Bansal et al, 2016; El Zarwi, Vij, and Walker, 2017). Age, income, education, gender, and many other factors influence such perceptions; these surveys also found that people are generally wary of autonomous technology (Kassens-Noor, Kotval, and Cai, 2019; Haboucha, Ishaq, and Shiftan, 2017). Those with more education were significantly more likely to be receptive to AVs, although, they too, are wary (Haboucha, Ishaq, and Shiftan, 2017). The same can be said for age: younger people are more likely to ride in an AV, as opposed to people from older generations (Haboucha, Ishaq, and Shiftan, 2017; El Zarwi, Vij, and Walker, 2017). Geography too plays a role, urban residents are more in favor of AVs than are rural residents, as North Americans are less receptive to the technology than are some Asian geographies, and Latin America seems to be the least welcoming (Hudson, Orviska, and Hunady, 2019; Bansal et al, 2016). Income also has an effect: people with higher income are more likely to ride in an AV (Kassens-Noor, Kotval, and Cai, 2019; Haboucha, Ishaq, and Shiftan, 2017. Gender also plays a role with males more likely than females to ride in or own an autonomous vehicle (Kassens-Noor, Kotval, and Cai, 2019; Haboucha, Ishaq, and Shiftan, 2017).

The potential benefits of AVs can be considerable in terms of safety and reduced road fatalities; the elderly or disabled may also benefit significantly from the increased mobility that AVs can provide (Bennett, Vijaygopal, and Kottasz, 2019). AVs are predicted to increase the mobility of the elderly and disabled more than any other group, with an expected increase in vehicle miles traveled of 14 percent (Harper et al, 2016). From a driver viewpoint, surveys show

that 72 percent of people expect AVs to lead to lower fuel consumption, 42 percent of respondents believe AVs will decrease travel time, and 86 percent of people believe that AVs will result in fewer accidents. Ultimately, 84 percent of people believe that an increase in safety is the most important benefit from this technology (Gkartzonikas, Christos, and Gkritza, 2019).

Additionally, and conversely, surveys have found a number of perceived concerns regarding AVs, with safety being the primary issue (Bansal et al, 2016). In some regard these surveys do take into account variations in geography, with samples from America (Gkartzonikas, Christos, and Gkritza, 2019), Europe (Liljamo, Liimatainen, and Pöllänen, 2018), and East Asia (Hudson, Orviska, and Hunady, 2019; Bansal et al, 2016) being included in this discussion. The way an AV behaves is a major concern to people, specifically, whether or not an AV will behave in either an ethical or moral manner; moreover, people's opinions on this change with demographics (Awad, et al., 2018). One study found that safety was a major influence regarding perception of AVs for 82 percent of people. Interestingly, that same study also found that 61 percent of people expect AVs to limit driver distraction, and that 86 percent of people believe that AVs will be responsible for fewer accidents (Gkartzonikas, Christos, and Gkritza, 2019). In a survey conducted in Finland, safety was again a major concern; 32 percent of respondents reported traffic accidents as their primary concern, along with unreliable technology, and the fear that "Automated vehicles won't work in dangerous situations according to my own morals" (Liljamo, Liimatainen, and Pöllänen, 2018, p. 42). Yet another study found that the possibility of the vehicle being hacked was a major concern for 52 percent of people (Bansal et al, 2016). Though some of these fears are not entirely misplaced, experiments show that AVs may not be as resilient to hacking as marketing materials lead consumers to believe (Yan, Xu, and Liu. 2016).

Familiarity with AVs plays a role in perception as well. The more familiar with AVs an individual is the more willing they are to ride in one; additionally, as familiarity increases people's concerns shift away from safety and more towards cost (both economic and social) (Liljamo, Liimatainen, and Pöllänen, 2018; Haboucha, Ishaq, and Shiftan, 2017; Gkartzonikas, Christos, and Gkritza, 2019; Choi, and Yong, 2015). The environmental costs of AVs focus on increased emissions if people are willing to travel longer distances (Ohnemus, and Perl 2016). However, another study found that approximately 60 percent of people would be more willing to purchase an AV if they were made to be more environmentally friendly than traditional vehicles (Gkartzonikas, Christos, and Gkritza, 2019). It should be noted that by environmentally friendly, most speak to the assumption that AVs and APT will operate as electric vehicles (Stern, et al., 2019), or that a public transit system will be in large part electric (Fox-Penner, Gorman, and Hatch, 2018). However, rarely is there a discussion of the materials or manufacturing process in which these vehicles will operate.

Cost, including purchase prices and trade-offs, is another factor in people's concerns regarding AVs, in addition to possible environmental concerns. The impact of AVs on the economy, especially on transportation and shipping, has people concerned for their jobs (Rajasekhar and Jaswal, 2015). Concerns exist that AVs will actually increase miles driven, and in turn, increase carbon emissions and worsen climate change (Ohnemus and Perl, 2016; Thomopoulos and Givoni, 2015). There are of course plenty of examples of how AVs could potentially save people money as well, and those too can influence perception. People value their time and money, and if an AV allows them to travel more efficiently and at a reasonable price, then they are in turn more likely to adopt the technology (Krueger, Rashidi, and Rose, 2016).

There are also people who under no circumstances would ever be willing to ride in an AV. Seniors are inherently less trusting of AVs than are younger people (Bansal, Kockelman, and Singh, 2016). Although, seniors, people with special needs, and those with medical conditions that restrict their travel make up the group of people who are most likely to benefit from AVs (Harper et al, 2016). Seniors are less receptive to technological improvements that have come about in recent years, and are less interested in having a machine or electronic voice teach them how to use new features; they often prefer to read a manual (Abraham et al, 2016). An anecdote showing that many seniors resist adapting to new technology, regardless of how others perceive their benefits.

Culture too has an impact on trust in AVs, survey respondents throughout different geographies all vary in their perception of AVs, Israelis have a more favorable view of AVs than do Americans, and trust the technology more; though safety is always the foremost concern regardless of nationality (Salonen, 2016; Haboucha, Ishaq, and Shiftan, 2017). Within the Anglosphere, Australians report feeling more positively about AVs than Americans, and people in the UK were the least receptive; interestingly, Americans were the group of people most likely to have a negative perception of AVs (Schoettle and Sivak, 2014). People living in developed countries are willing to pay more for an AV, but they are also more likely to be concerned about data security than those in developing countries (Kyriakidis, Happee, and De Winter, 2015). Culture also has an impact on ethics, and the decisions an AI makes for an AV need to be culturally sensitive (Awad, et al., 2018). More homogenous cultures may view the train track dilemma as a simple calculation, whereas cultures that value individuality may ascribe more value to the life of a single person (Applin, 2017; Bailey and Erickson, 2019).

Ultimately, increasing trust in AVs is vital if they are to be perceived in a positive light, or considered publicly acceptable. Studies found that trust in technology is based on several factors including: “perceived usefulness”, “system transparency”, “technical competence”, and “situation management” (Choi, and Yong, 2015; Wen et al, 2018). Emotion can influence trust as well, in either direction; some individuals are so emotionally attached to their own vehicles, and driving in general, that they are less likely to trust an AV (Liljamo, Liimatainen, and Pöllänen, 2018). Geography impacts trust as well, respondents in North America were more concerned with the ability to resume control of their vehicle, if the situation were needed, than were respondents in Israel, indicating less trust in the former country (Haboucha, Ishaq, and Shiftan, 2017). As AVs proliferate, and people experience them, trust may inherently increase; of course, assuming that they have a safe experience. Though, in general, many expect that AVs will outperform human drivers (Robert, 2019). Therefore, it may be safe to assume that the majority of interactions people have with them will be positive. However, directed marketing campaigns that assuage people’s fears and highlight benefits may be even more effective given that the technology has yet to become widely accessible (Kääriäinen, et al., 2008).

2.2. Autonomous Public Transit: Perception, Impact, and Feasibility

Even less research has been conducted into how people perceive APT, similar to the previous section on perception and attitudes towards AVs, despite the fact that autonomous shuttles are already on the road in some areas, and other cities have announced plans to incorporate different forms of autonomous transportation into their existing transit networks (Jan, Klein, and Berns, 2019). APT enthusiasts assert that the technology will lower costs and increase efficiency, thus it has garnered investment (Ohnemus, and Perl 2016; Litman, 2017a). Because the technology is already deployed in several places, a person’s likelihood of interacting with an

AV may very well be on an autonomous bus or shuttle. This is important because familiarity and experience with AVs has a significant impact on how a person perceives them (Liljamo, Liimatainen, and Pöllänen, 2018). If autonomous public transit proves to be a benefit to people, it may shape their overall personal feelings regarding AVs as a whole.

Both transportation planning and public transit could benefit from AVs, though there are many considerations to make. Planners often believe that AVs will lead to safer roads, and polices are already being crafted/implemented to suit AVs, and eventually lead to higher adoption rates (Liljamo, Liimatainen, and Pöllänen, 2018). Other benefits that some planners expect include: reduced traffic congestion, improved transfer speed, reduced transfer costs, reduced pollution, reduced noise pollution, and increased safety (Mezei and Lazányi, 2018). Moreover, autonomous transit could significantly increase mobility for the disadvantaged, disabled, and rural communities (Litman, 2017a). Though it must be noted that these benefits are not guaranteed.

Should APT lead to more miles traveled, they could actually increase pollution; moreover, if public transit systems employ fleets of AVs, that are constantly on the road, emissions may rise (Ohnemus, and Perl 2016). There is also no guarantee that AVs will decrease pollution, they may even increase it if personal AVs are used in leu of traditional busses (Millard-Ball, 2019; Venkatraman and Levin, 2019). Finally, where to park a fleet of AVs (assuming they are a part of an APT system) would be a serious consideration, and one that may motivate transit agencies to have them continuously in the field without passengers, further increasing miles traveled while at the same time increasing competition for parking spaces and forcing traditional passenger vehicles to continue driving (Millard-Ball, 2019). This may be less

of a concern in less-dense cities, though in places such as NYC, or other major metropolitan areas, the lack of on street parking is a contentious subject (Roth, 2004).

The availability of funding, and where money is being spent, are also major points of consideration in regard to AVs as public transportation. Public transit agencies often rely heavily on large numbers of passengers using their service, were people to switch to privately owned shared AVs, these agencies may have to downsize (Krueger, Rashidi, and Rose, 2016). Further, the notion that transit can be entirely privatized is also a threat to these agencies. Additionally, some argue that instead of investing in fleets of AVs, other, more affordable, and realistic options exist that transit agencies could utilize to improve service including updating busses, dedicated bus lanes, reduced fares, expanding light rail, improving their communications and scheduling systems, and increasing overall usability (Luo, et al., 2019). However, research has found that ridesharing services such as Uber and Lyft actually increase public transit usage and help close the last mile gap within some transit networks (Hall, Palsson, and Price, 2018). AVs may similarly complement, as opposed to compete with, public transportation. Finally, APT, may actually allow transit agencies to save a significant amount of money via the reduction in labor costs, counteracting other negative aspects of the service (Litman, 2017b). Ultimately, the exact ways in which APT will impact public transit agencies is unknown.

Perceptions and sentiment towards APT are even less studied than the technical and engineering aspects. One study of transit riders in Philadelphia found that the presence of a human significantly impacts willingness to ride; with a human attendant present 66 percent of riders were willing to ride in an autonomous shuttle, however only 13 percent would ride in one without a human present (Dong, DiScenna, and Guerra, 2019). A survey from Michigan found that APT may actually increase willingness to use public transit, especially among those who

already frequently utilize fixed-route public transit; though, the same study found that approximately 50 percent of respondents were wary to the idea of APT (Kassens-Noor, Kotval, and Cai, 2019). People are somewhat willing to ride in a shared AV assuming it was a component of an autonomous transit network, with over 40 percent of survey respondents stating that they would be comfortable sharing said AV; though, respondents were more likely to be comfortable sharing the ride for work based trips as opposed to leisure (Lavieri and Bhat, 2019). Demographics plays a strong role in perception as well, with males, younger people, more educated, and those with higher incomes all being more likely to ride in APT (Kassens-Noor, Kotval, and Cai, 2019; Lavieri and Bhat, 2019; Schoettle and Sivak, 2014; Liljamo, Liimatainen, and Pöllänen, 2018; Winter, et al., 2018).

Geography (location) impacts perceptions of APT as well. Within the Anglosphere, Americans are the most concerned about issues with APT, and the least likely to ride, with 49 percent of respondents being "very concerned", compared to 44 percent in the U.K. and 44 percent in Australia (Schoettle and Sivak, 2014). A survey out of Germany found that 77 percent of respondents would be willing to ride in an autonomous shuttle in the coming years (Pakusch and Bossauer, 2017). An assessment of an autonomous shuttle route in Switzerland found that at least 68 percent of passengers found the shuttle to be worthwhile (Wicki and Bernauer, 2019). Similarly, a study focusing on an autonomous shuttle route in Finland found that the majority of riders were satisfied with the shuttle, and reported feelings of safety and security (Salonen and Haavisto, 2019). It appears that interacting with APT increases positive sentiment of them.

Concerns surrounding APT are similar to those surrounding AVs. Personal safety is still at the forefront of people's minds and their number one concern when considering traveling in APT (Dong, DiScenna, and Guerra, 2019). These concerns are even greater when children are

involved (Winter, et al., 2018). The actual lack of a human bus driver is a cause for concern to some; the potential for disruptive or abusive behavior on APT, and the lack of an authority figure to stop it may deter people from using APT (Shen, Zhang, and Zhao, 2018). One survey found that 64 percent of people stated that their sense of security in a driverless shuttle was worse than on a conventional bus (Shen, Zhang, and Zhao, 2018; Salonen, 2018). Additionally, navigating a fully autonomous system may confuse or dishearten people, particularly the elderly. Non-millennials were found to be far more concerned about learning how to interact with autonomous technology than were millennials (Woldeamanuel and Nguyen, 2018). Given that older generations often prefer learning from books or other humans, a fully automated public transit system may appear off-putting to them (Abraham et al, 2016). The last mile gap, sometimes referred to as the first-last mile gap, refers to the distance a person has to travel to and from a designated public transit stop, E.g. a bus station, terminal, or stop (Shaheen and Chan, 2016). As mentioned, the potential benefits from APT are significant. Foremost, utilizing shared AVs may significantly increase the breadth and scope of transit agencies, allowing them to close the last mile gap and expand services out into more suburban areas (Ohnemus, and Perl 2016). The "last mile gap" is

This may significantly impact the lives of the elderly and disadvantaged, given that transportation barriers are a legitimate hindrance to their overall quality of life (Lucas and Musso, 2014). Disadvantaged populations often heavily rely on public transportation, and expanding coverage areas would undoubtedly ease some of their burdens (Wong, et al., 2018; Litman, 2017a). Transit agencies may actually save money by utilizing APT, allowing them to cut costs associated with human overhead, such as salaries and benefits, again allowing them to expand services (Litman, 2017b; Bösch, et al., 2019). Though, this of course comes with

negative social implications. Further, autonomous shuttles that are already in operation are often already perceived to be a benefit to their riders; these shuttles are cheaper to operate than traditional busses, meaning fares can be reduced, and they have the ability to operate for longer periods of time (2019; Salonen and Haavisto, 2019; Wicki and Bernauer, 2019). As the benefits of APT are further understood by riders, and as they experience the technology, they may be more inclined to ride in and promote it. For instance, the ability to multitask impacts perception and willingness to ride (Malokin, Circella, and Mokhtarian, 2019). As people understand the positive impacts that AVs and APT can have on their life, the more likely they are to support the technology and its addition to existing transit networks.

In order for transit agencies to successfully integrate APT into their networks, they must work toward increasing user trust and thus their willingness to ride. Data analytics may provide the necessary insight into how these agencies can spread their messages of benefits, and assuage concerns. To date, the topic of APT is understudied, especially in regard to how people perceive it, and even more so in reference to how it is discussed on social media platforms.

2.3. Measuring public perception with Social Media/Twitter

Measuring user preference and sentiment may make it easier for transit agencies to both encourage ridership, and use their marketing materials to specifically target people's fears. Especially because targeted messaging has been found to be more effective than generalized messaging (Kääriäinen, et al., 2008). However, gathering these data, as in measures of preference, attitude, and sentiment, can be difficult, expensive, and tedious. Many of the studies that have examined public perception of APT have either been conducted via online surveys, and a few have been conducted via in-person interviews. There have been no studies that specifically look at social media, specifically Twitter, as a means to measure sentiment regarding APT.

Social media platforms can serve as a repertoire of inexpensive (to gather), easily accessible public opinions on most any subject. Instead of a costly survey, data from these websites can generally be collected for free and with little time investment. Twitter data has been used as a means to successfully measure sentiment in the past (Kassens-Noor, Vertalka, and Wilson, 2019). Though, it must be noted that Twitter data is inherently self-selecting, and not all demographics are equally represented. Further, some Twitter users may indeed have perceptions of and opinions regarding APT, though they simply do not express it on the platform, so even analyzing Twitter data may not present a perfectly accurate portrayal of the platform's users. Older populations, socioeconomically disadvantaged groups, the disabled, and any other groups that lack access to the Internet and a computer or smartphone may not be able to use Twitter (Fetni, 2019). However, the abundance of data can certainly shed light as to how AVs and APT are viewed on social media, especially in younger demographics, how both social and traditional media can shape narratives, and ultimately how to encourage people to interact with and use the technology.

Twitter is frequently used by municipalities and municipal agencies to make announcements, and has become a prime means of communication in many circumstances (Sevin, 2013). Users often retweet these announcements and add their own opinions and experiences. Narratives that are shaped on Twitter are powerful, and can have long lasting effects on a person's own sentiment, going so far as shaping their opinions near entirely (Waugh, et al., 2013). Meaning that analyzing Twitter sentiment helps track how these narratives are forming, changing, and influencing individuals, which can help measure perceptions. So much so that using Twitter is now a major component of how politicians, lobbyists, corporations, and activists further their own agendas (Gupta, Ripberger, and Wehde, 2018). Moreover, not only can

opinions be formed on Twitter, but they can be reinforced by seeing multiple tweets about the same topic, which in turn increases the likelihood to retweet (Stieglitz and Dang-Xuan, 2012). Measuring perceptions on Twitter is a legitimate method for understanding how the public views a place, person, thing, technology, etc.

Sentiment analysis using Twitter data has been utilized by researchers for several years, many of whom employ algorithms or software to automatically code words as either positive or negative, generally based on a pre-determined lexicon (Go, Bhayani, and Huang, 2009; Jiang et al., 2011; Tang, et al., 2014; Plunz et al., 2019). Other sentiment analysis use either or both thematic and emergent coding to identify unique patterns or categories within datasets that can shed light beyond simple positive and negative sentiment (Charmaz, 2005; Braun, et al, 2019).

Identifying narratives on Twitter is generally as common as identifying sentiment, and employs similar techniques such as hunting for code words and the use of algorithms/software; though coding manually in order to identify narratives appears to be more common than it is for analyzing sentiment alone (Waugh et al., 2013; Murtagh, Pianosi, and Bull, 2014 Radzikowski et al., 2016; Gupta, Ripberger, and Wehde, 2018). Identifying and following a narrative on Twitter can help track, or even predict, how policies are formed and influenced by public opinion, including extremely serious issues such as public health, safety, and even elections (Waugh, et al., 2013; Radzikowski, et al., 2016).

Identifying sentiments, narratives, and public perceptions surrounding a technology using Twitter data has also been successful in the past (Bian et al., 2016). While the effect that Twitter has on public perceptions has yet to reach its peak, it is indeed comparable to the influence that television, magazines, and newspapers have on shaping perceptions (Arceneaux and Schmitz-weiss, 2010). Twitter can even affect the credibility/perception of professionals and individuals

(DeGroot, Young, and VanSlette, 2015). Implying that the discourse found on Twitter highlights not only perception, but also what directions narratives are being pushed.

2.4. Media Biases and AVs

Media, in many of its forms, especially news media and social media, suffer from inherent biases; oftentimes simply as a result of being created and or controlled by human beings (Ardèvol-Abreu and Gil De Zúñiga, 2017; Baron, 2006). User created media reflects their own individual preferences and opinions, whereas corporate media generally reflects business interests (Groseclose and Milyo, 2005). Further, individuals, in general, are well aware that media are biased, though to what effect this has on their perception is less understood (Baron, 2006). Social media and Twitter are no different, corporate, and municipal accounts have biases and agendas, and oftentimes so do individual users.

Media outlets tend to focus on negative narratives far in excess of positive ones (Soroka, 2012). This is not an American phenomenon, as European news sources have also been found to overly focus on negative aspects of stories, or the potential for harm (Garz, 2014). Blame for this cannot be placed entirely on media outlets as consumers are also partially responsible, they themselves often demand negative news stories and reward media outlets with views, clicks, and advertisement revenue by choosing to watch negative coverage in excess of positive (Trussler and Soroka, 2014). Not only does this influence discourse, sentiment, and opinion, it can have genuinely detrimental effects on a person. Negative news stories have been found to cause significant changes in a person's mood, opinion, and even cause negative health effects (Havrylets, et al., 2013).

AVs and APT are not immune from the negative frame. First, AVs come in multiple levels of automation, and fully autonomous vehicles are extremely rare (Yang et al, 2017). Yet media, and researchers to a degree, rarely differentiate the levels of autonomy and treat AVs as largely the same from one another, with engineering and computer science being the exception. When an incident happens, stories are often over-reported to a national audience, without noting that AVs are statistically safer than human drivers; that is to say that an AV is significantly less likely to end up in an accident than are human driven vehicles (Litman, 2017a; Doecke, Grant, and Anderson, 2015). This is important because positive information about AVs increases an individual's willingness to ride in one, and conversely (and unsurprisingly) negative information does the opposite (Anania, et al., 2018).

The literature is without a comprehensive study on how media and news coverage affect the perception of AVs or APT. We know that consistent stories can reinforce people's preconceived beliefs (Stieglitz and Dang-Xuan, 2012). Were media to use their platforms to more accurately report the benefits of AVs and APT, more people may be willing to ride in one. However, better understanding of how these stories proliferate will lead to a better method for introducing people to the technology. Moreover, demographics on Twitter generally are not representative of the general public, nor are they representative of the people who stand to benefit the most from APT. However, a person's belief and perceptions can be influenced by those around them, particularly family members.

2.5. Social Media Demographics & Familial Influence

Not all people actively participate in social media, and each individual may engage with social media differently than other users, or participate in different platforms. generally social media audiences are younger than average (Murthy and Pensavalle, 2016; Duggan and Brenner,

2013). Twitter in particular is attractive to adults between the ages of 18 and 29. Additionally, Twitter is used by less than 20 percent of all internet users, compared to Facebook which boasts nearly quadruple that number (Duggan and Brenner, 2013). However, that number may be even larger given the timeframe between its last reporting in the literature, and the writing of this thesis. Though, notably, Twitter may actually be the platform most used by socioeconomically disadvantaged people (Murthy and Pensavalle, 2016). Twitter is also used more often by urban residents and African-Americans (Duggan and Brenner, 2013). Clearly, not all voices are heard equally on the platform. However, and at the very least, socioeconomically disadvantaged people and minority groups are present on the platform, and these people may stand to benefit significantly from APT and AV's (Wong, et al., 2018; Litman, 2017a). More notable because other social media platforms tend to be more devoid of socioeconomically disadvantaged peoples, and their opinions are often excluded from analysis that utilize social media data (Fetni, 2019). Nonetheless, even if Twitter cannot be used as a means to communicate with all people, it still can serve as an opportunity to better understand how people perceive and interact with APT.

Though, if Twitter is to be used as a means to influence people's perception of APT, the audience needs to be expanded; especially to other markets which stand to benefit greatly from the technology, namely the elderly and disabled (Harper et al, 2016). This could be accomplished via familial influence. Family members are by far and away the most influential people in an elderly person's life, these people have the ability to dramatically alter the opinions and preferences of elderly relatives, even relative to extremely sensitive or controversial topics (Febrero, et al., 2018; Presson, 2003). Family members are often those that teach elderly people how to use the internet, interface with technology, and communicate with others (Naumanen and Tukiainen, 2007; Campbell and Nolfi, 2005). The website and social media preferences of

younger people may ultimately be passed onto the elderly people in their life. Additionally, the mere presence of a young person in the home of an elder actually leads to an increase of the elder's time spent on the internet (Campaña and Ortega, 2020). Therefore, it can be argued that although Twitter may primarily influence the opinions of young people, those opinions may in turn be transferred to their elderly relatives. Important because narratives are formed on Twitter, and opinions can be changed or influenced as a result (Radzikowski, et al., 2016; Bian, et al., 2016; Waugh, et al., 2013). Furthermore, in some instances elderly and disabled people are accompanied by chaperones or caregivers on public transit, though it cannot be said for certain, if these caregivers are younger, and participate in social media, there is a possibility that they themselves could be influenced and then in turn promote APT to their charges.

As noted, and similar to the lack of elderly people on social media, disabled people are often excluded from social media analysis (Fetni, 2019). Though, mobility impaired individuals E.g. those that rely on a wheelchair, may actually use social media more than the average person, and may even rely on it to access critical mobility information/knowledge especially relative to travel (Altinay, et al., 2016; Drews and Schemer, 2010). It could be fair to assume that these people's opinions are included in the analysis, though because of the lack of demographic information and personal characteristics, their specific preferences cannot be discerned. Other disabled people, including those with cognitive impairments, may be similarly influenced by family members or their caregivers; similar to how the elderly are influenced by their family. Caregivers are responsible for a tremendous amount of life choices for some disabled people, and could potentially introduce a disabled person to APT (Donelan, et al., 2002). The influence of social media on caregivers may then in turn influence the lives of disabled peoples.

Increasing mobility for disadvantaged people is incredibly important, and APT or AVs may help them overcome their mobility barriers; these people stand to benefit significantly from increased mobility, especially considering a lack of mobility is often correlated with decreased health and decreased access to essential services; moreover, lack of mobility is well known as a major contributor to decreased quality of life for disabled peoples, and even leads to severely negative health impacts (Lucas and Musso, 2014; Syed, Gerber, and Sharp, 2013). Notably, modern technology already exists that help disabled people navigate public transit via smartphone apps (Barbeau, et al., 2010). Were an AV able to be summoned via an app, then disabled people may have an easier time accessing the technology.

Chapter 3. Methods

Data from Twitter was collected that included the tweet itself and multiple additional variables such as the time and place of the tweet, username, followers, account status, number of likes and retweets, account descriptions, and hashtags. In total, 1422 tweets were included in the dataset. In order to qualitatively analyze the tweets emergent and thematic coding was employed to create categories with which to code the tweets into (Braun, et al, 2019; Charmaz, 2005). Though, thematic coding was employed more often than emergent, and only a single category emerged that was not derived from the literature.

3.1. Data collection

All tweets were from within the United States, and all were written in English. Tweets were collected from between January 1st, 2016 and December 31st, 2019. Dates were selected to cover a four-year period in which several trial runs of APT were being conducted, and to see if there were any temporal changes among sentiment.

In order to gain access to Twitter data, a Twitter developer account was created which allows access to the application programming interface. Creating a developer account was an arduous process constating of multiple questions to ensure data security and user privacy; focusing mostly on what a user plans to use their developer account for, and why they need access to the data. The process took approximately two weeks.

Once an account was created, an additional application, Jupyter Notebook, was used as a plugin to facilitate the running of a search, which was coded via Python. The search area was relegated to only accounts within the Unites States, only tweets written in English, within the given time frame, and only those that featured the keywords “autonomous vehicle”, “self-

driving", or "driverless", in conjunction with "bus", "shuttle", or "public transit". The search ultimately returned 1422 tweets. Data was then cleaned to remove erroneous entries and index tweets. It should be noted that mining data from social media and actually using social media are entirely different, they use different interfaces, accounts, methods, and require an entirely different set of skills; often basic understanding of a programming language is necessary, in this case, Python.

3.2. Limitations

Data was relegated to the United States, and this analysis could not be applied elsewhere. Additionally, Twitter users and their respective data is self-selecting, or more clearly, the representative opinions and viewpoints expressed on twitter are self-selecting. Younger people are more likely than the elderly to voice their opinions on the platform (Zhou and Na, 2019). Additionally, because posting on Twitter requires both an internet connection and access to a smartphone of computer, socioeconomically disadvantaged people may not be included in the analysis (Fetni, 2019). The same is true for some people cognitive disabilities. This is important because some of these people rely heavily on public transportation and their opinions could be vital for understanding sentiment and preference in regard to autonomous public transportation (Litman, 2017a). Additionally, it can be difficult to succinctly characterize social media data, in that demographic and geographic information is not always present; though some Twitter users do indeed list their geographic location in their bios, or include geodata in their tweets. Finally, because English tweets were exclusively collected (still, only within the United States), non-English speakers are excluded from the analysis.

3.3. Data Analysis and Coding

Tweets were analyzed, via emergent and thematic coding, that directly mentioned autonomous vehicles (AVs), specially, autonomous busses. Six categories of tweets were found in which the code was already present within the literature, and one code emerged. The emerged topic was "Public Transit Preferred/Shifting of Resources". This code is similar to costs, but because of how commonly It occurred, a new category was created. (**Table 1**). No software was used to code tweets, and all were coded by hand. Tweets were coded 1, 2, 3, 4, 5, 6, or 7, with each number referencing a different category. Only a negligible number of tweets fell into more than one category, likely due to a 140-character limit on tweets. Users were eager to quickly voice their opinion or experience, not necessarily have a conversation.

Categories of Tweets	
Positive Expressions	Positive changes that people believe will be induced by AVs or APT. Includes words such as: Future, amazing, exciting.
Safety Concerns	Mentions of AVs getting into accidents or decreasing road safety. Includes words such as: Fear, scared, dangerous.
Costs Concerns	Both the potential for AVs to be too costly for everyone but wealthy people to afford, and the costs to society. E.g. Job loss.
Automotive and Mobility Technology References	References to automotive or mobility companies working on or deploying AVs. Includes announcements and press releases of AV tests and partnerships.
Political	Politically charged comments.
Public Transit Preferred/Shifting of Resources	Comments that note the impact AVs may have on public transit, references to funding being spent on AVs as opposed to expanding/improving public transit.
Other	Tweets that mention AVs but wherein the sentiment could not be determined, or veered wildly off course.

Table 1. Categories of analyzed tweets and their description.

The most common tweets were automotive and mobility technology references at 41%, Positive expressions were mentioned in 26% of tweets, followed by safety concerns at 19%, and cost concerns were mentioned in 5% of tweets. Tweets that preferred public transit made up 5%,

and both the other category and political category comprised 2% of tweets, respectively (**Figure 1**).

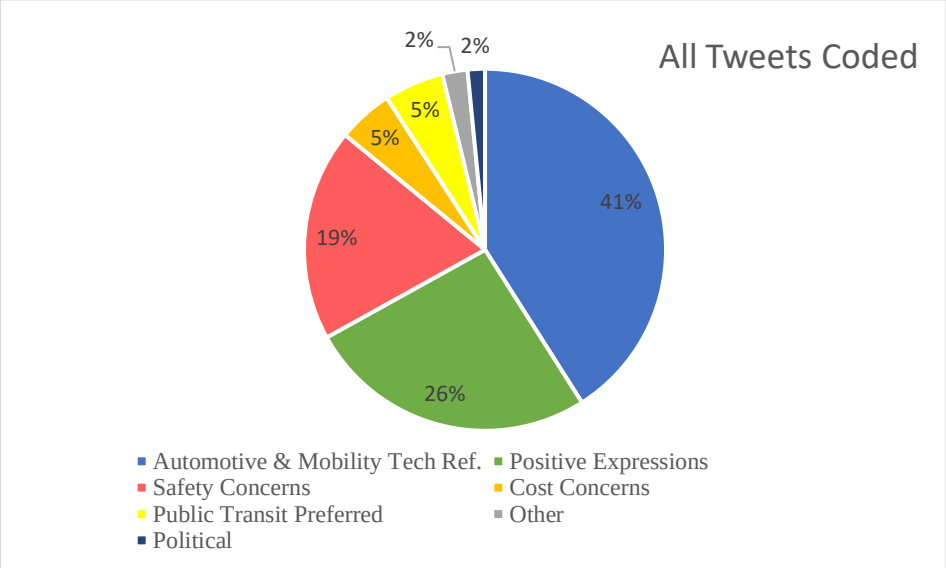

Figure 1. Chart depicting message topics found on Twitter referencing AVs. (n=1422)

3.3.1. Removal of Tech References including media reports, political, and Other Tweets

However, the above categories (listed in **Figure 1**) do not necessarily highlight perception, for instance, automotive and mobility references are often unemotional posts, that simply just mention technology, therefore perception of the user cannot be garnered therefrom. Further, automobile and mobility technology references were generally composed of announcements or press releases. Thus, those were removed for further analysis regarding sentiment. These references comprised 41% of all tweets (n=583).

The most commonly found category was automotive and mobility tech references, the overwhelming majority of which were announcements of autonomous bus or AV deployments, partnerships, funding, and tests. These tweets did not speak to how a user felt about AVs, or their impact on society, but rather about the technology itself. E.g. "*The route for Providences* [sic]

test of an autonomous electric shuttle" and "*Worlds First All Weather Autonomous Bus Rolls Out in Finland via* [link]". Many of these tweets were from Twitter accounts linked to journalists, news sources, municipalities, or universities. This category also includes tweets about users riding an AV bus, but which did not highlight anything other than the technologies existence, such as "*A quick ride in the autonomous shuttle Las Vegas Convention Center*".

A number of different companies were routinely mentioned in these tweets, including Toyota, Tesla, Xiaoyu, Baidu, Softbank, Mobility Detroit and MCity. However, the AV bus "Olli", developed by Local Motors, was the most commonly mentioned piece of autonomous technology. Olli was mentioned in 90 different tweets, 55 of which were categorized as automotive and mobility technology references making up 11% of the entire category. An example tweet about Olli being "*Delegates from Montreal tour Chandler s microfactory to get an inside look at the development of Olli a self driving electric shuttle AZMontrealVisi*t".

Several Universities were also frequently mentioned in these tweets including Texas A&M University, The University of Michigan, Tennessee State University, and Virginia Tech; all of which received relatively even mentions. A number of cities, the vast majority of which were conducting autonomous shuttle trial runs, were mentioned as well, including Detroit, Miami, Pittsburg, and New York City, however Las Vegas received the majority of tweets regarding their shuttle.

After which Positive expressions becomes the most common category comprising 44% of tweets, and safety concerns becomes the second most common category with 32% of tweets. Tweeters who prefer public transit and who raise cost concerns comprise 8% and 9% of tweets, respectively. "Other" tweets comprise 4% of all tweets, and political 3% of tweets (**Figure 2**).

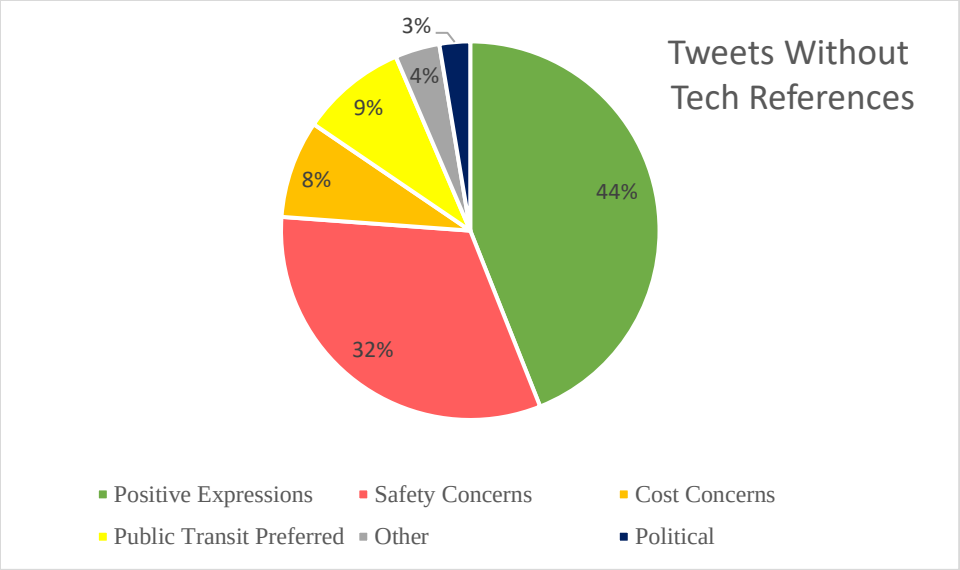

Figure 2. Chart depicting message topics found on Twitter regarding AVs, excluding technology and automotive references. (n=839)

Next, in order to solely highlight sentiment, the other and political categories were removed. Neither category accurately or clearly depicts how people perceive AVs, and their removal allows a cleaner understanding of the data when referencing sentiment. The "other" category consisted of 4% of all tweets (n=32), whereas the political category again consisted of 3% of all tweets (n=22).

Tweets categorized as "other" consisted of tweets that could not clearly be coded into any other category, and where sentiment cannot be accurately discerned. Some of these tweets were more comical, but do not give a clear understanding of the users perception of AVs, such as "*Rumor has it that a group of Master Jedis use to force to operate Mcity and its driverless shuttle*" whereas others are more incoherent "*Self driving bus foot praying mantis playground tower made of shipping containers carne asada fries Just lunch in DTLV*". Some of these tweets

were also those that simply define the word autonomous, e.g. "*an autonomous vehicle is a self-driving car*". Because of this, these tweets were removed in order to analyze sentiment alone.

Politically charged comments made up a small number of all analyzed tweets. These tweets did not highlight autonomous technology, or the technology was ancillary to the tweet. Most were attempting to push an agenda on either side of the pollical spectrum. An example being "*You know before it's all over with the GOP WILL TURN ON YOU They may be in your corner right now but at the rate you're going down hill they will all soon get off the driverless bus All the dirty names that Lindsey Graham called you while you were running are being proven true*". Again, the user's sentiment cannot accurately be defined, and therefore, like "other" tweets, political tweets are likewise removed in order to analyze sentiment alone.

Thus, an analysis of 1422 tweets and 785 tweets which expressed a sentiment towards AVs or APT were used for public sentiment analysis. It should be noted that in order to measure influence, and perceptions by place and time, the above categories were included in the analysis. They were only removed when explicitly discussing sentiment.

3.4. Statistical Analysis

In order to determine statistical significance, where applicable, different tests and or analysis were conducted. Though it should be noted that the aim of this thesis is more qualitative than quantitative, and the number of statistical analysis done on data are limited and infrequent. T-tests were conducted for positive and negative perception and verified accounts vs. non-verified. A Mann-Whitney test, also known as Wilcoxon rank sum test, was used for comparing overall sentiment to sentiments from influential tweeters, as well as the topics discussed in influential vs. non-influential tweets.

Chapter 4. Results

After the removal of announcements, political, and "other" tweets, positive expressions were the largest category, at 47%, followed by safety concerns at 34%, public transit preferred at 10%, and cost concerns at 9% (**Figure 3**). We found that although positive expressions were the most commonly tweeted about topic, safety concerns were far more often to be retweeted and tweeted about by influential users; and the overall perception of AVs on Twitter is slightly more negative than positive. On days where a safety incident occurred, Twitter was significantly more active in referencing the topic. The same is true for locations in which incidents occurred, most notably Las Vegas. Additionally, when a safety incident occurs, it tends to dominate the Twitter narrative for multiple days; details regarding these incidents are often taken out of context and include misleading headlines or frame the incident in a negative light, E.g. even when humans are responsible for an incident, blame is placed on the AV. Notably, neutral, and neutralized tweets were exceedingly rare outside of announcements and tech references. Few tweets tended to debate APT usefulness; the overwhelming majority stated their opinions without wavering.

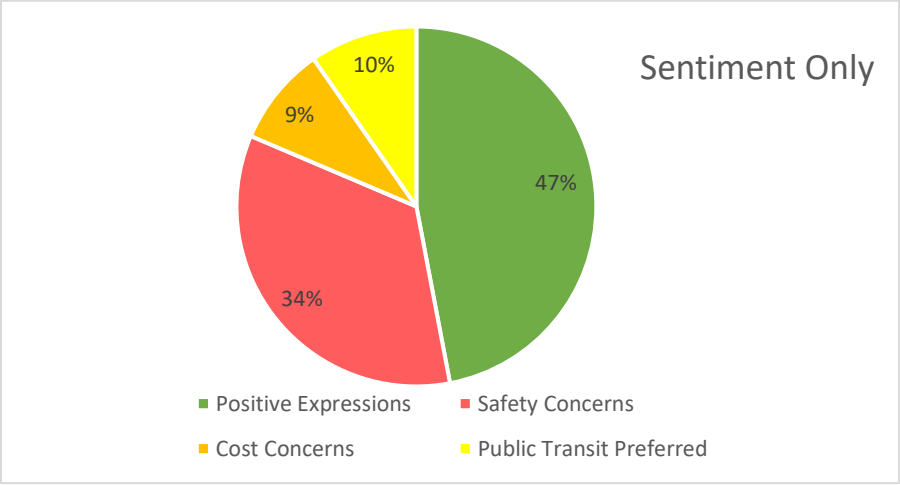

Figure 3. Chart depicting major sentiments found on Twitter regarding AVs. (n=785)

4.1. Perception/Sentiment Categories

In addition to topics from the literature including positive expressions, safety concerns, and cost concerns, one other category emerged. A notable number of tweets mentioned a desire to not see money spent on AVs or APT, and that they would rather see updated or better funded traditional public transportation. Some of these equated AVs to riding a bus, as in a person does not drive the bus themselves, thus making it "inherently" autonomous to riders. Each category consisted of unique themes and user perception as described below. Again, noting that political, other, and automobile reference tweets are excluded from the perception/sentiment analysis.

Positive Expressions (26% Total Tweets, 47% Sentiment, n=369)

Users express their perceptions about AV benefits focused on autonomous shuttles clearly in their tweets. Many users in this category are eager for the technology to proliferate and many note its positive benefits on different aspects of society. Users in this category commonly contemplate what the future of transportation will look like, e.g. "*Why the Bus Might be the Future of Transportation No emissions electric autonomous shared affordable*." Some note that AVs may actually increase road safety "*At what point do we ban human driving to more quickly progress to autonomous and prevent k deaths per year"* whereas others note the impact that these shuttles could have on disadvantaged or disabled people "*Shuttle bus will serve people with vision hearing physical impairments drive itself ibmwatson AI*".

Many of the tweets in this category are short and simple, even for a standard 140 character tweet, and some are just people noting that they have ridden on an autonomous bus and enjoyed it, such as "*Sweet driverless shuttle favsummit*" Notably, some users believe that autonomous shuttles will significantly improve public transportation systems, or make public

transit more accessible in suburban communities: "*down the road fleets of autonomous vans leased to cities replace bus systems with better coverage same or lower cost*." However, this is a point of contention among users on Twitter, as 5% of all tweets mention how public transit could be hurt by autonomous technology.

Safety Concerns (19% Total Tweets, 34% Sentiment n=270)

The second most common category contained tweets that mentioned people's fear or distrust of AVs, all of which referenced personal safety. Some of these were exaggerations speaking about hypothetical events or were overly sensationalized such as "*Despite an accident the Robot Takeover of Las Vegas continues VegasTech selfdriving*" or "*Driverless autonomous bus apparently just threw itself off the road*." Though some responses were far more grounded and spoke to legitimate issues with the technology, notably in a single tweet:

> "*Ppl support sacrifice by a self driving car of its passenger if it saves the lives of a large number of pedestrians but they personally would never buy a passenger sacrificing self driving car. Excellent piece on Bostons well intentioned but badly received bus algorithm*" and "*The scariest thing about autonomous vehicles is our areas shoddy G LTE data on some cell carriers And satellite data may not work in extreme heavy Florida thunderstorms Its one thing to shuttle people downtown Its another doing".*

Given that this is the second most common category of tweets, it indicates that there is still significant work to be done in order to get the public to trust AVs.

Though, a major trend within this category was medias penchant for focusing on negative narratives, at times seemingly and deliberately misleading readers, and a cavalcade of users

tweeting about the same stories. Two incidents involving AVs were reported in Las Vegas and California, in both cases the crashes harmed no one, and were the result of human error. However, headlines such as "*Self Driving Bus Crashes Hours After Launch In Las Vegas*" and "*APNewsBreak Video shows Google self driving car hit bus via*" are rampant, and many users retweet these stories without any additional context. These two events were referenced in 115 tweets comprising 42% of the entire category. Highlighting just how significant the role of media is regarding the perception of AVs.

Public Transit Preferred (5% Total Tweets, 10% Sentiment n=76)

The impact that autonomous busses will have on existing public transit networks is a point of contention on Twitter. Many users believe that it is pointless to fund AV projects when public transit is already underfunded, or believe that investing in AVs is pointless: "*We already have driverless cars its called the bus it has a driver but its not you*"; a few believe that there are negative social ramifications of investing in AVs "*Ummm this looks so efficient investment in autonomous vehicles instead of public transit is segregation policy*". Some users make their point more poignantly than others "*I was disappointed at pandering fascination with single user vehicles and autonomous cars on the show when we could make public transit much more efficient like any modern country Thank you for calling to emphasize mass transit today*". Clearly, AVs will have an impact on public transit, though the literature disagrees. In any form, APT will absolutely change public transit and the way people interact with it; further, it is clearly a point of contention on Twitter.

Costs Concerns (5% Total Tweets, 9% Sentiment n=70)

The costs, and negative ramifications thereof, of AVs are made clear in a number of tweets. Noting that this includes environmental and social costs, but excludes the impact on existing public transit networks, as that is its own category. Whereas users/tweets categorized as positive expressions may disagree, these users clearly view AVs as having the potential to significantly disrupt their lives and overall damage society. These tweets not only point out that AVs may be prohibitively expensive for a great number of people, but that the social and environmental costs of AVs may be high as well. One user noted that "*Without public policy intervention the likelihood is that the autonomous future mirrors today s reality more automobility more traffic less transit and less equity and environmental sustainability See for solutions*". Additionally, the impact that AVs will have on jobs is often discussed on Twitter, almost always in a negative light "T*he social and economic shift of self driving vehicles will be immense Imagine not having to worry about young or old drivers Also imagine displaced truckers and bus drivers*". Some of these users are also concerned that AVs and autonomous busses will actually increase congestion "*Horadam Without dedicated lanes those autonomous buses are just going to get caught in traffic and will not attract riders The increase in congestion is directly related to the huge decline in bus ridership*". Though these concerns are extremely serious, they were still far less common than perceived safety, though tweets mentioning costs are oftentimes much more coherent and articulate, pointing to the direct and possible impacts of AVs and APT on society.

4.2. Sentiment

Both concerns (safety and cost) as well as tweets that prefer public transit are negatively themed, whereas positive expressions are entirely positive. Thus, the majority of tweeters (53%)

view AVs in a negative light, and 47% as positive (**Figure 4a**). However, this is not statistically significant with (p>0.5) Though the range is close enough to call sentiment nearly evenly divided between positive and negative on Twitter. The overwhelming majority of these tweets came from unverified accounts (90%), as opposed to only 10% from verified users, the majority of which are online news sources and technology blogs (**Figure 4b**). Again, this finding was not statistically significant with (p>0.5). Thus, the vast majority of analyzed tweets are from users voicing their individual opinions. Notably users who rode an autonomous bus rarely mentioned anything negative.

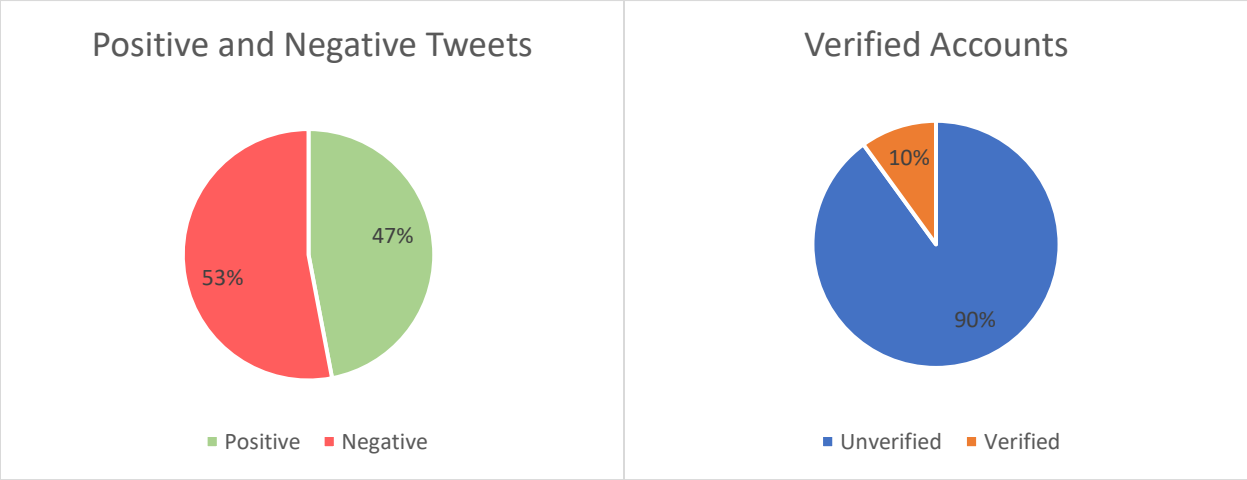

Figure 4a & 4b. Positive and negative sentiments within Twitter and account status on Twitter. (n=785, n=1422)

4.3. Perceptions by Place

All tweets were collected from the US tweeters, Some US regions, states, and cities were far more active when tweeting about autonomous public transportation: Dallas, San Francisco, Las Vegas, Washington DC, and New York City were the most active locations, comprising 31% of all tweets (**Figure 5**). Location data reflects either where the tweet originated from, using geodata, or where the tweeters location mentioned in their biography. Generally, these places either were announcing that autonomous shuttles would become part of their transit networks in

the future, or active AV tests were being conducted. Ultimately Texas, California, Michigan, Florida, New York, and Washington DC are on the center stage of Twitters discussion about AVs and autonomous public transit (**Figure 6**).

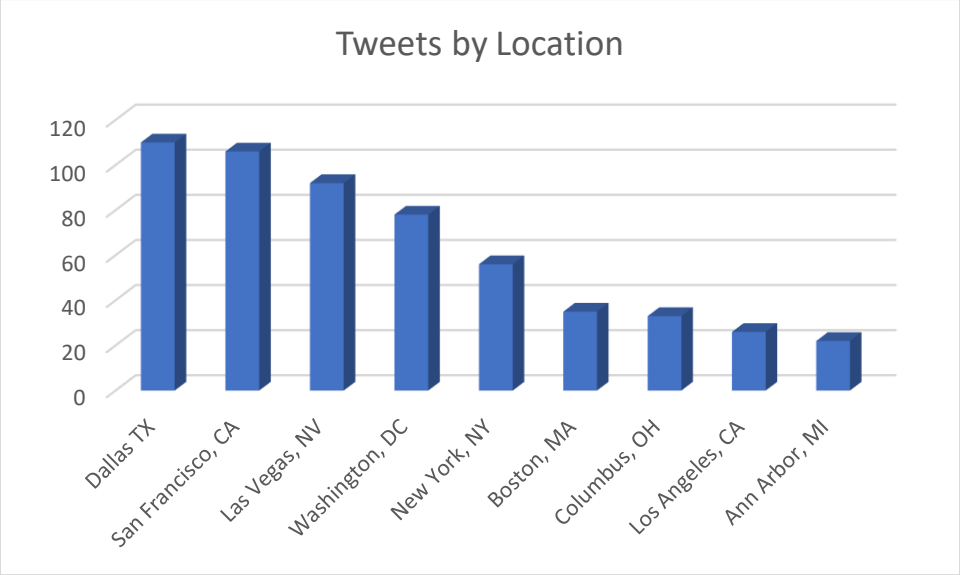

Figure 5. Tweets by location, top ten most active cities. (n=558)

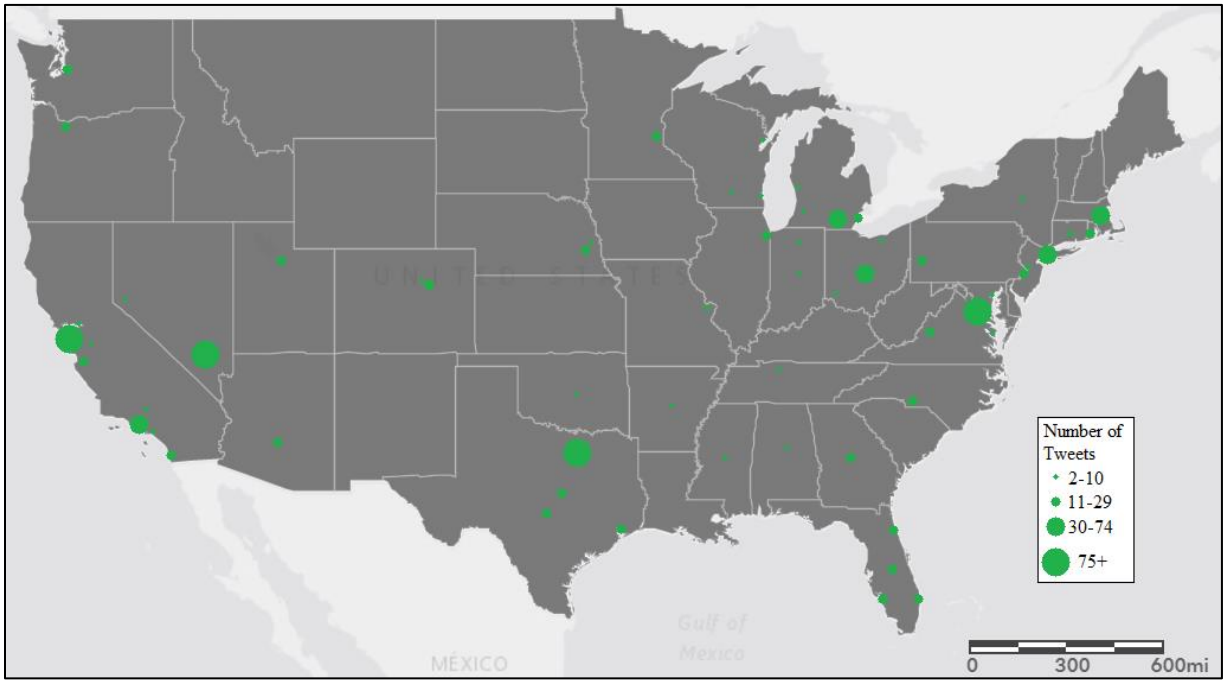

Figure 6. Tweets by location throughout the United States. Basemap courtesy ESRI. (n=804)

Topics and sentiment were largely the same across all geographies. However, in some cases, notably Las Vegas, a significant portion of the tweets were as a result of an incident in which a human driver crashed into an autonomous shuttle; the same is true for the Los Angeles area, though to a lesser extent. Ultimately leading to Las Vegas being home to an abundance of negative themed tweets aimed at safety concerns. Overall, when a negative incident occurred it was tweeted about at length and numerously, despite them being rare occurrences.

4.5. Perceptions by Time

All tweets were collected between January of 2016 and December of 2019. In general, most days during the timeframe saw at least one tweet, with few off days, and had an overall average of 0.97 tweets a day. However, some days saw significantly more tweeting than others. Eight days during the timeframe had over ten tweets, referred to as "major tweet days" within this study, with the lowest being fifteen, and the highest being 61 on 2017-11-09 (**Figure 7**).

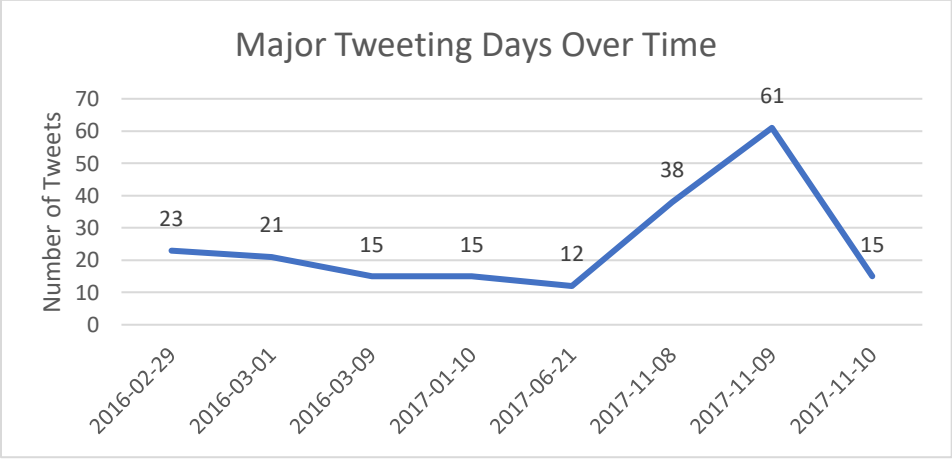

Figure 7. Days with more than ten tweets. (n=200)

Major tweet days occurred in conjunction with major events regarding autonomous transit and AVs. Launch events and announcements of autonomous shuttles were responsible for

25% of major tweet days, however safety concerns were by far the most common reason for the uptick in tweets (**Table 2**). Exactly 75% of major tweet days coincided with safety incidents, two in particular, comprising 22% of all sentiment tweets. Further, these two incidents account for six of the eight major tweet days, and each incident was tweeted about heavily for at least three days.

Major Tweeting Day	**Count**	**Context**	**Type**
2016-02-29	23	A Google AV swerves in front of a bus, both parties partially responsible. No injuries.	Safety Concern
2016-03-01	21	Repeat of the same news story from previous day.	Safety Concern
2016-03-09	15	Repeat of news story from 2016-02-29.	Safety Concern
2017-01-10	15	Autonomous shuttle debuts in Las Vegas	Launch Event
2017-06-21	12	The University of Michigan announces plans to introduce an autonomous shuttle to campus.	Announcement
2017-11-08	38	Autonomous shuttle is struck by a passenger vehicle. No injuries and human at fault.	Safety Concern
2017-11-09	61	Repeat of the same news story from previous day.	Safety Concern
2017-11-10	15	Repeat of news story from 2017-11-08.	Safety Concern

Table 2. Major Tweet Days, context, and type. (n=200)

Though only 8 days of tweeting is a small sample, it appears to be significant because of how rare a day with more than 10 tweets is within the dataset; only 0.5% of days received more than 10 tweets. Further, both of the major incidents were the result of human error. In one, a personal vehicle struck an autonomous shuttle, yet tweets such as "*A driverless bus got into a crash on its first day*" were rampant, especially from news sources and blogs, with very few pointing out the fact that humans were at fault. The second incident in California involved an AV

sideswiping a standard bus, however, fault cannot be placed entirely on the AV, as the bus driver expected the vehicle to stop. None of these incidents were serious, and certainly no more dramatic than an average day's drive, but yet they were both highly dramatized on Twitter.

These tweets can absolutely influence perception as several users tweeted something akin to "*Hmm Self driving bus Not sure I'd hop on after this*" or "*Oh geez I won't be riding that when I'm there next week*". The two incidents were responsible for over 100 tweets and collectively comprised 42% of the entire safety concern category. Were these tweets not present, positive perceptions of AVs would have been far greater than negative perceptions.

4.6. Influence

Both the type of account and number of followers has an effect on a person's/accounts influence. On average, users within this dataset have 7993 followers, though the median number of followers is 1516. Clearly some accounts are far more influential than others. Only 106 accounts have over 10,000 followers, comprising 7% of analyzed accounts, 2% of accounts had over 50,000 followers, and only 16 accounts (1.1%) had over 100,000 followers. Though some of these accounts tweeted about autonomous public transit and AVs multiple times; 1.39 tweets per account, on average.

The account with the highest number of followers (293,642) was @MayorOfLA, the official account of, appropriately, the mayor of Los Angeles. He was taking questions about how autonomous shuttles may impact Los Angeles' transit network. Though he voiced no sentiment. There is a disparity in followers for the top ten tweeters, with the top having over 300,000 followers, and the tenth having just over 100,000. However, some of these accounts are responsible for more than one of the most influential tweets. With @evankirstel having 8 out of 148 (~5%), and @WDNT having 2 (~1%). Indicating that although follower counts do have in

impact on influence and retweets, some users are more prolific than their follower account may lead someone to believe. Moreover, verified accounts are more commonly influential than unverified; 50% of the top ten most influential accounts are verified, whereas on average only 10% of the accounts in the dataset were also verified (**Figure 8**).

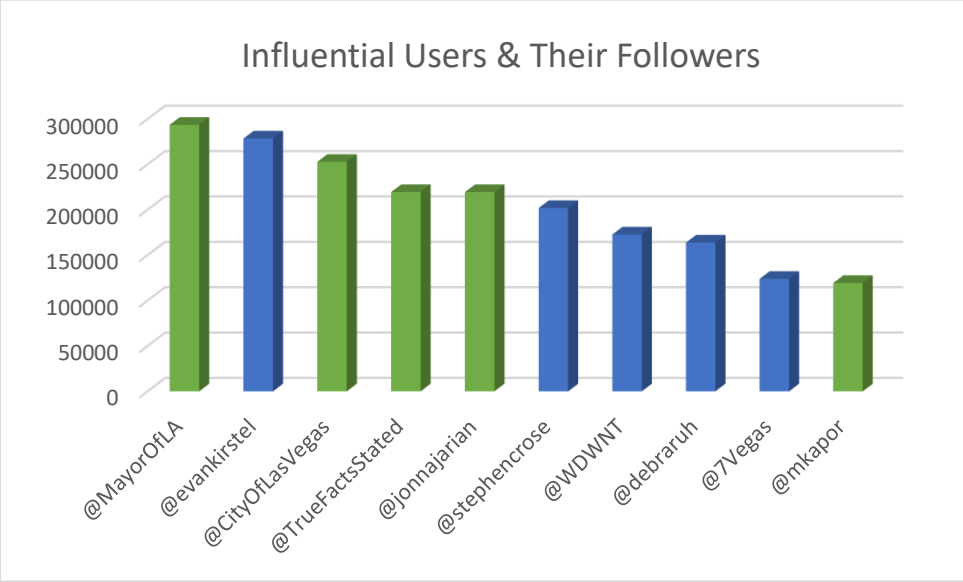

Figure 8. Influential users (names), their number of followers, and account status. Green indicates verified, whereas blue is an unverified account. (n=10)

Topics tweeted about by influential tweeters were relatively similar to all tweets overall. Out of 148 tweets, automotive and tech references, which lack sentiment, are still the largest category of tweets at 45% (41% overall). However, positive expressions are tweeted about *less* often by influential tweeters (18% as opposed to 26% overall), and safety concerns are tweeted about *more* often (26% as opposed to 19% overall). A preference for public transit is tweeted about slightly more often by influential tweeters at 7% (5% overall), and cost concerns are tweeted about slightly less often by influential tweeters at 4% (5% overall) (**Figure 9**). However, comparing influential tweeters with standard tweeters was not found to be statistically significant with ($p>0.5$). Influential tweeters did not tweet about politics or "other" topics. When automotive

references are stripped away, safety concerns dominate the narrative on Twitter at 47% (34% overall), followed by positive expressions at 33% (47% overall), public transit preferred at 12% (10% overall), and cost concerns at 7% (9% overall). (**Figure 10**). Again, compared to average tweeters, no statistical significance was found with ($p>0.5$). Whereas all tweets collectively, analyzed for perception, mentioned positive expressions more often. Highlighting the tendency for influential users to focus on negative narratives as opposed to positive expressions or other positive impacts that APT could have on society.

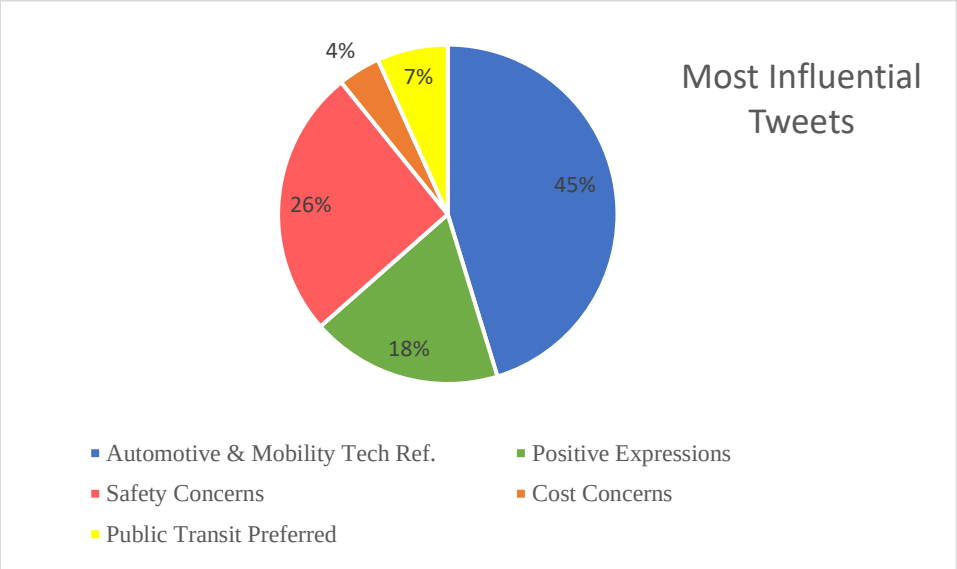

Figure 9. Topic of tweets from users with over 10,000 followers. (n=148)

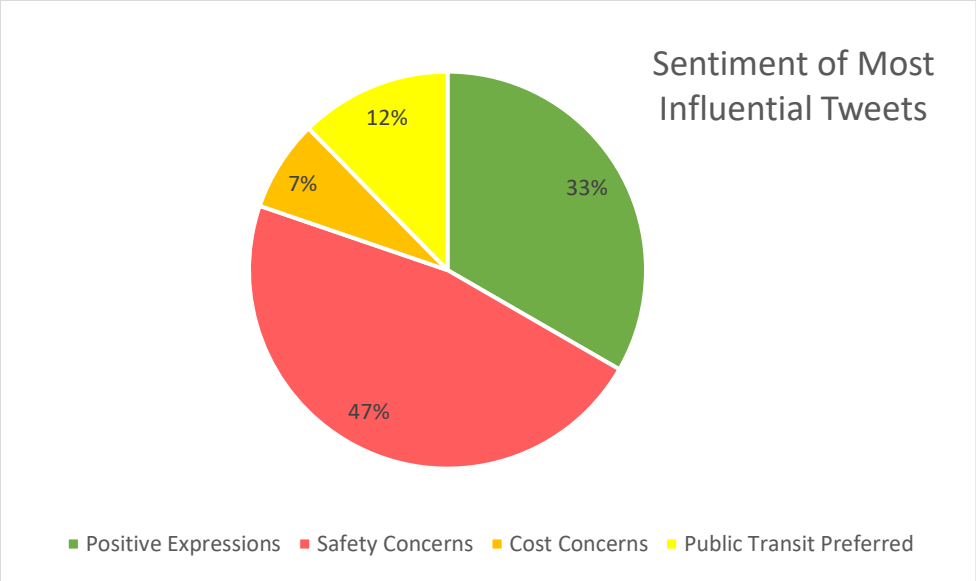

Figure 10. Sentiment of tweets from users with over 10,000 followers. (n=81)

Multiple retweets were relatively uncommon within the data, though a single retweet was at least moderately common. Expectedly, users with more followers had their tweets retweeted more often than did users with fewer followers. The average rate of retweeting was 1.6, however the median rate of retweets was 0. Approximately 32% of tweets were retweeted at least once, 7% five or more times, though only 1% were retweeted 20 or more times. Further, only 7 tweets were retweeted fifty or more times, and only 1 tweet with 100+ retweets. 99% of all tweets which received 5 or more retweets came from accounts with more than 10,000 followers.

Of tweets with more than 5 retweets, automotive and tech references were still the most common topics at 40% (41% overall). Safety concerns came in second at 26% (19% overall), positive expressions at 22% (26% overall), public transit preferred at 9% (5% overall), and cost concerns at only 3% (5% overall) (**Figure 11**). However, comparing influential tweeters with standard tweeters was not found to be statistically significant with ($p>0.5$). Tweets about safety concerns are more likely to be retweeted than are positive expressions or other topics. When

examining sentiment of retweets alone safety concerns are the most common at 44% (34% overall), followed by positive expressions at 36% (47% overall), public transit preferred at 16% (10% overall), and cost concerns at 5% (9% overall) (**Figure 12**). Once again, compared to average tweeters, no statistical significance was found with ($p>0.5$).

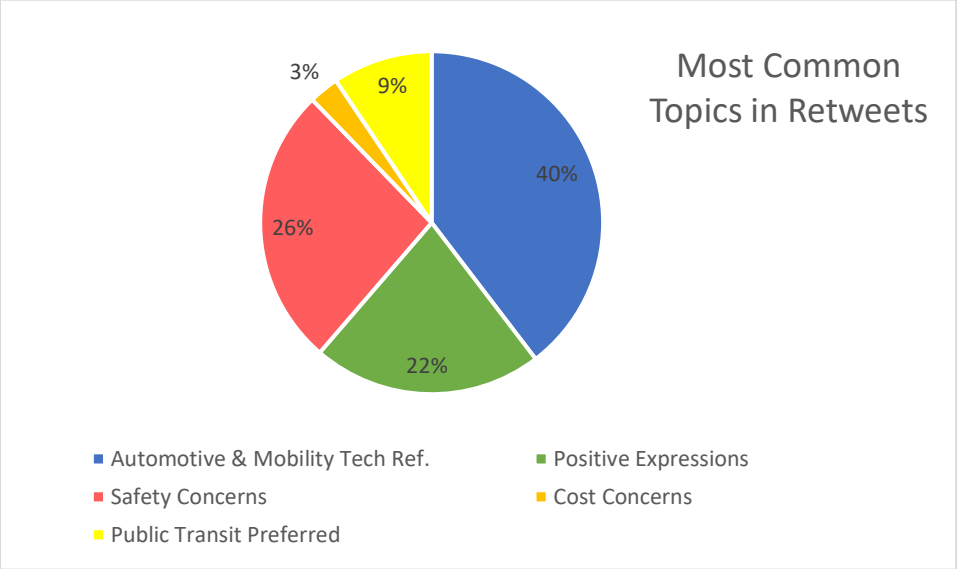

Figure 11. Topic of tweets with five or more retweets. (n=106)

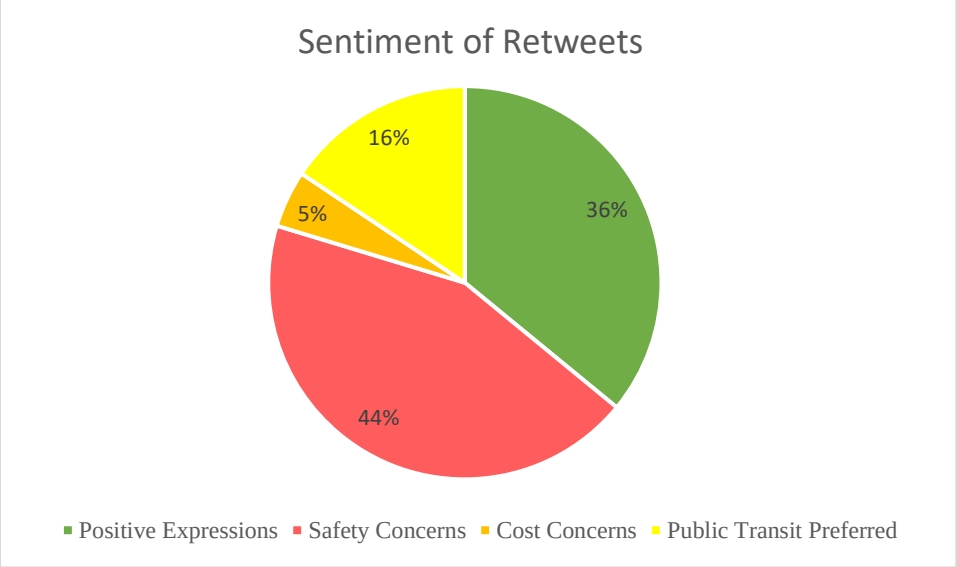

Figure 12. Sentiment of tweets with 5 or more retweets. (n=64)

Chapter 5. Discussion

APT suffers from negative perceptions and safety concerns, regardless of whether or not those concerns are based in reality. Negative opinions are also more likely to be shared online, and more likely to proliferate. Convincing people to ride in APT may be a challenge, but once they do there is a significantly higher likelihood that they will begin to view the technology in a more positive light, which may then compel them to encourage other people to ride. Social media is an excellent tool for both measuring perception, how opinions form and are changed, as well as having the potential to alter narratives and present people with information about the benefits that come along with APT.

5.1. Attitudes on Twitter

The analysis of Twitter data found that Twitter users' sentiment regarding AVs and APT is largely in line with other studies. Positive and negative sentiment were split nearly evenly at 47 percent positive and 53 percent negative. Similar to the results that Schoettle and Sivak found in their survey showing that 49 percent of Americans were concerned about APT in general (2014); and similar to the results that Kassens-Noor, Kotval, and Cai found in their survey with 50 percent of people being wary of the technology (2019). This implies two things, the first being that Twitter data may be genuinely representative of the general public, and that the platform may be a valuable tool to help ease people's concerns regarding AVs, or at the least, better understand them.

Positive expressions and concerns observed on Twitter were also largely proportional to those felt by the general public. Positive expressions are the largest category of tweets when analyzing sentiment alone at 47 percent, though just less than all concern categories combined. Most of the positive expressions mentioned in tweets were simple praise, though many tweeters

did mention how APT may allow for the expansion of transit services, and several others mentioned that there could be positive environmental impacts, were the AVs electric. However, when automotive references are stripped away, concerns about safety overwhelm all other concern categories, making up 34 percent of tweets, as opposed to just 9 percent for cost concerns, and ten percent for public transit preferred; in line with most of the literature which also found that safety is always the prime concern (Chen and Lee, 2019; Haboucha, Ishaq, and Shiftan, 2017; Bansal et al, 2016; Salonen, 2016). Cost concerns were rarer than safety concerns, however these tweeters often emphasized significantly larger impacts that APT could have on society – beyond personal safety. These tweets are often ethically charged, and worry that APT will hurt disadvantaged people. All of this indicates that there is still an abundance of work to be done in order to persuade the public to trust AVs and APT.

One notable aspect observed in the dataset was the near total lack of neutral or neutralized tweets. Users were extremely opinionated, on both sides of the debate, and no user mentioned both the positive and negative aspects of APT in a single tweet; though, this may have to do with the platforms limited character count. Still, the analysis included replies to tweets, which again were never neutral or neutralized. Finally, it was expected because the demographics on Twitter skew younger, that there would be more acceptance of APT on the platform, and because the majority of the literature shows that younger people are far more favorable to the concept, however, this was not the case as sentiment was again largely in line with the general public (Kassens-Noor, Kotval, and Cai, 2019; Haboucha, Ishaq, and Shiftan, 2017; El Zarwi, Vij, and Walker, 2017; Bansal et al, 2016).

This gives cause to believe that although AVs are more accepted by younger generations, APT may not be viewed in the same light, giving credence to the research of Woldeamanuel and

Nguyen, who found that millennials were more concerned with APT than are older generations (2018). There is little research into how millennials view APT or AVs, or as to why they may perceive it differently than expected, considering younger people routinely view AVs more positively than older generations (Kassens-Noor, Kotval, and Cai, 2019; Haboucha, Ishaq, and Shiftan, 2017). Perhaps millennials are more concerned with societal costs of APT, environmental issues, or simply do not trust the technology; more research is needed in this area. Though, because older people are more likely to rely on public transportation, they may be more willing to see it updated or improved (Wong, et al., 2018; Litman, 2017a). Perceived usefulness may have an even more significant impact on perception than expected (Malokin, Circella, and Mokhtarian, 2019.

5.2. The Impact of APT

Public transit will undoubtedly be changed by APT. Some literature suggests that the technology could save agencies a considerable amount of money, and allow them to better serve their riders, while other literature predicts that APT will lead to more pollution, less equity, and less funding for these agencies (Hall, Palsson, and Price, 2018; Litman, 2017b; Ohnemus, and Perl 2016; Krueger, Rashidi, and Rose, 2016). When employing emergent coding, the only category that emerged were tweets noting that they would prefer money be spent on updating existing transit networks or expanding coverage. These users felt that APT was a waste of time and resources, comparing it to glamour projects or publicity stunts. These tweets were moderately common, comprising 10 percent of sentiment tweets, which was one percent greater than cost concerns. These tweets were also exclusively negative, often emotionally charged, and highlighted that the fears surrounding AVs are far more broad than mere safety considerations.

However, the literature shows that after APT is implemented, opinions drastically change. Of the studied autonomous shuttle routes, all found that a majority of riders were happy with the technology (Wicki and Bernauer, 2019; Salonen and Haavisto, 2019; Pakusch and Bossauer, 2017). Moreover, the literature also shows that perceived usefulness and familiarity with the technology breeds trust. Though many people are concerned about how APT will impact transit networks, their opinion are likely to change once they themselves experience APT (Malokin, Circella, and Mokhtarian, 2019; Liljamo, Liimatainen, and Pöllänen, 2018; Wen et al, 2018; Choi, and Yong, 2015). It should be noted that of the tweets whose authors mentioned actively riding on APT, none reported negative sentiments. Though it may be quite some time until the average person sees APT in their region, it does not stop them from posting on social media, nor does it stop media outlets from reporting about the perceived dangers of the technology.

5.3. Negative Incidents

A recurring trend within the data was the tendency for negative events to be reported on, tweeted about, and retweeted about at great length, which is typical of both media, and a human desire to focus on negatives (Garz, 2014; Trussler and Soroka, 2014; Soroka, 2012). Of the eight days with more than ten tweets referencing APT, six were synonymous with negative incidents, comprising 75 percent of all major tweet days. Moreover, those six days were correlated with only two negative incidents. Each incident caused an increase of tweets which lasted approximately three days. One incident in Las Vegas was responsible for 42 percent of all tweets mentioning safety concerns. This also means that Las Vegas was the only city studied that had significantly more negative tweets than positive. Moreover, were this incident to not have occurred, positive sentiment would have been greater than negative. Notably, the incident in

question was the result of a human driver striking an autonomous shuttle, though many of the tweets did not mention this fact.

There were a number of tweets which called out this behavior, or noted that the technology is actually safe, but they were in the minority. Some users even citied the incidents in their tweets as the reason they would never ride on APT or in an AV. This shows that incidents, regardless of fault, significantly damage the reputation of both AVs and APT, and that media will overlook the benefits of the technology if there is potential for a dramatic story. A serious problem considering that one of the most effective ways to change perception of AVs is for people to interact with them. Advocates for the technology would do well to quickly and effectively control the narrative and social media chatter in an effort to highlight the safety benefits of AVs. Efforts like this would be even more effective if they originate from influential accounts/users.

5.4. Influence and Negative Perceptions

Influential users play a significant role in the online discourse surrounding AVs and APT. Influential users were more likely than average to tweet about safety concerns or other negative aspects of APT than they were to tweet about positive expressions. These users were 36 percent more likely to tweet about safety concerns, and 40 percent less likely to tweet about positive expressions. These tweets are seen by and retweeted by other users far more often than the average tweet/tweeter. Given how powerful social media can be in shaping one's perception and opinion, this may be a serious cause for concern for APT advocates (Gupta, Ripberger, and Wehde, 2018). Moreover, influential users are far more likely to have their tweets retweeted, 99 percent of all tweets with five or more retweets came from influential users. This is especially important given that the more often a person sees a tweet, the more likely they are to both change

their opinion about a subject, and the more likely they are to retweet the same message themselves (Gupta, Ripberger, and Wehde, 2018; Stieglitz and Dang-Xuan, 2012). These users have the potential to significantly impact the perception of APT and AVs for the average Twitter user. Were they to tweet about positive expressions (benefits) and the positive aspects of APT, those tweets too would be more likely to influence others, and more likely to spread across social media. APT would benefit, and have an easier time assuaging people's concerns, were influential users more likely to tweet in the technologies favor.

Chapter 6. Conclusion

Not only does Twitter appear to be a powerful, though in some cases admittedly limited, resource for measuring perception regarding AVs and APT, it may actually be a powerful tool in the aim to help proliferate the technology, change sentiment, and alter perceptions. Tweeters readily speak to both the potential benefits and their concerns about APT. They are eager to share their opinions, and their opinions can also be influenced by others. Pushing people to interact with APT will likely lead to more positive perceptions, especially once people begin to recognize the benefits such as increased mobility, ease of access, lower costs, and greater service area. However, as noted not all of these market segments actively engage in social media, and although they can be influenced by family members, additional marketing strategies would be needed to fully keep them abreast of and interest them in the technology. More research must be conducted to better understand exactly how APT will impact society, as many people on Twitter are eager to point out how the technology could negatively impact society and mobility. Negative opinions spread quickly on Twitter, even when those opinions are based on misleading details or headlines.

Safety incidents involving AVs are a serious detriment to the technology as a whole. They receive unfair, or at the least heavily biased, reporting in traditional media, and people are far more likely to talk about them online. These tweets can and do influence people and make them more wary of the technology; they are then more likely to tweet negatively, and in turn influence other people, akin to a feedback loop. Advocates and planners would do well to help keep track of and ensure their voices are heard via the online narrative about APT, or at the least ensure that the technology is spoken about accurately online, and that relevant information about benefits is readily accessible. Though it may be unethical to "control" an online narrative, the

findings in this study do show that certain individuals do indeed hold a significant amount of sway regarding the online discussion of AVs and APT. Moreover, hiring "influencers" is becoming an increasingly common form of marketing, and one that APT advocates could potentially pursue.

The implications of this study range from benign to profound. First, we know that there is a tendency on Twitter to discuss negative narratives. This may be a problem for people and entities who wish to see the technology proliferate, especially those that believe it will improve people's lives. More profoundly, for manufacturers, it means that they may have a significant amount of work to do to ease people fears and confusions regarding their products. They may even want to consider hiring professional social media influencers who are more truthful/accurate in their reporting of events, progress of, or incidents regarding AVs and APT. Finally, planners working in cities where they hope to either pass policies aimed at allowing/incentivizing AVs and APT within their city need to clearly understand that public perceptions of these products may not be entirely in line with reality. Although a planner may fully comprehend that AVs will lead to safer and more efficient roads, the general public may be unconvinced. That means an open dialogue with residents and, potentially, education is needed if cities are to realize the maximum benefits from APT, without delay or hindrance.

This study adds to the literature by being one of the first to analyze perceptions of APT using data from Twitter. Additionally, it notes that in addition to the known categories of concerns and benefits, that there is a significant number of people who would prefer public transit agencies focus on traditional transportation means, or updating their networks, rather than investing in AVs. These people are extremely concerned with the equitability of AVs and APT. Finally, the study points out how negative stories, incidents, events, and opinions are more likely

to spread on social media than are mentions of the potential benefits that APT may bring; while also providing advice as to how advocates for the technology may better control narratives, and encourage people to interact with AVs and APT.

Future research on the subject may include larger datasets that contain additional geographies and languages, to see if there is a geographic difference in perception and sentiment, or even a difference between English and non-English speakers in the United States. Our analysis did find some geographic variation, though not to a significant extent; a dataset including more detailed and abundant geodata may provide for a better spatial analysis. Regression analysis, or other quantitative analysis, could also be conducted in order to determine if there are statistically significant differences between perception among various groups. Though, additional datasets would be needed that actually contain demographic information, which is not always present with social media data. Further, Twitter is just one social media platform in a sea of many, data from other networks including Facebook or Instagram may include additional demographic data which would further the understanding of perception. Finally, as APT, specifically autonomous shuttles, are becoming more commonplace, a study examining the difference in perception and sentiment both before and after riders interact with the shuttles would further the understanding of how familiarity fosters trust.

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