PLANNING FOR AN EQUITABLE FUTURE WITH TRANSPORTATION TECHNOLOGIES

A Dissertation

by

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Submitted to the Graduate and Professional School of
Texas A&M University
in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

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December 2021

Major Subject: Urban and Regional Sciences

ABSTRACT

This dissertation presents cross-sectional research on the state of planning for the equitable deployment of technology in transportation through three studies. A triangulation strategy was utilized to gain a comprehensive understanding of planning for technology, through an equity lens, in the past, present, and future.

The first study, “Equitable Investment? An Analysis of Transportation Technology Projects in the Bay Area”, reviews the transportation improvement programs (TIP) for the San Francisco region. Technology projects were spatially analyzed to understand their impact on low-income communities. 43 out of 54 technology projects were located in low-income areas, which led to an in-depth review of five projects to better understand the true impacts. Overall, the results highlighted how dollars invested does not automatically lead to benefits for a community. Projects must focus on community needs, which requires tools to assess the specific equity impacts of technology projects.

The second study, “Are We Planning for an Equitable Transportation Future? Lessons Learned from Regional Transportation Plans”, is a content analysis of regional transportation plans (RTPs) from 52 MPOs. Results show that the discussion of equity and justice remains limited, with 58 percent of plans including equity, which ultimately leads to a limited discussion of the equity implications of technology in transportation (25 percent). Over half of the plans reviewed discussed emerging technologies to some

extent. These results indicate a gap between equity and technology planning efforts that must be bridged if a more just transportation system is to be realized.

The third study, “Looking Ahead: An Assessment of Planners’ Intentions and Concerns regarding Transportation Technologies & Equity”, surveyed planners at all 402 MPOs in the U.S. The survey asked questions related to technology, equity, and the equity impacts of emerging technologies. Responses show that MPOs continue to focus on established rather than emerging technologies while their equity efforts are evolving to focus on outcomes. In terms of emerging technology deployment, planners are weighing the benefits and challenges but are concerned about their financial ability as well as the political will to ensure equity in deployment and use.

DEDICATION

This dissertation is dedicated to everyone that has been affected by inequitable transportation investment. May this research move us one step closer to a just transportation system.

ACKNOWLEDGEMENTS

First, I would like to thank my committee, Dr. Li, Dr. Goddard, Dr. Bullock, and Dr. Ellis, for the continued support throughout this process. Completing a PhD is not easy and without their sound advice and often encouragement, I would not have been able to complete this research.

Thank you to my coding assistant Samina who helped keep me on track and coding correctly when all the other stresses of life took over. I would also like to acknowledge the many people that assisted by both sharing and completing my survey; this research would not have been possible without their assistance and willingness to contribute to this emerging area in transportation.

To all my friends, both those within my cohort and outside, thank you for your support and understanding throughout the long process that is a doctoral degree. And to my PhD cohort specifically, thank you answering my questions, providing much needed laughter, and keeping me sane during this time!

Finally, to my family, partner, and closest friends – I cannot thank you enough for the constant support, encouragement, and ensuring I take a break and enjoy life from time to time. To my parents and sister, thank you for standing by my decisions to stay in higher education for over a decade! I would not be here without their patience and love.

CONTRIBUTORS AND FUNDING SOURCES

Contributors

This work was supervised by a dissertation committee consisting of Professor Wei Li, Professor Tara Goddard, and Dr. David Ellis of the Department of Landscape Architecture and Urban Planning and Professor Justin Bullock of The Bush School of Government and Public Service.

The analyses depicted in Chapter 3 were partially conducted in conjunction with Samina Limkhedawala of the Department of Landscape Architecture and Urban Planning.

All other work conducted for the dissertation was completed by the student independently.

Funding Sources

Graduate study was supported by a scholarship from Texas A&M University – Department of Landscape Architecture and Urban Planning.

NOMENCLATURE

AV	Autonomous Vehicle
BIPOC	Black, Indigenous, People of Color
CAV	Connected Autonomous Vehicle
CV	Connected Vehicle
DOT	Department of Transportation
EV	Electric Vehicle
FHWA	Federal Highway Administration
FTA	Federal Transit Administration
ITS	Intelligent Transportation Systems
MPO	Metropolitan Planning Organization
RTP	Regional Transportation Plan
TIP	Transportation Improvement Program
USDOT	United States Department of Transportation

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1. INTRODUCTION

Technology is a disruptive force; the impact of technologies on society is highly dependent on how they are wielded by both the public and private sectors. Transportation technologies are especially susceptible to the push and pull between public and private actors. Electrification, automation, and artificial intelligence are being driven by the private sector as they design vehicles, infrastructure, and new methods for collecting and utilizing data. However, transportation exists in a more public domain with our personal mobility interacting with those around us and utilizing public space to access different activities. While technologies hope to solve many of the problems that pervade our transportation system from a lack of mobility to congestion to environmental concerns; ensuring equity and justice is at the forefront of any technological development will require public actors to step in. Although many private mobility companies are beginning to incorporate considerations relating to people with disabilities, low-income communities, and justice issues related to Black Indigenous People of Color (BIPOC)[1] interactions with technology, deployment and implementation will lack equity without involvement from planners and policy makers.

[1] Different terminology is used across this dissertation to refer to these populations. Where necessary a "deficit" approach was avoided (disadvantaged or communities of concern) and the term equity or equity-priority populations and communities was used. However, the term "communities of concern" is used throughout the first study, as well as other chapters, as this is the terminology utilized by the Metropolitan Transportation Commission (MTC).

Planning for emerging transportation technologies through an equity lens is complex, and planners and policymakers must be considering their impacts, what could work best for society as well as specific regions, and any barriers to a more just transportation system that these developments could erect. Understanding the current state of the practice in terms of technology planning and equity planning provides a baseline for understanding where we *should* be in terms of ensuring equitable outcomes from transportation technologies. This dissertation aims to address whether we are planning for an equitable future with transportation technologies, as well as providing practical advice to planners on how to ensure that technologies bring benefits to underserved communities not more costs. The research utilizes a mixed method approach to assess the past, present, and future of planning for emerging technologies and whether that planning has equity at its core. The following section will provide an overview of the literature that formed the foundation for this research; highlighting the great promise as well as the great challenge of technology, the struggle for justice in transportation, and how technologies may impact that struggle.

1.1. Background

Rapid expansions in the field of information communication technology (ICT) and artificial intelligence or autonomous and intelligent systems (A/IS) have necessitated research on strategies for their implementation in the public sector. Technological developments do tend to originate in the private sector, especially emerging transportation technologies, such as connected autonomous vehicles (CAVs). Private

sector investment in transportation beyond the private automobile has expanded pushing them into a domain that was historically controlled by the public sector i.e., government. Eventually this leads to public sector investment as governments and agencies attempt to leverage technological solutions to solve "wicked problems" (Rittel & Webber, 1973). While relatively little investment by the public sector can be directly tied to autonomous vehicles (AVs) or A/IS at the current time, lessons can be learned from investment patterns in electrification and electric vehicles (EVs) as well as intelligent transportation systems (ITS).

1.1.1. The Rise of the Smart City

One key driver of technology investment in cities has been the smart city movement. The definition of the smart city is hotly contested; split between a focus on hard systems and infrastructure, such as the internet of things (IoT) and ICT applications for governance (Batty, 2013; Batty et al., 2012; Fromhold-Eisebith, 2017; Park et al., 2018; Yigitcanlar, 2016) and a definition that focuses on the human element of smart cities (Almeida et al., 2018; Lara et al., 2016; Meijer & Bolívar, 2016). Other efforts have attempted to bridge that gap by suggesting that a city should both promote its human capital and quality of life, but use technology to reach those goals and provide a more efficient urban environment (Angelidou, 2015; Herzberg, 2017; Hollands, 2008; Nam & Pardo, 2011a, 2011b; Stimmel, 2015). Regardless of how a city defines its "smart" goals, this movement has generated a great deal of interest and investment in technologies. Non-profit and private sector initiatives arose that aim to allow cities to try

new technological solutions by providing an influx of capital (Angelidou, 2015; Paroutis et al., 2014). Beyond initiatives, technology companies and developers can partner with cities to test their product, which can then lead to further investment by both the public and private entity (Eidam, 2017). However, a private sector push in terms of investment and testing of new technologies does not always align with public sector goals. It can also defy performance measurement, which hampers a government's ability to justify further investment if they do not have access to data due to private ownership.

The full benefits of the smart city have not been realized as different models for development have met challenges and risks along the way. Smart cities built from the ground up are driven by technology and efficiency to the detriment of liveability, while tweaks to existing cities may not always lead to the intended benefits (Herzberg, 2017; Martínez-Díaz et al., 2018). The goal of a smarter city is noble but ensuring that the driving force behind investments from both the private and public sectors are aligned with broader goals and objectives needs to be the focus rather than profit or efficiency.

1.1.1.1. Investing in the Electric Future

Electric vehicles have a huge potential to reduce the transportation sector's overall emissions and impact to the climate; however, the initial cost of owning an EV can be prohibitive. This led to a number of initiatives both in the private and public sector to incentivize the purchase of low or zero-emission vehicles (Hartman & Dowd, 2017). The purchase of EVs has necessitated investment at the local level in charging infrastructure to support their usage (Belenky & Kornhauser, 2019); as many cities focus on reducing

their impact to the climate, investment in these technologies has grown. The driving force behind investment in EVs has been to meet the needs of the public as well as promote climate and sustainability-based goals. However, the private sector has also played a role; partly profit-driven and partly due to regulation, such as the Renewable Energy Standards (National Conference of State Legislatures, 2019). The introduction of EVs required local governments to establish standards and provide incentives for the charging infrastructure as well the vehicle. In many respects, state level policy and incentives can be seen as a driver in terms of technology investment as they provide direction and funding that the local government can adapt to their own needs.

1.1.1.2. The Future of Transportation Technology Investment?

Investment often starts with a private push due to companies hoping to deploy and profit from new technologies that they have developed; but if these technologies are seen to benefit cities or align with their goals, it can lead to greater public sector investment. The driving force behind technology investment does not always have to be profit-oriented, in terms of EVs, the motivation can be focused on environmental benefits. If investments align with a city's overall goals, then the driving force is the overall improvement of the city. Cities and regions should bear this in mind as new technologies are presented to them as crucial for their cities; AVs and A/IS can benefit an urban environment, but there should not be investment in technology merely for the sake of it (Martínez-Díaz et al., 2018). Even though private sector investment can be a lifeline to local governments, it should not also be the driver of investment by the public sector.

The main drivers of investment in technology may differ depending on the type of technology and the problem it intends to solve. Private companies often provide the initial push by offering to test their technologies within a city or providing funding for technology-based initiatives along with non-profits. However, cities will have a different motive for investing in technologies, often that focus on pre-established goals or objectives. As more and more technologies enter the transportation sphere, it is useful to remember what the driving force behind investment *should* be and craft plans and programs that carry out those intentions.

1.1.2. Incorporating Justice

One of those driving forces behind investment must be the incorporation of justice into the transportation system. However, this requires a re-orientation of our understanding of transportation planning and demand. Currently, transportation planning and policy, which in turn impact investments and investment strategies, rely on demand as the key driver for determining transportation projects or solutions (Martens, 2006). The use of demand seems clear; if that is the transportation mode or improvement that the community wants, then it should be invested in and funded. However, the current methods for determining demand, and therefore determining investment and funding levels, do not take into account the principle of need (Martens, 2006; Pasha, 2018). Transportation demand does not inherently reflect need, and theories of justice can provide an understanding of the different principles that could be applied to move toward a more just transportation sphere that does reflect need. This does not mean that

demand is irrelevant, instead there should be an understanding of both need and demand and how they interact. In order to combine these effectively, there should be an underlying principle that guides planning efforts. Theories of distributive justice are especially important in this regard, and in terms of transportation investment strategies, as they can help ease the transition to innovative solutions and a new transportation landscape without unfairly burdening underserved populations. These theories provide a basis from which to develop investment strategies for the future, while also maintaining the flexibility needed to incorporate new technological developments and transportation solutions.

1.1.2.1. Distributive Justice and Transportation

In terms of transportation planning and policy, there is both a need for justice in the process and the outcome of any plan or policy. Without a just process, there is unlikely to be a just outcome, but a just process does not automatically lead to a just outcome. The way an outcome is measured, and therefore determined to be just, can depend on the specific theory of justice that is being applied. Desert-based theories and libertarianism can emphasize market equity, which is often based on the concept of willingness to pay; resource-based theories, intuitionism, and utilitarianism more often relate to the equity of opportunity; while egalitarianism and the capabilities approach focus on outcome equity (Pereira et al., 2017; Taylor & Tassiello Norton, 2009; Uitermark & Nicholls, 2017). Each theory has guiding principles that can determine distribution patterns and what is

considered fair; however, transportation has generally focused on a willingness to pay or market equity with attempts to move toward equity in opportunity.

Market equity reflects the principle of horizontal equity that considers members of the same group, such as income class, and treats them in comparison to one another. The reflection in practice would be members of the same income class paying the same amount for the same transportation benefits (Litman, 2007; Litman & Burwell, 2006; Taylor & Tassiello Norton, 2009). Desert-based theories reflect capitalism where those who increase wealth in society are entitled to benefit from that increased wealth, whereas libertarianism focuses on individual control (Lamont, 2017; Miller, 1990; Sadurski, 1985). Libertarianism emphasizes absolute equality without interference from the state and views transfers of goods and services within a society as just by definition (Nozick, 1974). The emphasis on fundamental rights and liberties, however, fails to consider that an individuals' choices cannot be separated from their natural and social context. Individuals do not choose to be born into poverty or even in a certain area; this context inherently constrains choice, which in turn constrains demand of transportation goods and services. In addition, markets fail; this cannot be viewed as "fair" in terms of distributive justice or transportation (Pereira et al., 2017). Although market equity attempts to treat individuals equally; this does not inherently lead to fair and just transportation planning or policy (and therefore investment) because it ignores inherent truths about society.

Resource-based theories argue that the difference principles of justice do not take into account the actions of individuals in society; that certain individuals can squander their resources rather than being productive (Dworkin, 1981). The focus is then on equal distribution at the onset to provide equity in opportunity. While intuitionism makes the argument that the important "goods" within a society depend on the context, which requires a context-specific distribution of resources (Barry, 1990). These two theories differ in the way they attribute guiding principles of distribution; there is a generally hands-off approach that characterizes both theoretically. Although intuitionism could lead to a clear distributive pattern if the context required it. Neither of these theoretical foundations provide a generalizable framework for transportation policy and investment, but the flexibility of intuitionism could become more important as vast changes to the transportation landscape are made. Local needs are specific, which could demand specific investment strategies or patterns to ensure a just transportation system. Utilitarianism moves closer to the ideals of outcome equity but is still limited to opportunity equity as it aims to maximize aggregate welfare without distinguishing how well-being is distributed between individuals (Mill, 2010). Improving access to transportation in the aggregate can still leave equity populations behind if it does not consider the differences in need and the different starting points or baselines that are inherent in society. Providing equal respect or weight to everyone's welfare does not consider that certain preferences can violate the rights and liberties of others. Although attempting to provide the maximum increase in welfare to the greatest number appears fair; it can fail to consider individual needs. This is especially important as new

technological advances are made in transportation that change how we move and operate; these new modes will require targeted investment to ensure that the focus is on equity and justice rather than the appearance of it.

Outcome equity emphasizes the importance of reality and how investments can be distributed equally but not have an equal effect. Rawls' egalitarianism reckons with this in considering the distribution of primary goods; those that are essential for our health and wellbeing in society. Rawls emphasizes the need for basic rights and liberties but also introduces the difference principle that provides equal opportunity and suggests that fairest pattern of distribution is one that maximizes the prospects of the most disadvantaged (or least advantaged) groups in society (Rawls, 1971). This is referred to as the maximin criterion, which aims to maximize the level of primary goods for the people that are considered to be in the worst-off position (Pereira et al., 2017). In applying egalitarianism and Rawlsian theory to transportation; transportation must be considered a primary good (Martens, 2012; Martens et al., 2012). Although this criterion provides a step forward in programming transportation investments, it does little to establish standards of accessibility or provide a way to account for the issue of planning for travel need rather than travel demand. Ensuring the worst-off have the greatest improvement may not lead to equitable or just transportation systems overall.

The Capabilities Approach (CA), which is derived from Rawlsian theory, works to establish such standards, and provide a way to increase the power of the maximin criterion while ensuring basic needs are met. The CA believes that human dignity and

respect should be upheld above all and emphasizes equal distribution while ensuring a minimum basic level of human dignity (Beyazit, 2011; Hananel & Berechman, 2016; M. C. Nussbaum, 2001; M. Nussbaum & Sen, 1993; Pereira et al., 2017). Capabilities are sets of freedoms and opportunities, which returns the focus onto individual needs rather than a set of arbitrarily determined primary goods. These are essentially the freedom and opportunity to convert goods, services, and activities; collectively known as functions; into desired outcomes (Hananel & Berechman, 2016; M. Nussbaum & Sen, 1993). The CA focuses on the individual as an end and does not assume that all transportation needs are equal or the same; however, a basic threshold or level of transportation should be provided to all individuals in society (Beyazit, 2011; Golub & Martens, 2014; Hananel & Berechman, 2016; Martens, 2012; Martens & Golub, 2018). Investment strategies that establish thresholds for accessibility and aims to fund projects that improve those without that baseline would follow a CA theory of justice.

1.1.2.2. Accessibility as Justice

Theories of justice establish a framework for intentions and programming of transportation plans, policies, and investments; however, there still needs to be a measure of success in this regard. Ensuring justice in outcome as well as opportunity cannot just be assumed through appropriate apportionment of funding to certain areas or certain modes. Transportation equity generally refers to the fair distribution of benefits and costs from transportation infrastructure and planning activities; while this is a necessary step towards a more just system, it is not the full picture (Karner et al., 2020).

Accessibility is commonly referred to as the appropriate measure for understanding equity in transportation, especially in terms of investment (Golub et al., 2013; Golub & Martens, 2014; Litman, 2007; Martens, 2012; Martens & Golub, 2018; Pereira et al., 2017). Accessibility can be understood as the number of activity sites available to an individual using the transportation network; it considers the modes available and understands that accessibility via public transit is different to accessibility via a personal vehicle. Theories of justice cannot provide direct solutions to transportation problems because they cannot account for every individual's situation and needs; however, ensuring a baseline of access available to those without a personal vehicle should be essential for any transportation system. Determining increases in accessibility from transportation technology investments is complex and often beyond the capacity and scope of most planning agencies; so, while accessibility is the gold standard, other measures may be required to ease the burden on planners.

Accessibility as a measure of justice in a transportation planning and policy understands that the needs of individuals will differ; it also represents a step past just travel demand to provide a more holistic conception of how we should invest in transportation. The CA can provide an appropriate framework for determining a just level of transportation benefits, and this threshold can be measured using accessibility as the determining factor (Martens, 2012). Investment strategies should seek to incorporate transportation solutions that improve accessibility while still ensuring the safe and efficient operation of the entire system. Ultimately transportation justice refers to a system where no person

is disadvantaged by a lack of access to opportunity, due to transportation (Karner et al., 2020). As the transportation landscape changes, balancing those goals will bring new challenges and require different investment strategies.

1.1.2.3. Transportation Investment Strategies in a Changing World

In the recent past, transportation investment strategies have focused on automobility and therefore highways; increases in capacity are continuously funded despite the theory of induced demand proving its futility (J. R. Brown et al., 2009; Cervero, 2003; Taylor, 2000). If investment strategies are to incorporate innovative solutions and changes to the transportation landscape, there is a need for greater flexibility in planning and programming projects across the board. Cooperation at all levels of government will be necessary to ensure that the transportation network operates as effectively, efficiently, and equitably as possible. Technological advances and new mobility modes are already changing the way we move and interact with our environments by providing greater options but also raising issues surrounding privacy, control, and financing. Policymakers and planners should be wary of the unknown costs of technological developments, while also fostering innovative solutions.

Current planning and investment cycles rely on comprehensive and long-range planning efforts that aim to plan for the next 30 years; if innovative solutions are to be incorporated into these investment strategies, there needs to be greater flexibility. Federal funding is apportioned to states and localities based on projects that are

programmed in these long-range plans, but the reality of transportation today is that needs are constantly changing. In the last planning cycle, approximately five years ago, e-scooters were almost nonexistent, and so cities were not wrestling with the challenge of regulating space for this new mode. Even the two year timeline of the transportation improvement programs at the state and regional levels can lock agencies into projects that are no longer useful or feasible because they are directly connected to the long-range plans (Federal Transit Administration, 2016; Sciara & Wachs, 2007). A more flexible way of planning and programming will be necessary as the way we move around in our environment changes.

The innovations and changes to transportation and mobility are largely being introduced at the local level, but state and federal governments still have a role in regulating and investing in these new developments (Rauch & Schleicher, 2015; Schleicher, 2016; Tranter, 2017). This will require greater coordination and cooperation between regional, local, and state planning agencies to incorporate best practices but also maintain a connected transportation network. Investment strategies are connected to available funding and regions and local governments are constrained by their allocation and the projects approved by their Metropolitan Planning Organization (MPO), as this determines eligibility for federal funding (Sciara, 2017). If infrastructure is built that eases the transition to new modes of transportation, there will be a need to coordinate across states and regions.

Establishing a framework for investment and developing investment strategies that are specific to transportation technology can help to provide the accessibility benefits to those who need them most. Most of the investment in new transportation technologies is happening in the private sector with governments scrambling to regulate their testing and usage but not completely exclude them from their cities or regions. Cities are at the forefront of these technological developments, from the testing of AVs to the incorporation of the Internet of Things (IoT) into their intelligent transportation systems, to the introduction of emerging mobility modes (Freemark et al., 2019; Herzberg, 2017). Transportation technology investment strategies should be developed that consider justice and equity considerations and aim to maximize the benefits of new developments to the communities that need them the most, akin to the maximin criterion. All the while ensuring that progress is being made toward a baseline level of transportation for all individuals in society. Certain cities and transportation agencies have developed technology investment priorities or strategic plans that hope to direct investment in technologies toward pre-established goals rather than allowing for their testing regardless of purpose (ICF, 2016; LADOT, 2019; Philadelphia, 2018). This allows cities and planning agencies to incorporate new solutions that match their intended goals rather than merely pursuing all new technological developments.

1.1.3. Justice and Equity in Transportation Technologies

Pursuing targeted technological investments can help cities and regional planning agencies to focus on equity in deployment and use. Emerging transportation

technologies, such as AVs and IoT, have the potential to increase safety, accessibility, and reduce environmental harms. This is especially true for underserved populations in transportation, such as the elderly and disabled. However, these technologies raise concerns over the spatial distribution of transportation benefits, the digital divide, and privacy. Previous technological advances have not necessarily increased mobility for all users because there is a tendency to trust technological solutions rather than critically assess them (Gebresselassie & Sanchez, 2018; Martínez-Díaz et al., 2018). The equity implications of emerging technologies should not be taken lightly; communities have either been left behind or disrupted by changes to the transportation landscape, and the newest round of technological developments is unlikely to be any different (J. R. Brown et al., 2009; Bullard, 2003, 2007). The two potential models of AV ownership currently being considered will also have equity implications; one focuses on shared ownership and transportation-as-a-service, while the other maintains the status quo of private ownership (Meyer et al., 2017; Schleicher, 2016). These models of ownership will affect investment patterns, land use, and travel behaviour with varying impacts to equity priority groups.

1.1.3.1. Increased Accessibility

AVs and increased technology in transportation have the potential to improve overall safety and accessibility for all populations, but especially people with disabilities and elderly individuals (Bansal & Kockelman, 2017; Claypool et al., 2017; Cordts et al., 2021; Freemark et al., 2019; Milakis & van Wee, 2020). Increases in accessibility could

occur across modes, especially in terms of public transit. Currently, paratransit services are difficult to coordinate and often expensive, but automation could reduce these costs and provide better service to users (Cuellar et al., 2018; Gonzales et al., 2019; Kaufman et al., 2016). Additionally, elderly individuals who either do not drive or avoid driving at certain times will be able to move freely around their environment (Faber & van Lierop, 2020; National Center for Mobility Management, 2018). These increases to accessibility provide a step forward for certain equity priority populations but do raise policy and planning concerns. If private vehicles are utilized to improve mobility, this will lead to more vehicles on the road and greater vehicle miles travelled (VMT). These impacts will put further strain on roadways rather than leading to efficiency benefits. Adaptions to current infrastructure will be required to ensure ease of drop off and pick up; curb cuts will become critical infrastructure. In addition, the vehicles will need to designed with a variety of different situations in mind such as visual, auditory, cognitive, and ambulatory disabilities (Cuellar et al., 2018; Hwang et al., 2020; Kuzio, 2021).

1.1.3.2. Transportation Investment

Previous investments in transportation technologies tend to concentrate in either high-income or high automobile traffic areas, which can reduce the benefits that are received by equity priority communities. For example, electric vehicle infrastructure tends to be concentrated in high income areas due to the initial investment cost of an EV tending to shut out the lower income groups (MacArthur et al., 2018). Considering the spatial and outcome equity of technology developments is crucial, but planners must understand that

while spatial location is important to access, the implementation of the technology plays a far greater role in ensuring equity and justice.

1.1.3.3. Digital Divides

Previously, the digital divide concerned access to digital resources such as computers, smart phones, and the internet (Elizabeth, 2005). Although a great deal of work has been done to close that gap through expanding internet access; many areas still suffer from a lack of connection and new issues have arisen over quality of access. New issues include differential allocations of broadband and internet access as well as varying patterns of use (Stimmel, 2015). Emerging technologies currently use internet-based platforms to offer their services, as will AVs in the future; these platforms will require strong broadband connections in order to operate efficiently (Fromhold-Eisebith, 2017). Beyond broadband or smartphone access is the knowledge requirement to access phone applications as well as accessibility concerns for people with disabilities. If the shared model of ownership is chosen, issues of digital literacy and financial stability will raise new challenges. Low-income communities do not always have bank accounts or access to funds that allow them to utilize emerging mobility modes (Golub et al., 2021). There is also a lower acceptance of financial risk within these communities as being victims of frauds can be far more debilitating than for those with greater financial stability.

1.1.3.4. Privacy

Ethical considerations surrounding AVs and autonomous systems more broadly have focused on human well-being and reducing harm due to the inherent financial imperative surrounding the development of these technologies. These considerations will be especially important in the shared model as private companies will likely retain ownership and control of AVs and the requisite data. Autonomous systems can rely on big data and real-time information to operate effectively, which inherently raises issues over security and privacy. Ensuring public understanding of the possible privacy concerns surrounding increased sensors and data collection is one aspect of bridging the new digital divide (Stimmel, 2015). Recent research found that over half of U.S. adults could not answer a majority of questions concerning digital privacy and security correctly (Vogels & Anderson, 2019). If new technologies intend to use large amounts of data and further integrate networks, efforts should be made to address these gaps. Planners and policymakers should develop frameworks that aim to protect the most vulnerable users in terms of privacy and data collection as well as educate them on protecting their financial information.

1.1.3.5. Shared versus Private Ownership Models of AVs

The shared model of AV ownership could operate in a similar manner to transportation network companies (TNCs), such as Uber and Lyft. Whereas the private model would maintain current ownership rates of vehicles but see a slow transition to autonomy. The first scenario should reduce congestion by increasing higher occupancy travel and

allowing for the conversion of current parking spaces. However, the private ownership scenario would exacerbate inequity by reducing opportunity for autonomous travel by lower income groups as well as causing increases to VMT. Increased VMT leads to more demand on roadways as well as urban sprawl due to the lower opportunity cost of travel (Anderson et al., 2014; Fagnant & Kockelman, 2015). The knock-on effect of these changes could see a reduced investment in transit as more users shift to AVs and more investment is required in road infrastructure (Cervero, 2003; Fagnant & Kockelman, 2014; Schleicher, 2016). Although the shared model may provide greater benefits, neither option would reduce VMT under current transportation pricing schemes.

Land use laws and planning regulations support the second scenario through zoning and continued patterns of auto-oriented growth. This will inherently harm equity populations by pricing them out of the AV market and reducing transit connections, concurrently reducing their mobility and accessibility (Manaugh et al., 2015; Meyer et al., 2017). Auto-oriented growth and land use policies have previously led to greater urban sprawl with attempts to promote smart growth finding that regulations hold them back (Levine & Inam, 2004). If this continues, it will further exacerbate inequality and lead to reduced investment in transit as ridership falls. Cities are already struggling to reverse the rising trend toward inequality; adding another disruption will only further harm equity populations by reducing transit availability, and potentially limiting the ability to drive non-automated vehicles due to safety concerns.

So far, the literature has acknowledged the need to plan for emerging technologies, although often focusing on AVs alone, but has not fully explored the potential equity implications (Freemark et al., 2019; Guerra, 2016; McAslan et al., 2021). Current technologies[2] that rely on app-based solutions to provide access have shown both promise and problems relating to the digital divide and accessibility for certain groups (Gebresselassie & Sanchez, 2018). In addition, financial concerns due to being underbanked or unbanked may impact this access. Testing new technologies to determine best practices and uncover potential benefits to equity populations should be part of transportation plans and programs. Understanding equity challenges before many of these technologies alter communities and daily lives is key to reducing harm and ensuring the intended benefits of these innovations.

1.1.4. Planning for Equity with Transportation Technologies

The timeline for the introduction of AVs into the urban environment is still unknown; pilot studies and testing of autonomous systems is occurring across the globe, but recent setbacks have led to a reevaluation of whether the technology is truly ready (Berboucha, 2018; Madrigal, 2018). This does not mean that cities and regions should stop preparing for a more automated and connected future in terms of transportation, but there is a need to be wary of making large scale changes to infrastructure and the urban environment

[2] The term "current technologies" refers to established or "currently available" technologies such as intelligent transportation systems or electric vehicles throughout this dissertation. While some MPOs do view electric vehicles and electrification as emerging; they are widely available and in use across the U.S. today.

based on the introduction of AVs (Guerra & Morris, 2018). Municipalities can plan and prepare for AVs in several ways; by conducting a pilot study of how AVs operate within their environment, conducting surveys and outreach to determine acceptance levels and issues perceived by the public, and ensuring that current investments can be adapted or useful in setting the stage for new forms of mobility.

One of the most comprehensive methods for preparing for AVs is to pilot and test them in a city to understand their interactions with the urban environment; at the end of 2019, 29 cities across the U.S. were piloting AVs (*Bloomberg Aspen Initiative on Cities and Autonomous Vehicles*, 2019). However, not all pilots have a strong connection to the local government; if planners and policymakers hope to be ready for the introduction of AVs, they need to understand the issues these systems have encountered within their city (Pettersson & Karlsson, 2015). The pilot tests should have pre-established goals that allow a city to improve their regulations or policies, as well as determine whether land use changes will be necessary. As many cities are not owners of autonomous technologies, partnerships with the private sector or local universities will need to be made to test and develop their own policy and governance around these systems. Pilot testing allows a city to see in real-time and in a real-world setting how these systems interact with the nuances of their specific urban environment, but planners should also be considering the end user of these systems. Surveys and outreach can help cities understand the preferences of the public toward the usage of AVs, such as which use cases they will feel comfortable with; a low-speed shuttle in a restricted

environment? Or an AV operating within the normal driving domain? Surveys on public opinion of, and public acceptance of, AVs has been conducted to understand the perceptions of different road users, age groups, and gender identification (Bansal et al., 2016; Bansal & Kockelman, 2017; Deb et al., 2017; Hohenberger et al., 2016; Jardim et al., 2013; Kyriakidis et al., 2015; Penmetsa et al., 2019; Schoettle & Sivak, 2014). These surveys offer an initial framework for a city or region to incorporate into their own travel surveys to better understand the needs of their citizens. In addition to surveys, long-range plans should incorporate considerations of emerging technologies, such as AVs, to enable regions to invest in these technologies when and where it is appropriate. Planners and policymakers are likely concerned about "over planning" or investing in infrastructure for new technologies that never materialize in their cities. Current issues surrounding the maturity of the technology have shown that these fears are not unfounded. The best course of action for most cities and regions is to invest in infrastructure changes or new systems that will benefit their transportation network regardless of AVs. One example of this is enacting parking reforms; parking utilizes a large amount of land in major cities across the U.S.; if driving or the ownership or cars declines overall, these spaces will no longer be necessary (Guerra & Morris, 2018; Zhang et al., 2015). Repurposing this land could provide more welcoming spaces or promote more active modes of transportation. As sustainability and climate change issues continue to dominate the governance and policy of cities, planners should consider vehicle electrification and whether their city is prepared for AVs that are not internal combustion engine vehicles (Hardman et al., 2016; Sperling et al., 2018;

Todorovic et al., 2017). In addition to electrification, incorporating intelligent transportation system technology into transportation networks will ensure a smooth transition to connected vehicles, which can improve the efficiency of traffic operations and enable the safety benefits of AVs to be fully realized (Guerrero-Ibanez et al., 2015; Kumar et al., 2018; Milakis et al., 2017; Sperling & Brown, 2018).

There is no one policy prescription that will enable a city to be fully prepared for the introduction of AVs; however, certain planning efforts that aim to create a desirable city regardless of new technologies, and that focus on the needs of the public, is a step toward a smooth transition. Cities have different populations with unique needs; cities where biking is a popular form of transportation will need to create connections between AVs and those vulnerable road users (Deb et al., 2017; Penmetsa et al., 2019). Large elderly or disabled populations will require research into their interactions with AVs and the potential modifications that need to be made to ensure ease of use. Overall, cities should focus on planning efforts that meet the needs of their current population and transportation network as well as enabling adaptations to accommodate AVs. Critically, they must be planning for the introduction of these technologies if they hope to reap the equity benefits.

1.1.4.1. Disruption as a Force for Change

Disruptions in transportation can be temporary or a permanent change to the status quo; temporary disruptions involve specific events that cause individuals to change their

travel behavior, such as a sporting event or extreme weather event. Temporary disruptions force individuals to change their behavior for a limited amount of time, but it can lead to more long-term alterations in overall travel patterns or mode choice (Laird et al., 2015; Marsden et al., 2016). Disruptions that cause permanent changes to the transportation landscape are less frequent; the introduction of the automobile provided one of the greatest disruptions to transportation by revolutionizing mobility and ultimately giving rise to auto-oriented development (J. R. Brown et al., 2009; Lutz, 2014; Urry, 2004). The next great disruption to cities and their transportation networks will be AVs and the A/IS that enable them.

Major disruptions offer a chance to alter policy directions and change the transportation system in favor of the public good. The automobile was a huge catalyst for change, but planners and policymakers struggled to understand the far-reaching impacts that this new form of mobility had on society (J. R. Brown et al., 2009). The same could be true of AVs; there is a huge potential to alter current travel patterns and behavior toward a more sustainable transportation network. However, the mistakes of the past cannot be repeated, and planners need to prepare for and understand the potential changes and challenges of this disruption (Freemark et al., 2019; Guerra, 2016). Technology does not necessarily bring the promised benefits and often it brings a host of new issues to the forefront (Martínez-Díaz et al., 2018); learning from previous disruptions should enable cities to create more adaptable policy frameworks that work with disruptions rather than suffer through them (Kent et al., 2017).

Using transportation disruptions as a catalyst for change could occur at a variety of levels of government; however, these disruptions will have largely localized effects that should benefit from regional planning efforts. MPOs in the U.S. are a pass-through funding organization from the federal government to local agencies, but their role also includes creating a continuing, cooperative, and comprehensive planning framework (Sciara, 2017). Although this framework provides opportunities for regional coordination, it can also run into issues of political capture and policy making that follows regime compliance rather than testing new policy solutions (Gerber & Gibson, 2009; Handy, 2008; Nelson et al., 2004). There is also an inherent bias toward the status quo as this ensures a smoother planning process and that all local agencies receive their "piece of the pie" (Innes & Gruber, 2005; Marsden & Docherty, 2013). Changes to the transportation landscape, especially rapidly occurring and evolving changes such as technology, offer a chance to switch to regime testing and provide a more flexible means of developing transportation policy (Lyons & Davidson, 2016).

Recent examples of transportation disruptions that are related to new technologies can provide an opportunity to understand the risks and prepare new roadmaps for policy, planning, and regulation in an era of AVs and A/IS. The introduction of dockless bikeshare, e-scooters, and ride hailing have caused major disruptions as cities and regions have struggled to regulate new modes. AVs will present a much greater disruption and present a far greater risk to safety if the same problems occur; these new modes do not fit into current forms of transportation governance, and neither will AVs

(Dowling, 2018). Although policy and regulation are created at the federal, state, and local levels; regional investment will be key in providing the necessary funding for infrastructure upgrades to ensure safety and security of new systems. Further, coordination at the regional level could provide an opportunity to regime-test policies in certain localities and then apply then across the board to the region. This local level testing could advance overall regional goals by providing frameworks for implementation and regulation. AV pilots are ongoing in cities across the globe and harnessing the results of those tests will improve not just local mobility by regional mobility as well. AVs are being tested and deployed by the private sector, in a similar manner to other new modes of mobility; cities do not want to be caught off guard and not have the legal and regulatory policies in place when A/IS are implemented (Dowling, 2018; Dudley et al., 2017).

Although disruptions can offer a chance to alter policy and switch to a policy testing rather than policy compliance environment; governments at all levels should still focus on meeting the transportation needs of the people. In terms of AVs, public trust and acceptance is key to integrating them into the transportation system; research has found that overall attitudes are positive but fears over safety and privacy remain (Adnan et al., 2018; Bansal et al., 2016; Deb et al., 2017; Haboucha et al., 2017; Hulse et al., 2018; Jardim et al., 2013; Kyriakidis et al., 2015). E-scooters offer an example of a new mode that does not fit well into established governance frameworks and have a variety of safety and regulatory issues; leveraging lessons learned from the introduction of these

modes and including public input should be the guide for policymakers. Technologies are inevitably going to have unintended consequences, and it is often difficult to determine the adoption rate pre-introduction; however, recent disruptions have shown the need to institute policy and regulations swiftly (Anderson-Hall et al., 2019; Dudley et al., 2017; Sikka et al., 2019).

Although previous disruptions can provide a framework for addressing and developing policy for new disruptions; there are still several limitations in terms of preparing for a new mode of transport. Current disruptions have seen policies implemented at the local level in a piecemeal manner due to the inherent time constraints; e-scooters are dropped into cities one day without a great deal of warning. The lack of time displays the need for adaptability and a shift in policymaking to a more continuous and flexible framework while still maintaining consistency across a transportation network (Lyons & Davidson, 2016). However, when most planning cycles are rigid and require decisions to be made five years in advance when transportation is at a point where it is changing constantly; it is difficult to build in such flexibility (Banister, 2004; Cullingworth, 1997; Marsden & Reardon, 2017; Sciara, 2017; Sciara & Wachs, 2007). There is also a disconnect between policy and funding within the U.S. as MPOs provide federal funding access but do not control local policies. Despite this, regional planning does allow for coordination with local governments as well as providing an overarching framework for the region; this can reduce the stress and burden on localities. Including the stress of changes to revenue due to a disruption, such as reduced parking needs due to AVs. Parking fees and fines

can be a key source of revenue for certain cities. Since MPOs and regional planning authorities are often not revenue generating entities, they can continue to craft policy and conduct studies and research to support struggling local governments.

Disruptions do not just impact a single city; a disruption can begin in a city, but there is a likelihood that the entire region will be impacted by changes to transportation modes and behavior. Also, transportation networks do not end at the city limits, which was one of the driving forces behind the creation of regional agencies (Federal Transit Administration, 2016; Gerber & Gibson, 2009; Handy, 2008; Innes & Gruber, 2005; Sciara, 2017; U.S. Department of Transportation: Federal Transit Administration, 2016). State level policies can provide guidance but often do not understand the nuance of the local context; state transportation agencies are often tasked with larger scale projects as well to ensure benefits are distributed across the state. Not all localities will immediately need a state level policy for a transportation disruption, but they may need to cooperate with their peer cities to find the right solution. MPOs conduct long range planning efforts, in part, to address the bigger questions and provide a direction in terms of the overall transportation landscape. This makes the MPO perfectly placed to learn from past disruptions, combine best practices from localities, and implement a plan that works for their network. Although not all planning efforts can be regional in nature, dealing with large-scale disruptions to the transportation network will take a more coordinated approach and require multiple levels of government to agree on the best course of action.

1.2. Study Overview

Addressing the question, are we planning for an equitable future with transportation technologies, requires, at minimum, an understanding of the equity impacts of recent transportation technology investments, how planners and planning agencies are incorporating transportation technologies and equity into their plan documents, as well as how they view the role of transportation technologies as both a tool and challenge for equity moving forward. This research includes an attempt to address each of those elements through three studies that both increase in scale and change in timeframe. The first study, EQUITABLE TECHNOLOGY? AN ANALYSIS OF TRANSPORTATION TECHNOLOGY PROJECTS IN THE SAN FRANCISCO BAY AREA, is a case study analysis of transportation technology projects from 2014-2021. The case study aims to address spatial equity of transportation technology investments before diving deeper into project level impacts that highlight the nuances of equity within individual projects and how large dollar investments can often disrupt communities without providing benefits. The second study, Are We Planning for An Equitable Transportation Future? Lessons Learned from Regional Transportation Plans, assesses the RTPs of 52 MPOs across the U.S. This study focuses on how we are currently planning for emerging technologies and asks whether an equity lens is being applied to these new developments. The results present a broader snapshot of the missing pieces in ensuring equitable transportation technologies as well as focusing on current planning efforts. Finally, the third study, LOOKING AHEAD: AN ASSESSMENT OF PLANNERS' INTENTIONS AND CONCERNS REGARDING TRANSPORTATION TECHNOLOGIES & EQUITY,

looks to the future and how planners have developed their understanding of technologies since the last plan update. This research attempts to address what is left unsaid in planning documentation, the writing that does not go on the wall, to maintain flexibility and ensure fiscal responsibility. The results highlight how rapidly the transportation sphere is changing and the efforts being made by planners to maintain focus and select sound investments. Technology has the potential to alleviate some of transportation's "wicked problems", but they are not without challenges especially to equity and justice. These three studies provide an overview of how planning is reacting to the challenge of equitable technology as well as showing where more research and funding is needed, but ultimately shows that while planning for equitable transportation through technologies is underway, there is still a long way to go.

2. EQUITABLE TECHNOLOGY? AN ANALYSIS OF TRANSPORTATION TECHNOLOGY PROJECTS IN THE SAN FRANCISCO BAY AREA

Transportation and technology are inherently linked; advances in technology have led to our modern mobility system that is highly auto centric. However, even before the introduction of the automobile and the internal combustion engine, technological advancements provided modes of transportation ranging from bicycles to trolleys. Although technologies have always played a part in the development of transportation systems, today's transportation system is increasingly being shaped by technologies that move past pure modes of transportation to incorporate artificial intelligence, machine learning, and other emerging developments that ultimately impact the way we move and interact with our environment. These technologies interact with emerging developments such as autonomous vehicles (AVs), connected vehicles (CVs) and even micromobility solutions such as e-scooters. Currently available technologies form the infrastructure and networks required to both integrate these new developments and ensure the full benefits of them; these current technologies include the electrification of vehicles and infrastructure as well as intelligent transportation systems (ITS). While technologies may not appear to be inequitable on their face; the development of these technologies, systems, and how they are implemented are subject to the biases of planning and policy making. No technology can be considered value neutral if it is designed by humans, as no human can be truly value neutral. Ensuring that transportation technologies lead to a more equitable and just transportation system relies on several factors ranging from

community engagement to ensuring that technology projects are focused in areas with the most need.

Early adopters of technologies, such as electric vehicles, AVs, and CVs, are often considered to be younger, male, and more affluent (Bansal et al., 2016; Bansal & Kockelman, 2017; Hulse et al., 2018; Kyriakidis et al., 2015; Schoettle & Sivak, 2014). Due to this, the need for transportation technology projects might be thought of as the areas where these populations reside; however, this leads to greater inequity as low income and elderly communities are not provided with access to these new developments. In addition, heavily congested areas may receive greater investment without a consideration for those truly benefitting from that investment. An assessment of the types of technology projects that are being invested in as well as where these investments occur is the first step in determining whether these are equitable investments.

This paper presents an overview of three core areas of transportation technology; electrification, ITS, and emerging technologies before presenting the purported benefits of these technologies and the challenges they present for transportation-equity communities. The authors attempted to address the following questions: do investments in transportation related technologies benefit communities of concern? Have investments become more or less equitable over time? The authors hypothesized that technology investments would be clustered in mid-to-high income neighborhoods and that they

would become more equitable over time. In order to address the potential equity impacts of past and current transportation technology projects, a case study of the Metropolitan Transportation Commission's (MTC) technology projects in the Bay Area is presented. After technology projects were identified, they were then categorized and mapped to determine their potential spatial equity. The data of projected investment was collected in an attempt to determine patterns over time. Finally, an example project was chosen from each category to assess whether the location and level of investment is enough to determine the equity impacts of transportation technology projects.

2.1. Background

Transportation technologies can refer to a variety of disruptions, innovations, and inventions that have fundamentally altered the way we move and the impact that that movement has on society. One of the most important technological advances, in terms of transportation, was the invention of the automobile. The creation of personal transportation that eventually became accessible to *most* has driven planning, policy, and design for the past century. Since then, the influence of technology on transportation has only grown, with new developments promising to fix seemingly unfixable issues such as environmental harms, congestion, and safety. This paper focuses on three different types of technology that are currently impacting transportation and will likely play a large role in the future of transportation; electrification, ITS, and emerging technologies such as autonomous and connected vehicles. Each group of technologies has multiple components; some of which can benefit transportation-equity communities and increase

accessibility, but others have the potential to further police, disrupt and harm those very same communities.

2.1.1. Electrification

As the move toward sustainability and sustainable transportation grows, so does the market for electric vehicles and electrifying the transportation system to a greater extent (Mosquet et al., 2020; U.S. Energy Information Administration, 2020). The contribution of transportation in terms of global emissions is huge; many cities and states are taking the lead in promoting "greener" transportation through alternative modes, incentivizing transit, and ultimately pursuing the electrification of vehicles across the spectrum (Block et al., 2017). Merely incentivizing electric vehicle purchases and transitioning public fleets is not enough, however; investment in electric vehicle infrastructure such as electric vehicle supply equipment (EVSE) is required (Lee & Clark, 2018). EVSE encompasses charging stations and docks that enable electric vehicles to keep running; cities and regions need a strong EVSE infrastructure throughout their city as well as improvements to the electric grid to support the growth in electric vehicles. This paper uses electrification to cover the variety of investments being made in EVs, EVSE, and electrification across modes, such as ports and transit.

2.1.2. Intelligent Transportation Systems

Intelligent transportation systems today are comprised of several different technologies, hard and soft infrastructure, and management tools that seek to enable the safe and

efficient movement of traffic around a transportation network. These include tracking technologies such as closed circuit television (CCTV), communication tools, for example; dynamic message boards on highways, and traffic control centers that work to aggregate and disseminate data that is flowing into the center from various sensors across the network (Auer et al., 2016; Ran et al., 2012; Sumalee & Ho, 2018). ITS has grown over time from simple navigation infrastructure to include the collection of vast amounts of data to enable efficient management of the transportation system by tracking and monitoring of weather conditions, potential crash locations, and many other factors that can impact the smooth flow of traffic. ITS can be considered the backbone of smart transportation and will be a significant enabling infrastructure for connected and autonomous vehicles.

2.1.3. Emerging Technologies

Emerging technologies mainly refer to autonomous and connected vehicles, but also include new forms of micromobility that use electric motors, such as e-scooters and e-bikes. These technologies are likely to be, and have been in the case of micromobility, disruptive to the transportation system. Micromobility modes offer a new way of completing short trips that does not require a significant investment on the part of the user; however, they tend to be disruptive as current laws and regulations were not designed for motorized vehicles to be on the sidewalk or sharing bike lanes/road space (Anderson-Hall et al., 2019; Clewlow, 2019). Autonomous vehicles are disruptive in the sense that they break the status quo in transportation; those who cannot drive or do not

drive will have the option to ride in a driverless vehicle instead. This has the potential to change work schedules as commute times can be used for other tasks in certain professions and those who avoid driving at night or during peak hours may now decide to ride in a AV. Although AVs are mostly being developed by the private sector; the public sector can prepare for their arrival through research, pilots, and testing. Currently 32 U.S. cities are piloting AVs within their boundaries; these pilots are a mix of private sector partnerships, university or research institute collaborations, and publicly funded projects (*Bloomberg Aspen Initiative on Cities and Autonomous Vehicles*, 2019). Each city has unique goals or objectives they are considering with their pilots; piloting or testing for transit and paratransit applications could have a positive impact on the overall equity of the transportation system.

These technologies are all inherently linked in a smart city system; AVs and CVs rely on intelligent transportation systems for their "Internet of Things" collection of sensors and actuators to operate safely and efficiently. The autonomous and connected future is also increasingly believed to be electric to maximize environmental benefits from these new developments. Most cities and states have been developing their ITS over the past few years or even decades to increase efficiency and reduce the likelihood of crashes (Auer et al., 2016; Greer et al., 2018; Sumalee & Ho, 2018). However, this has also helped to prepare for the electrification of vehicles and especially the introduction of connected and autonomous vehicles. These new vehicles essentially act as new sensors for the network as well as acting as data points in terms of tracking congestion and crash

locations. Many believe the main benefits of the smart city will first take place in terms of transportation by completing the system and providing real-time accurate data for cities and regions to use to ensure an effective movement of vehicles across the network (Batty, 2013; Batty et al., 2012; Fromhold-Eisebith, 2017; Sumalee & Ho, 2018; Yigitcanlar, 2016).

2.1.4. Challenges and Benefits of Transportation Technologies

The purported benefits of transportation technology are numerous; advancements in electrification improve environmental conditions by reducing emissions and provide better air quality, which leads to better health outcomes (Catenacci et al., 2015; Hawkins et al., 2012; Sperling & Brown, 2018). ITS, while struggling to "solve" congestion, has improved safety through effective communication with drivers, improved traffic management, faster incident response, and better overall system management through increased data and signal control (Auer et al., 2016; Greer et al., 2018; Guerrero-Ibanez et al., 2015). Emerging technologies, such as AVs, CVs, and micromobility, claim to provide all the benefits of electrification, ITS, and provide greater accessibility to those who are mobility limited due to not having access to a vehicle or a driver's license (Allu et al., 2018; Cohn et al., 2019; Fagnant & Kockelman, 2015). Autonomous technology does not rely on an electric vehicle, but many prototypes are electric in order to provide environmental as well as safety and efficiency benefits (Anderson et al., 2014; A. Brown et al., 2014; Fagnant & Kockelman, 2015, 2014). AVs can precisely control speed and allow for smaller travel distances between vehicles, which should improve overall

mobility. Despite the purported benefits of these emerging technologies, they are not without costs or challenges.

A core problem with new technologies is the unforeseen impact or unintended consequences. This creates the potential for technologies to further alter, enhance, or deepen inequities in our transportation system is vast. Introducing ITS to a network with the hope of increasing efficiency does not consider the additional surveillance that will occur along that corridor or at that intersection. The introduction of technologies that "learn" such as artificial intelligence (AI) and machine learning (ML), both of which can and likely will be leveraged through AVs, have proved that technologies hold the biases of the creator (Benjamin, 2019; Raji et al., 2020). Algorithms that are intended to create fair systems for distributing limited resources, such as housing for the homeless, or determine risk, such as with Child Protective Service cases, as well as those aimed at increasing efficiency, have proven to be inequitable and most likely to hurt the poorest in society (Benjamin, 2019; Eubanks, 2018). In addition, surveillance technologies such as facial recognition are often ineffective when presented with anything other than white, often male, skin (Benjamin, 2019; Buolamwini & Gebru, 2018). All these advanced technologies have a role to play in the future of ITS, autonomous and connected vehicles, and even micromobility. Companies see the efficiency and risk reduction benefits but can ignore the potential for further policing and punishment of BIPOC and low-income individuals. Surveillance technologies are already a component of ITS, providing additional data and allowing the transportation network to be monitored from

a control center, and will be included in AVs and CVs to capitalize on their data collection potential to provide individualized “service”. As these technologies enter the transportation system through AVs and CCTV, public officials must be aware of the potential for these new developments to deepen inequities by disproportionately tracking and punishing certain groups within society (Benjamin, 2019; Eubanks, 2018). In addition, ITS has failed to “solve” congestion, as was originally intended, by reducing inefficiencies, which raises questions of whether the costs are truly worth the benefits in certain cases (Guerrero-Ibanez et al., 2015). In order to make that determination, a full accounting of the potential benefits, costs, and challenges should be made to understand the impact of a technology and whether the improvement will ultimately move the transportation system towards equity.

Challenges are often exacerbated by the pace and evolution of technology in transportation, which leaves planners and policymakers playing catch-up. The majority of technological innovation and development is driven by the private sector, due to their access to greater capital, with public entities and government having to pursue pilots or conduct their own research in order to plan and prepare for their introduction (Angelidou, 2015; Paroutis et al., 2014). Public entities then rush to ensure their community, city, or region can benefit from these technologies often without fully understanding their limitations, challenges, and the potential negative impacts of a fast implementation.

Withstanding the potential negative impacts of these technologies on the most disadvantaged in the current transportation system, research shows that investments and developments must occur within poor and minority neighborhoods in order for them to reap the benefits at all (Klein, 2007; Mooney et al., 2019; Tamakloe, 1980; P. Zhao & Li, 2016). A spatial connection to technology benefits allows equity priority communities to reap the environmental, safety, and efficiency gains of incorporating ITS or switching to electric buses within the transit fleet. Without this connection, the ability of these communities to benefit is limited. Planners and policymakers must ensure an equitable distribution of investment, especially in transportation technologies, but an equitable distribution goes beyond further investment in equity areas; instead, it requires a total accounting of the planning and policy actions necessary to ensure it is possible for these communities to benefit at all.

Although transportation technologies are often promoted as improving our daily lives through reduced congestion, lower emissions, and a safer system; these benefits do not always reach the most disadvantaged populations. Historic disparities in the distribution of transportation benefits *and* harms only increase as planners struggle to "re-level" the playing field; in terms of technology developments this is especially difficult due to early adopters of technologies often being more affluent, educated, and younger. Consequently, technology investment can be concentrated in areas where these populations reside. This limits physical access, but issues surrounding financial access, privacy, and security can also limit the equitable distribution of transportation

technology benefits. Without access to these technologies, or the supporting infrastructure and resources, transportation-equity populations, especially low-income individuals, are far less likely to benefit from technological innovation. This research established the spatial connection between transportation technology projects and low-income communities, while understanding that a greater review of the project details will be needed before a true determination of equitable technology investment could be made.

2.2. Methodology

This research used a case study style design to assess the distribution and impact of technology projects across the San Francisco region, specifically those completed by the Metropolitan Transportation Commission (MTC). This section will detail the research questions and hypotheses, the decision to examine MTC projects, parameters set to bound the analysis, as well as how projects were selected for analysis. Then, the coding and categorization process will be detailed as well as the spatial analysis completed in ArcGIS.

This research aimed to answer the following questions:

1. Do investments in transportation related technologies benefit communities of concern?
2. Have investments become more or less equitable over time?

The authors hypothesized that,

H_1: Investments in transportation technologies are clustered in mid-to-high income neighborhoods.

H_2: Investments have become more equitable over time.

Early adopters of technology, and transportation technologies, tend to be young, male, and affluent, which could lead to transportation technology projects prioritizing those early adopters in terms of investments (Bansal & Kockelman, 2017; Haboucha et al., 2017; Hardman et al., 2016, 2018). If a certain neighborhood has a higher percentage of EVs, principles of planning would suggest that investment in EVSE should occur in those areas. While planners try to meet the needs of the community, there is also an increasing concern over equity and equitable investment and development. Therefore, as more transportation technology projects are programmed and as equity becomes a more prominent goal, transportation technology projects should become more equitable both spatially and in terms of investment.

2.2.1.1. Initial Design

In determining a case study for assessing the impact of transportation technology projects across a region, factors such as availability of data and planning capacity had to be considered. MTC was chosen as case example region for a number of reasons, including size, proximity to Silicon Valley which is known as a tech hub, and previous research that has used MTC as a best practice for regional transportation planning

(Golub et al., 2013; Golub & Martens, 2014; Innes & Gruber, 2005; Karner & Marcantonio, 2018). MTC also provides GIS data online as well as hosting previous year planning documents on their website; both of which facilitated this analysis. Once MTC was chosen as the initial study region, additional parameters were set to guide the analysis scope.

2.2.1.2. Analysis Parameters

A timeframe of five years was initially chosen for the review of projects; MTC completes their Transportation Improvement Program (TIPs), their detailed short-range planning document, every two years. This led to the analysis covering a roughly six-year timeframe as the TIPs from 2015, 2017, and 2019 were chosen for analysis. Projects will span a greater timeframe than the TIPs as they can span across multiple investment periods and projects that were completed since the last TIP was published will be included in the next TIP to show the close out of funds. Exact project start and end dates were not collected for the full dataset. Projects duplicated in two or more TIPs were removed prior to the analysis; information from the most recent TIP was used for these projects as this was considered a more accurate reflection of total investment. The next step involved searching these planning documents for projects that were technology-driven or included a technology component. A keyword search was completed on each document for the three categories of technology projects: electrification, ITS, and emerging technologies. Table 1 displays the keywords utilized.

Table 1. Keywords List

Electrification	ITS	Emerging Technologies
electric	intelligent	Technolog(y/ies)
hybrid	ITS	Autonomous
“e-“	Adaptive traffic control	Connected
EV	Dynamic message	AV
		CV

For MTC, the TIP project list document was searched; this document provides an overview of all the projects in the TIP as well as providing details on implementing agency, location, and funding amount. The keyword searches were used to narrow down potential projects with a technology component. For example, “electric” would provide projects on electric bus purchases by transit agencies or the conversion of certain cable car lines to electric cars. Data for these projects, such as year of funding allocation, receiving agency for funds, implementing agency, and dollars allocated, were collected alongside project descriptions. The project descriptions formed the basis of the qualitative coding process that intended to assess the type and impact of the project.

2.2.1.3. Project Categorization

Once the project data had been collected, the next step was to categorize the projects by type or impact. The following categories emerged from the project descriptions:

- Bicycle/Pedestrian

- Mobility
- Electrification
- Pilot
- Support.

Bicycle and pedestrian projects typically have an ITS element that is aimed at improving bicycle or pedestrian detection, as well as introducing safety improvements and a new data collection methodology.

Mobility refers to projects aimed at improving efficiency in the transportation network using ITS and other emerging technologies. These projects generally involve ITS improvements, such as installing advanced transportation management systems or introducing dynamic ridesharing technology to reduce congestion and improve safety on major roadways.

Electrification projects involve the switch to electric power from more traditional sources, such as gasoline or diesel. These projects support the purchase of electric vehicles for transit and government usage, as well as education and outreach to support the public in purchasing and using these vehicles. Alongside vehicle purchases, these projects also install EVSE, such as charging stations.

Pilot projects relate to the testing and development of emerging technologies to meet a number of transportation needs within the region. Emerging technologies include

autonomous and connected vehicles, but also includes pilots of microtransit programs that utilize new technologies to operate.

Support refers to projects that form the backbone of the technological infrastructure for transportation. These projects range from regionwide improvements in vehicle location technologies, improved data storage and management facilities, as well as updating communication systems for both transit and highway users.

2.2.1.4. Spatial Analysis

After categorizing the projects, spatial boundaries were determined depending on the type of project. These boundaries were derived from both practice and the literature; in terms of bike and pedestrian projects, a spatial buffer of a ¼ mile was chosen (Yang & Diez-Roux, 2012). The quarter-mile boundary assumes a standard walking distance is a ¼ mile. While this metric has its limitations, in this analysis it focuses the benefit or cost of these investments to the surrounding community. For transit projects that were focused on a corridor or specific location, a ½ mile boundary was utilized. For transit to be accessible, the accepted standard is that users should live within a ¼ to ½ mile of a transit stop (*Pedestrians and Transit - Safety | Federal Highway Administration*, n.d.). Many of the transit investments in this analysis were purchasing electric buses, which has a clear health impact of those living in proximity to the bus routes. Highway projects were allocated a one mile boundary if the intended benefit or impact was economic or mobility related, but if the project intended to improve environmental outcomes, a boundary of an 1/8 of a mile was chosen (Li & Saphores, 2012). For port projects, the

environmental impact zone from the Port of Oakland's study was used as both projects had an environmental focus. This zone is typically 2 miles for the Port of Oakland, but the boundary is set by the study designers (Port of Oakland, 2019). If a project was listed as regionwide or covered an entire city or county, the spatial buffers were not applied. Instead, the city, county, or region in question was used for analysis.

Table 2. Spatial Analysis Boundaries

Project Type	Spatial Buffer	Justification
Bicycle and Pedestrian	¼ mile	Yang & Diez-Roux (2012)
Transit	½ mile	FHWA
Highway	1 mile	TTI
Port	2 miles	Port of Oakland environmental impact zone

The mapping effort relied mostly on publicly available data through MTC and the various implementing agencies, which includes local governments, transit agencies, and Departments of Transportation. These datasets were used to map the corridor, roadway, transit line, and site-specific projects; regional projects relied on county and regional boundaries provided through open data entities of both local governments and the state.

Once the technology projects were mapped, American Community Survey (ACS) data from 2018 was added to represent income by block group. Calculations were completed in GIS to determine the percentage of the residents in that block group that fell into MTC's definition of low income. MTC uses 200 percent of the federal poverty level as their low-income threshold and if more than 28 percent of the block group is low income, they fall into MTC's Community of Concern definition (MTC, 2020). In 2018, the federal poverty level for a family of four was $25,100. Therefore, 200 percent of the federal poverty level was $50,200. Using the ACS data, the total households earning less than $50,200 per year were calculated for each block group. The total households earning under $50,200 was then divided by the total number of households in that block group; this created a percentage of households that would be considered low income by MTC. This was included as a map layer to display income level in relation to the transportation technology projects.

Finally, the determined spatial boundaries were mapped as buffers around the projects. The final map included the percentage of low-income households, as determined using the ACS data, the technology projects in the region, and the buffer zones. This allowed for an analysis of the technology projects in relation to the income level of the surrounding community. The percentage of low-income households falling within the spatial buffer zones was calculated using GIS to complete the equity impact analysis. The equity impact of these projects is dependent on scope, category of projects, and

investment; all of which were used in providing an overall assessment of the equity of transportation technology projects conducted by MTC.

2.3. Equity Impact

The initial hypothesis stated the technology investments would be clustered in mid-to-high income areas as early adopters of transportation technologies tend to be relatively affluent along with being younger and often male (Bansal & Kockelman, 2017; Haboucha et al., 2017; Hardman et al., 2016, 2018). An additional hypothesis stated that technology projects would have become more equitable over time. While it was not possible to test these hypotheses with any statistical significance, the levels and type of investment can provide insight into the equity of these technology investments.

In terms of level of investment, the largest project is the BART Oakland Airport Connector, which used automated guideway technology to provide a new connection between the airport and the BART system as the Coliseum station. In addition to the size of the investment, the area surrounding the airport is almost 100 percent low income. This project fell into the Mobility category. Mobility projects had the largest average investment partially due to the impact of this one project. Figure 1 shows the BART extension to Oakland with a half mile buffer. Areas without a shade of blue represent airport property and therefore have no household income data.

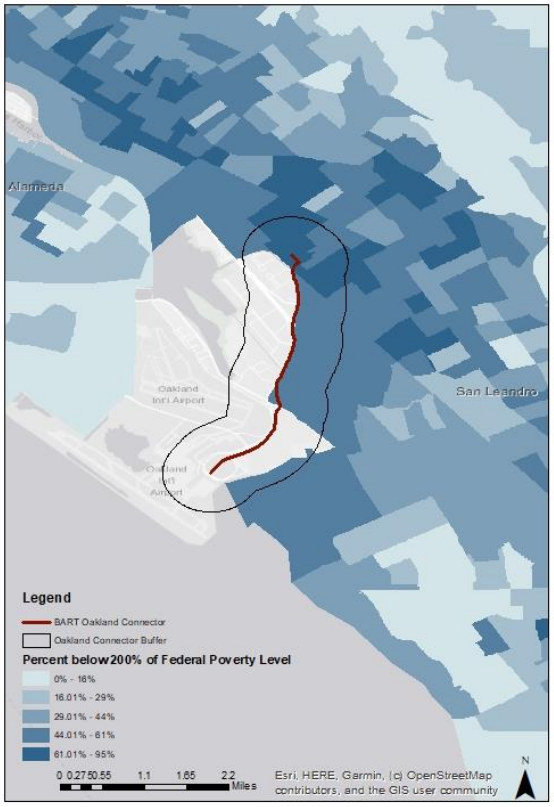

Figure 1. BART Oakland Connector Project

Bicycle and pedestrian and pilot projects tended to be lower dollar investments overall, but these projects are often expanding the range of transportation options. Depending on their location, they can have bigger impacts to equity than high dollar investments. Table 3 shows the average investment by category; this gives insight into MPO priorities in terms of technology investment.

Table 3. Investment by Category

Category	Average Investment	Median Investment
Bicycle/Pedestrian	$4,832,557	$2,161,509
Electrification	$13,300,434	$5,613,000
Mobility	$76,526,079	$11,478,500
Pilot	$5,464,000	$4,453,000
Support	$1,244,484	$945,000

Mobility projects have the highest average investment, which highlights the expense of non-bus transit and highway projects as well as being skewed by one large dollar project. The median investment is presented to account for the skew of the high dollar projects but the overall trends by category do not change. On the lower end of the average investment is bicycle and pedestrian, pilot, and support projects. These projects tend to be smaller in nature, but total investment in Table 4 shows that these can be lower priority in terms of technology investments. In order to support all modes of transportation, technology investments must consider non-highway projects as well as ensuring that the supporting infrastructure is capable of transitioning to a more connected transportation future.

Table 4. Total Investment by Category

Category	Total Investment
Bicycle/Pedestrian	$14,497,671.75
Electrification	$332,510,853.59
Mobility	$1,071,365,103.78
Pilot	$27,320,000.00
Support	$8,711,384.90

In terms of the first hypothesis, the analysis does not support those investments in technology are clustered in mid-to-high income neighborhoods; the average percentage of low-income residents across all the projects and their spatial boundaries was 41 percent. This is above the threshold to be considered a community of concern by MTC; set at 28 percent. In addition, 43 of the 54 projects analyzed were in low-income communities. These results reflect a commitment to spatial equity but the projects themselves may have significant equity concerns; a discussion of five projects will highlight these concerns in the next section.

In terms of increasing equity over time, the analysis does not find strong evidence in support of this hypothesis either. The small sample size and inability to determine exact years of investment, beyond the TIP year, play a role in this determination. Table 5 presents data over time to show the technology investment trends.

Table 5. Investment Equity over Time

Year	No. of Projects	No. of Projects in Low Income Areas	Total Investment (2019 $)	Average Investment	Median Investment
2015	15	14	$727,632,895	$45,619,741	$2,427,956
2017	11	10	$424,769,119	$37,466,469	$4,677,000
2019	28	19	$302,003,000	$10,480,759	$5,995,000

The average and total investment show a steady decline over time, this investment represents a small subset of the entire TIP as it only includes technology projects, but it may be a sign that the agency is being more cautious with their technology investments. The BART Oakland Connector project is represented in the 2015 TIP, which is a large overall investment that occurred between 2010 to 2015. This large investment appears to be skewing the results towards a more "equitable" impact in 2015 versus 2017 or 2019; the role of this project will be discussed further in the following section. In addition, while the number of technology related projects appears to have increased significantly in the 2019 TIP, they are smaller in terms of total investment and less are in the low-income areas. As more transportation technologies enter the market, the need for pilot testing and evaluation increases. However, these pilots must consider equity and

environmental justice communities for them to benefit from these investments. All the projects categorized as pilots in this analysis were included in the 2019 TIP.

2.3.1. Equity Evaluation & Analysis

Whether a project can be deemed truly equitable relies on more than just investing in low income and minority communities; investment must stem from a true accounting of community needs, the impact this project will have beyond providing transportation solutions, and whether the investment will truly benefit equity communities. Moving past the investments, this analysis discusses the potential equity implications of the project categories and presents one project from each category as an example. These examples show the nuance of individual projects and how that can ultimately be the determinant of an "equitable investment" rather than just the location and extent of the investment.

Electrification projects tended to involve the conversion of vehicles to electric power or the expansion of infrastructure to support this. The reduction in emissions is a benefit felt by both the surrounding community and the users of these vehicles. Projects that support the expansion of these technologies provide a similar benefit, but there is a need to consider the cost burden for low income individuals when promoting EVs (MacArthur et al., 2018). Electric buses or electric vehicles for transit usage have a broader impact and will likely support EJ populations, such as low-income communities. While bicycle and pedestrian projects protect vulnerable road users, these types of developments are

often linked with gentrification and a disregard for community needs (Butler, 2020; Hoffmann, 2016; Thomas, 2020). This is especially true in the case of bicycle infrastructure such as bike lanes; these can come before necessary improvements to pedestrian or even road infrastructure (Hoffmann, 2016). This analysis did not assess the level of community engagement for these projects and whether each would present a true benefit. However, the connection to racism, gentrification, and the inequitable structure of planning means that bicycle and pedestrian projects are considered a net neutral to take into account both the potential benefits and the problems of these types of projects. In a similar manner, mobility projects can reduce congestion while also directing funds away from the investments desired by the community. With an understanding that all modes should be equitable, which requires an investment in all modes, these projects are also considered net neutral. Finally, support projects often provided technology investments that would contribute to the entire transportation network. Whether these projects are equitable largely depends on the technology or infrastructure they are supporting.

2.3.1.1. Project Examples

The following projects were further examined to better understand the project rationale, community views on the project, and whether equity was a consideration in the project development process. One project was chosen from each category.

Table 6. Overview of Project Examples

Category	Project	TIP Year	Investment ($ 2019)	% Low Income in Spatial Boundary
Bicycle/Pedestrian	Linked Price Electric Bikesharing in San Francisco	2015	$2,161,509.70	30
Electrification	AC Transit Purchase of 10 40' Zero Emission Buses	2017	$13,665,514.29	32
Mobility	BART Oakland Airport Connector	2015	$556,473,773.66	100
Pilot	Bay Bridge Forward (Sterling/Bryant St Managed Lane)	2019	$7,633,000.00	44
Support	Santa Rosa City Bus Transit Enhancements	2019	$945,000.00	59

2.3.1.1.1. Linked Price Electric Bikesharing – 2015

The electric bikesharing pilot cooperated with a current carshare operator to test the colocation of e-bikes and their cars available through the program. MTC and San

Francisco coordinated with UC Berkeley's Transportation Sustainability Research Center to test differential pricing for the e-bikes as well as usage, distribution, and impacts of the e-bike share (SFMTA, n.d.). In order to utilize the program and choose a cheaper mode of travel in the e-bike, the user had to be a member of City CarShare (Dinkelspiel, 2013). While this provided an easy method of implementation, it does have potential equity impacts. City CarShare members would likely have required a credit card to utilize their vehicles, as well as a valid driver's license. Although this pilot intended to test whether users would opt to take an e-bike rather than a carshare, it may have limited the possible impact and usage of the pilot by excluding those without access to a credit card or reliable method of electronic payment, as well as those that do not have a valid license. Overall, the project hoped to provide a complement to the regional bikeshare as well as offer an environmentally friendly mode for grocery shopping and other errands. The project ended in 2018 and a final report is forthcoming.

2.3.1.1.2. AC Transit: Zero Emission Buses (ZEB) – 2017

While this project is for the purchase of 10 40' zero emission buses, AC Transit has a comprehensive plan for the conversion from fossil to clean fueled vehicles at its agency. From 2003 to 2018, AC Transit led a coalition of state, federal, and local actors, and agencies in three phases of ZEBs. During the demonstration of technology period, 3.2 million zero emission miles were driven, far exceeding the expectations from those involved. Moving forward, the agency intends to move into advanced stages of ZEB deployment and support their efforts toward The Innovative Clean Transit (ICT)

regulation. This regulation was adopted by the California Air Resources Board in 2018 and requires that all public agencies transition to zero emission vehicles. For transit agencies, this means that by 2029 all new vehicles purchased must be zero emission (AC Transit, 2020). Switching from diesel powered buses to electric or hydrogen fueled has numerous environmental and health benefits for those living along the AC Transit service routes or utilizing the service (Hawkins et al., 2012; Kühne, 2010; Sperling & Brown, 2018; Zhou et al., 2016). In terms of equity, AC Transit is prioritizing equity communities, especially those along routes with high ridership, through its Clean Corridors program (AC Transit, 2020). This ensures that communities who have suffered past harms due to environmental injustices such as poor air quality are the first to receive the benefits from this transition to cleaner energy.

2.3.1.1.3. BART Oakland Airport Connector

The BART Oakland Airport Connector caused controversy when initially proposed and then planned and funded to the extent that an official complaint was filed with the Federal Transit Administration (FTA). This complaint was driven by a number of concerns but mainly, the lack of a federally-required equity analysis, the project further prioritized transit funds for rail capital at the expense of funding for bus service, and that stimulus funding designed to support existing transit service was being diverted to this project (Mayer & Marcantonio, 2009). The failure to complete an equity analysis was especially problematic due to a number of community concerns regarding the increased fare of the service compared to the current bus, and the removal of intermediate stations

that would have benefitted the community as well as those who work at the airport (San Francisco Bay Area Rapid Transit District, 2010). Transit advocates felt that the cost of the project was untenable and argued that the same transit benefits could be gained from a bus rapid transit (BRT) system at a much reduced cost (Roth, 2010). The controversy over funds led to MTC having to find an alternative funding source after the complaint raised issues over both the Darensburg v. MTC case that challenged the prioritization of rail projects, and that use of American Recovery and Reinvestment funds should be limited to existing service. Despite the public backlash and funding issues, the Connector project went forward and eventually opened to the public in late 2014.[3] The project is a prime example of how high dollar investment does not always benefit the community in which the investment is taking place. In the mile area around the connector, 100 percent of the population falls into MTC's low-income definition. However, this project was never intended to benefit those that lived near or worked at the airport. A comment by then head of the MTC made this clear when he stated that the Connector was designed with "a very special class of transit rider in mind" (Roth, 2010). The general trend toward greater equity consideration does remain throughout MTC and they conduct an equity in investment analysis that goes beyond most other MPO efforts; however, this project displays the potential pitfalls of not considering equity and that investment in low-income communities does not always benefit those very communities.

[3] The project was included in the 2015 TIP as a close out of funds from the 2014-2015 year.

2.3.1.1.4. Bay Bridge Forward (Sterling/Bryant St Managed Lane)

The Bay Bridge Forward Initiative is an effort to improve congestion and reduce wait times on the Bay Bridge approaches. This project focused on piloting a Vehicle Occupancy Detection (VOD) technology for their high occupancy vehicle (HOV) requirements for certain lanes, as well as increased California Highway Patrol (CHP) enforcement at Sterling and other pilot sites. In addition, the project supported planned HOV lanes onto the bridge and converting a HOV lane to an express lane. Figure 2 shows all three pilot sites for this project under the Bay Bridge Forward Initiative. The express lane used variable pricing, those meeting the HOV requirements could use the lane for free and solo drivers could utilize the lane for a specific price (MTC, 2016). The discussion of the project in the media focused on the CHP enforcement actions, but both the VOD technology and the CHP were used to monitor violations of the vehicle occupancy requirements. The pilot of the VOD technology found it was 78 to 88 percent accurate (Rudick, 2020), while the CHP enforcement had a more obvious impact on the community in terms of news reporting (Batey, 2015; Cabanatuan, 2017). The increased enforcement of carpool violations has obvious impacts to minority communities when considering the danger of interactions between the police and these individuals, especially Black individuals (Donohue III & Levitt, 2001; Pierson et al., 2020; Ramachandran & Kramon, 2016; Weitzer & Tuch, 2006). The success of the VOD technology should offer an alternative method to police enforcement of HOV violations, these violations could be accidental in nature and enforcement by mail or other non-

contact method is both more cost efficient for public agencies and safer for minority communities.

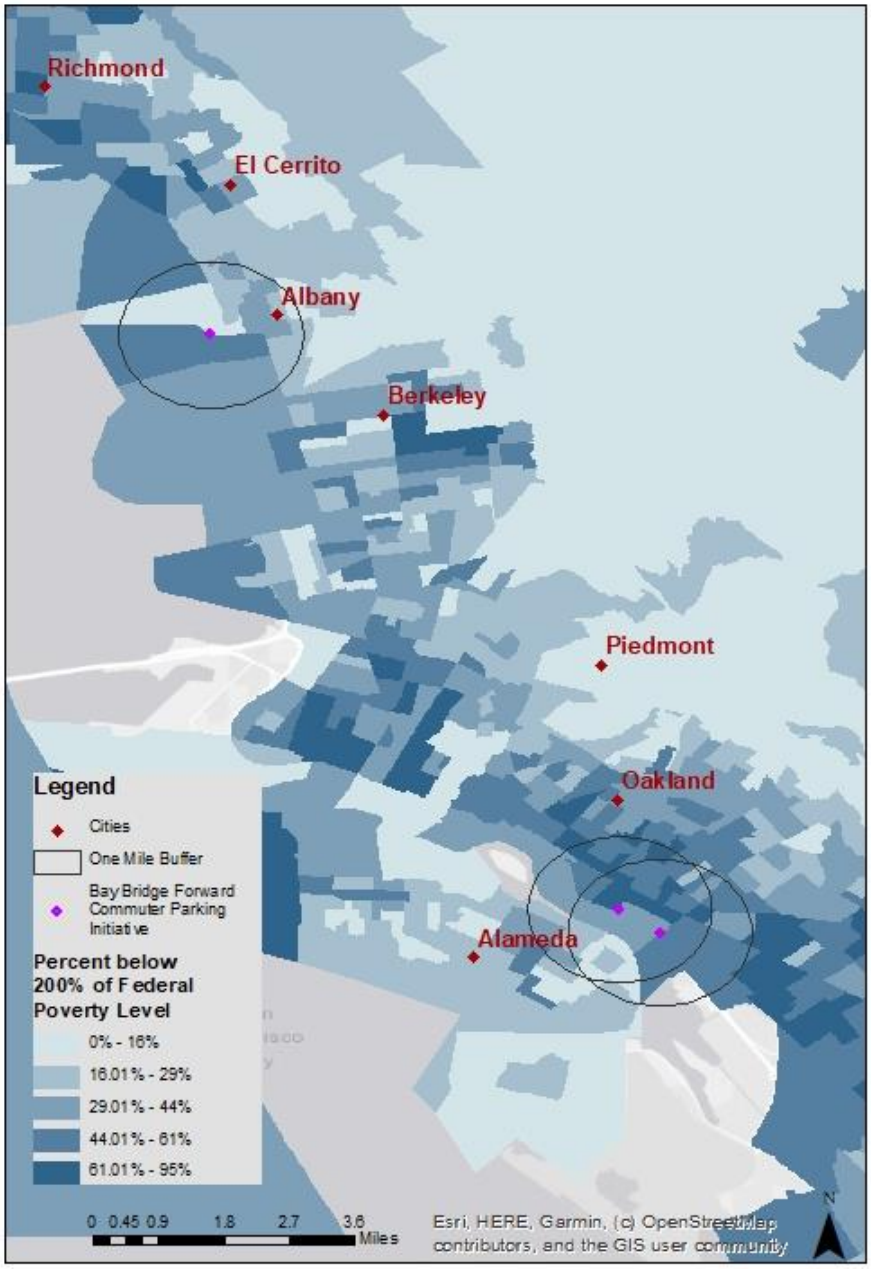

Figure 2. Bay Bridge Forward Project Sites

2.3.1.1.5. Santa Rosa City Bus Transit Enhancements

Support projects often have a broad array of enhancements and goals tied to their investment. The TIP notes that the project planned to upgrade and improve transit facilities including amenities, accessibility, ADA compliance, pedestrian and bicycle access, as well as upgrading technology in terms of transit system management and customer facing technology. It was not possible to find an exact information on the project and the technology upgrades, but the enhancements were connected to a transformation that Santa Rosa City Bus completed of their entire schedule (Nelson Nygaard, 2016). Figure 3 shows the Santa Rosa City Bus routes with the analysis boundary. The redesign relied heavily on community input, which is key to creating an equitable system (Ede, 2019). The technology upgrades mentioned in the redesign point to paratransit and pedestrian improvements as well as overall transit system improvements. This shows a focus on equity-priority populations as well as meeting community needs, both key to a more equitable and just transportation system.

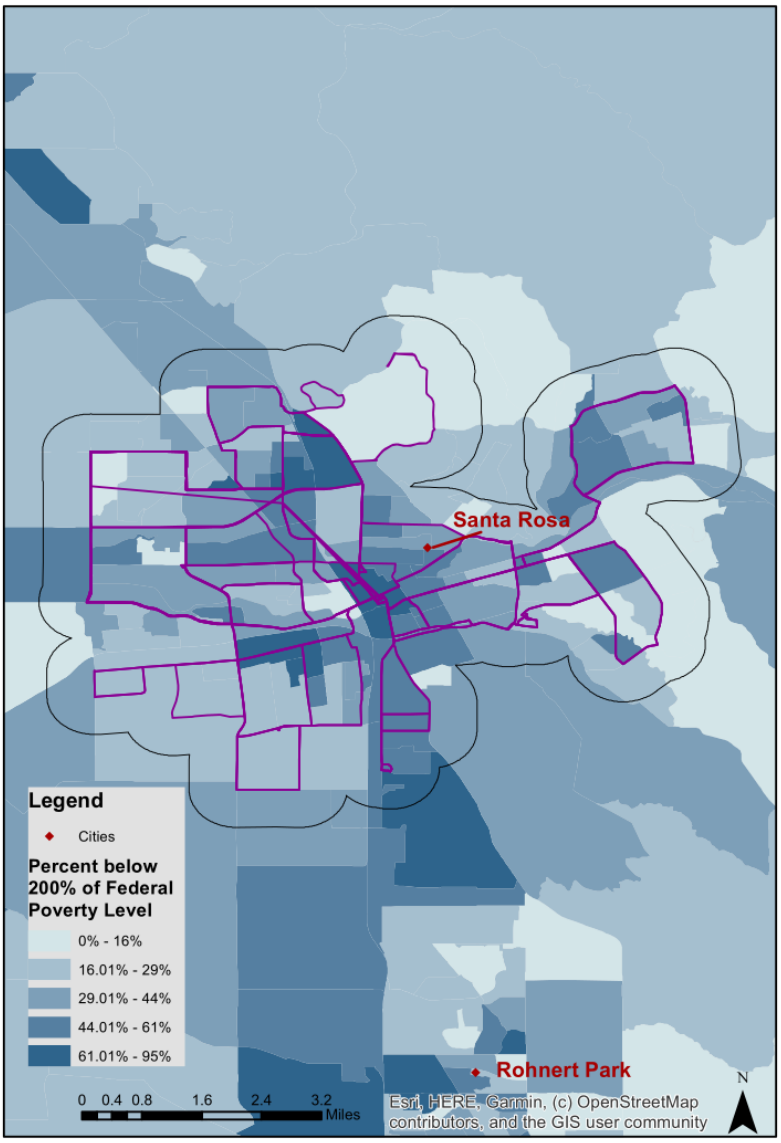

Figure 3. Santa Rosa City Bus - Technology Upgrades

2.4. Conclusion

Developing equitable transportation technology solutions requires an understanding of how technology has impacted, and is currently impacting, the transportation system and

urban space. Previous and current investments into transportation technologies or technology-oriented projects can provide insight into areas that are better prepared for further technological advancement as well as see who is benefiting from such investments. The analysis of MTC's technology related projects has shown the potential for benefits to communities of concern as well as provided lessons learned where projects have not considered the totality of benefits and costs that will be borne by communities. Ensuring equitable and just projects rely on listening to and understanding communities needs as well as enabling the community where the project is located to benefit from it. For example, the BART Oakland Connector suffered by failing to listen to community needs and ultimately invested in a project that will not truly benefit the community in which it is located. In contrast, recent transit improvements have specifically focused on disenfranchised and previously harmed communities. While the change in investment over time may not have signaled a move to equity, some of the individual projects show that a greater focus is being made on equity and justice. This trend must continue with the introduction of emerging technologies both in terms of pilots and full integration. Technology is not neutral; its impact depends on planning and policy to ensure the full benefits are received and the costs are mitigated for transportation-equity communities.

This research has highlighted the need for a holistic understanding of the equity and justice of technology projects within transportation as well as programs of projects. Future research should address the additional factors that impact equity beyond levels of

investment and spatial connection to consider the level of public involvement by community members, whether the project developed from community needs, and if the program is working against the inherent injustices of the current transportation system.

3. Are We Planning for An Equitable Transportation Future? Lessons Learned from Regional Transportation Plans

Regional transportation plans (RTPs), also known as the long-range transportation plan, provide the vision and goals for a region over a 20-to-30-year time frame. These documents offer key insights into the changing wants and needs in terms of mobility and accessibility for individuals in each region. They can also offer a window into the future of transportation and show us what is being considered and what might be missing. Emerging technologies in transportation is a hot topic that most cities, regions, and states are considering when they plan and program projects over the long-term. These have the potential to improve safety, efficiency, and reduce the environmental impact of transportation (Anderson et al., 2014; Cohn et al., 2019; Fagnant & Kockelman, 2015, 2014; Sperling & Brown, 2018). In contrast to emerging technologies, concepts of equity, justice, especially environmental justice (EJ), have played a role in planning for decades (Agyeman et al., 2016; Bullard, 2003, 2007; Clinton, 1994). When considering emerging technologies, it is crucial to understand the potential equity and justice implications to reduce the burden to equity groups as well as ensure the full range of benefits is felt by the underserved in transportation. Technologies have the ability to both improve and worsen accessibility for people with disabilities, the elderly, as well as low-income and minority individuals (Benjamin, 2019; Cordts et al., 2021; Faber & van Lierop, 2020; Golub et al., 2021; Hong & Williams, 2019; Hwang et al., 2020). In order to understand how metropolitan planning organizations (MPOs) are considering equity, technology, and the equity impacts of technology; a plan evaluation was conducted on 52 long-range or regional transportation plans across the U.S. The plan evaluation extended previous assessments of technology and equity in plans to

provide a broader cross-section of planning agencies both geographically and in terms of population (Kuzio, 2019). The following questions drove the evaluation framework:

- How are planning agencies incorporating technology, especially emerging technologies, and equity into their planning documentation?
    - Is there a consideration of the equity implications of emerging technologies?

The plan evaluation looks for evidence of equity and technology planning as well as a discussion and potential implementation of the equity impacts of technology. Results show that the discussion of equity and justice remains limited, which ultimately leads to a limited discussion of the equity of technology in transportation. Most planning agencies are discussing technology to some extent within their plans. These results indicate a gap between equity planning efforts and technology planning efforts that must be bridged if a more just transportation system is to be realized.

3.1. Planning and Equitable Transportation Technologies

Planning for equitable technology in transportation requires a strong focus on equity and especially equitable planning in transportation. The history of transportation investment in the United States is one of displacement and racial inequity (Boschmann & Kwan, 2008; Bullard, 2003; Giuliano, 2003). Transportation infrastructure, such as the interstate highway system, has irrevocably altered the landscape of the U.S., fracturing communities, and cutting economic ties. Despite efforts to address the impacts of transportation to minority and low-income communities, the gap in access to transportation has not truly been diminished (Clinton, 1994; Marcantonio et al., 2017; U.S. Department of Transportation: Federal Highway Administration,

1999). Other underrepresented and underserved groups, such as people with disabilities and English language learners, have also suffered from ineffective transportation service and a lack of communication. The continued struggle to address injustice within transportation will continue, and could be exacerbated, by technology. Technological developments have often begun in the private sector with the introduction of electric vehicles (EVs), the development of connected and autonomous vehicles (CAVs), and other emerging solutions that contribute to intelligent transportation systems (ITS). The limited public sector involvement in the early stages of design and development can lead to issues in integrating these developments into existing transportation networks; vehicles that are not designed with all passengers in mind can limit accessibility to people with disabilities or English language learners (Allu et al., 2018; Cordts et al., 2021; Cuellar et al., 2018; Hwang et al., 2020). In addition, technological developments that require infrastructure investment or upgrades will put additional strain on tight transportation budgets (Anderson et al., 2014; Hallmark et al., 2019; Nicholas, 2019; Terry & Bachmann, 2019). These additional costs could disrupt current efforts to create a more equitable transportation system by shifting funding to prepare for new technologies. While emerging and current technologies can provide a range of benefits, from safety to environmental benefits, the impacts to equity are not so straightforward. CAVs provide the ability to collect large amounts of data on both the user of the vehicle itself and even other users of the network introducing a myriad of privacy concerns (Ayub et al., 2018; Collingwood, 2017; Glancy, 2012; Peterson et al., 2020) that will likely target Black, Indigenous, People of Color (BIPOC) to a greater extent (Benjamin, 2019). Increased investment in technologies, including transportation technologies, can exacerbate issues of privacy and surveillance that will disproportionately harm populations that have previously suffered under transportation policies and planning. While it is necessary to

ensure that these populations receive the full benefits of transportation technologies, planners and policymakers must also consider the potential for increased harm.

MPOs create two main planning documents on a regular basis: the Transportation Improvement Program (TIP) and the RTP, also known as the Long-Range Transportation Plan or the Metropolitan Transportation Plan. The TIP provides an overview of investments in the short-term and is usually updated every two to four years showing either two or four years of projects. The RTP is the long-range plan that can have a horizon of between 20 to 30 years and is completed every four to five years. The RTP is the visioning document for the MPO showing the priorities and the transportation system the agency hopes to build for their region. While projects are often proposed and completed by local governments within the MPO, the MPO selects and prioritizes projects through a board of regional stakeholders (Federal Transit Administration, 2016; Sciara, 2017). Therefore, the RTP is essentially a blueprint for how the region could, and should, change in terms of transportation over the planning horizon. All projects that intend to utilize federal funding must be included within the RTP and TIP, further establishing the importance of these planning processes and documentation (Sciara & Wachs, 2007). Both the RTP and TIP have EJ analysis requirements imposed by executive order during the Clinton administration (Clinton, 1994). The requirement for EJ establishes a baseline to address equitable impacts to low income and minority populations but should be considered a starting point to address the equity of the entire transportation plan. In addition, since the RTP is planning for the future, the impacts of technology, especially emerging technologies must be considered within the document (Guerra, 2016; McAslan et al., 2021). Through these requirements and the core

focus of the RTP, this planning document should provide insight into whether we are planning for equitable technology in transportation.

Understanding how agencies are planning for certain issues or conducting analyzes is often achieved through a plan evaluation; most evaluate the quality of these efforts in some form. While plan evaluations are common in disaster mitigation and climate change planning research (P. R. Berke, 1996; P. R. Berke & Conroy, 2000; Lyles et al., 2016; S. C. Woodruff & Regan, 2019), analyzes of specific components of transportation planning have been conducted. The impact and usage of EJ analyzes has shown the variety of methods used by planning agencies due to a lack of guidance. Without clear standards, these analyzes can range from qualitative assessments of project scope and location to complex models that assess the impact to travel time, the environment, and quality of life for EJ populations (Golub et al., 2013; Karner, 2016; Karner & Niemeier, 2013a). The inclusion of these processes in planning documents has been scrutinized (Karner & Niemeier, 2013a; Marcantonio et al., 2017) along with a broader assessment of the inclusion of equity within long-range plans (Golub & Martens, 2014; Manaugh et al., 2015). In recent years, assessments have included a review of AVs in transportation plans as these vehicles could fundamentally alter the transportation system as we know it. A 2016 evaluation of the 25 most populous MPOs in the U.S. found that only one mentioned AVs, but interviews with these agencies indicated that the MPO was tracking the technology but not yet ready to formalize these efforts in their RTP (Guerra, 2016). A recent update to that study showed that, out of 52 MPOs, 41 of them included AVs in their RTP and 12 included policies related to AVs (McAslan et al., 2021). This shows a significant increase over five years in the inclusion of an emerging technology in plans; however, only five of those plans included a

discussion of “equitable communities”. While plans may be including emerging technologies to a greater extent in their plans, there is still a disconnect between equity and technology planning (Kuzio, 2019). This assessment takes a specific focus on the equity of technology while also assessing both the equity and technology planning efforts separately. The goal is to assess the status of planning for equitable transportation technologies as well as understand whether equity or technology planning efforts play a role in making the connection to equitable technology.

3.2. Methods

Understanding the current thoughts and potential applications regarding transportation technologies by planners and planning agencies can be gained through reviewing official documents and plans. Plan documents can provide insight into the vision of an MPO and how different elements of the transportation system fits into that vision. This research focuses on one main question: How are planning agencies incorporating technology, especially emerging technologies, and equity into their planning documentation? This is assessed by looking at how they incorporate equity, emerging issues related to technology, as well as whether there is a consideration of the equity implications of technologies. The plan document focused on is the long-range plan, or RTP, and the inclusion of technology and key equity and justice components. The RTP was selected due to the time frame that the plan considers as well as the detail generally provided in these plans. Since many emerging technologies are in the pilot stages and not fully integrated into the transportation system, the 20-year, or longer, time frame of the RTP allows planning agencies to discuss the potential of technologies without committing resources prematurely. The review of RTPs utilized a plan evaluation approach that drew on a previous

study as a pilot, the transportation literature, as well as the plan evaluation and content analysis literature more broadly.

3.2.1. Plan Evaluation Protocol Development

The pilot study, completed in 2018, used a basic protocol developed from research questions and a literature review but was ultimately more exploratory in nature (Kuzio, 2019). The plan evaluation protocol for this study took the lessons learned from the initial pilot evaluation as well as extending the literature review to include a focus on technology beyond autonomous and connected vehicles and EJ as well as equity. The pilot study utilized a summative content analysis method based on keywords derived from the literature and the documents themselves (Hsieh & Shannon, 2005). The final protocol incorporated some of the same summative content analysis techniques and processes, and included 42 elements across the following categories and subcategories:

- Equity & Environmental Justice
    - Environmental Justice in Plans
    - Equity in Plans
- Current & Emerging Technologies
    - Technology
    - Electrification
    - ITS
    - Emerging Technologies

Equity and EJ include a significant amount of overlap in the academic literature, but in terms of transportation planning, EJ focuses on the requirements of the executive order which includes low-income and minority populations. Equity encompasses EJ populations but also includes other populations that have and can be transportation disenfranchised. These populations include people with disabilities, the elderly, as well as Title VI protected classes such as limited English proficiency populations. EJ in plans analyzes the efforts being made to address federal requirements, such as the EJ analysis and determination of EJ communities in their region. The lack of clear guidelines on what constitutes an effective EJ analysis had led to a variety of approaches with different levels of detail (Duthie et al., 2007; Karner & Niemeier, 2013a). In developing the protocol, the authors utilized the literature to determine promising practices and guidance for completing a strong EJ analysis.

In terms of equity in plans, the emphasis is on all equity or disenfranchised groups. This expanded emphasis looks for planning efforts beyond the required EJ analysis especially a broader commitment to equity throughout projects and programming. For example, including equity in the project prioritization framework is a way of signaling a commitment to equity *and* putting it into practice (Twaddell & Zgoda, 2020a; Williams et al., 2019). Equity must be a consideration throughout the planning process to ensure that transportation investments benefit those communities as well as avoiding further harm. The protocol evaluates the ways in which equity can be included in planning, such as through goals, specific projects, and considering land use impacts. This establishes a baseline for the equity efforts including in plans that then can be connected to their specific discussions or planning in terms of the equity of transportation technologies.

The technology portion of the protocol looks for the presence of planning efforts for several current and emerging technologies. This first section addresses technology more broadly and is assessing whether planning agencies are connecting the variety of technologies with their system together. For example, ITS can support and enable connected and autonomous vehicles but planners must know the status of their current assets to develop a plan for the deployment of these emerging technologies (Grzejszczyk, 2020; Guerrero-Ibanez et al., 2015). Without an understanding and assessment of these connections, technology investments are likely to be piecemeal and disjointed. The protocol then seeks evidence of planning or research on electric vehicles, intelligent transportation systems (ITS), and emerging technologies such as autonomous and connected vehicles as well as micromobility. In addition, while a focus on electric vehicles in a plan can signal a commitment to sustainability to be truly sustainable, the plan must consider equity (Agyeman, 2008; Boschmann & Kwan, 2008). Therefore, the protocol assesses whether equity is considered regarding technology more broadly as well as specific projects or programs related to technology and each of the separate technology groups.

3.2.2. Evaluation and Coding Process

A stratified random sample of MPOs was taken based on population thresholds determined by the U.S. Department of Transportation. Table 7 shows the population thresholds and the number of MPOs from each threshold that were included in the sample. There are 402 designated MPOs in the U.S. and its territories, and the sample included 53 MPOs. From the 53 plans, one planning agency listed as an MPO by USDOT did not have an RTP available online. Efforts were made by coders to locate a sufficient alternative document; however, the protocol was developed with the

RTP in mind, so no alternative plan was sufficient to be evaluated. The final analysis included 52 plans in total.

Table 7. Sample Overview

Population Category	Sample MPOs	Total MPOs
0-140,000	19	151
140,001-250,000	9	69
250,001-600,000	12	99
600,001 – 1 million	6	33
1,000,001 – 2.5mill	4	28
2.5 million +	3	22
Total	53	402

The plan evaluation process utilized a protocol that provided a mixture of quantitative and qualitative coding. The quantitative evaluation utilized two coders to enable a more thorough review of the plans and reduce the likelihood that planning, or policy elements would be missed during the data collection and plan evaluation process. The protocol collected data on both the presence of planning efforts, through the quantitative coding process, and details regarding those planning efforts, by collecting excerpts of the plan for qualitative coding. The quantitative

coding used a 0, 1, 2 system to determine both the presence of a certain planning effort and to indicate where additional details or analysis had been included in the plan document. 30 of the 52 plans were quantitatively assessed by both coders with the codes reconciled at the end of the process, the remaining 22 plans were quantitatively assessed by one coder.

Qualitative coding follows the summative process by collecting excerpts, utilizing the keywords, for comparison and then interpreting the context of those excerpts. The development of codes used a mostly inductive approach; however, previous research was utilized in developing the protocol and informed the final overall coding categories. Through the content analysis process, the categories presented in Table 8 were developed. The qualitative coding focuses on larger categories to provide an overview of how MPOs are incorporating social equity, technology, and the equity of technologies into their planning documentation.

Table 8. Qualitative Coding Categories

Category	Codes
Social Equity	No substantial discussion
	Plan Component
	Program or Policy
	Goal
	Guiding Principle
Technology	No substantial discussion
	Preparing for greater technology integration

Category	Codes
	Concerned about technology integration into current system
	Focusing on established technologies
	Expanding use of technologies
	Investing in Technologies
Equity of Technology	No substantial discussion
	Increased Accessibility
	Barriers to Access
	Concerns surrounding current goals
Emerging Technologies	No substantial discussion
	Mentioned in the plan
	Monitoring Progress of Technologies
	Plan or Strategy for Emerging Technologies
	Investing in Emerging Technologies
Equity of Emerging Technologies	No substantial discussion
	Increased Accessibility
	Barriers to Access
	Concerns surrounding current goals

Social equity focused on substantial discussions relating to equity and how equity and justice are included in long-range planning documents. While MPOs are required to complete EJ analyzes,

truly equitable planning requires a focus on a wide range of vulnerable or previously underrepresented populations in planning. Equity goes beyond traditional EJ analyzes that are completed by MPOs by taking a more holistic approach to the planning, design, and development of the transportation plan. Equity as a plan component indicates that some discussion of equity and transportation was present in the plan, but it did not amount to a program or policy. Plans will often discuss equity implications of transportation in various contexts but may not make the step of connecting that with their planning efforts or programmed projects. Equity as a program or policy reflects a greater commitment to equity throughout the planning process, by either instituting a policy that directs the plan to consider equity impacts or having a program that directs funds toward equity or EJ projects. Goals show the commitments of the long-range plan and reflect the vision of the agency in terms of current and future projects. Including equity as a goal or within the goals section show that the MPO is prioritizing it in the planning process. Finally, equity as a guiding principle indicates that every aspect of the planning process and the plan creation has been viewed through an equity lens. Guiding principles will be more direct than goals and provide an overview of the focus of the agency. Technology relates to how current and emerging transportation technologies are discussed and incorporated into long-range planning documentation by MPOs. Incorporating technology is complex for many MPOs due to uncertainties over use cases and deployment of certain technologies. In addition, smaller MPOs may not have the capacity to effectively conduct research into technology and how best to deploy them in their region. Along with capacity constraints, project prioritization and funding availability may constrain the discussion of technology within a plan. The content analysis found that some MPOs are preparing for greater technology integration in the future with the understanding that they should be targeted in their

technology deployment. Other MPOs, while preparing for greater integration, are concerned about the interoperability of certain emerging technologies with the current transportation system. These concerns stem from the introduction of AVs and the ability for the current system to support both electric and connected vehicles. Focusing on currently available technologies can be a sound strategy for MPOs that have concerns about technology integration and even unmet promises from technology. MPOs that already have several technology components in their system appear to either be incorporating projects to research or expand use in technology in the future or investing in programs of technology projects.

Emerging technologies relate to AVs, CVs, new electric micromobility solutions, as well as other transportation technology solutions that are currently under development. Incorporating emerging technologies is more difficult than just technology as a whole; many agencies are wary about committing to a position on a certain technology without good data on public approval and trust. Despite this, most MPOs understand the need to acknowledge these technologies and monitor their progress for potential benefits to their region. Incorporation of emerging technologies ranged from a discussion of their capabilities to planning or strategizing to actual investments in this new area.

Finally, the inclusion of equity in relation to both technology as a whole and emerging technologies on their own was assessed. Often technology is viewed as value neutral or unbiased, but decisions related to design, deployment, and investment all affect the distribution of benefits and costs to different groups. Equity issues with technology tend to relate in terms of access to the technologies by various groups but can differ beyond that. In terms of technology, concerns

related to their current goals and whether technologies were contributing to the equitable transportation system they were planning, while concerns in terms of emerging technologies were often related to specific goals, such as the impact to transit and the subsequent equity impacts of a reduction in ridership.

The categories were based on an overall review of the content collected through the protocol; once these coding categories were determined, each plan was assessed individually to determine which category fit best with the content collected from that document. The coding of social equity and technology separately allowed for a comparison with how equity planning and technology planning connects with the plan's consideration of the equity of transportation technologies.

3.3. Results & Analysis

Planning documentation, especially long-range plans, can provide great insight into the vision, optimism, and concern that planners might have toward technology. The plan evaluation protocol provided both quantitative and qualitative results through numeric coding and content analysis. The quantitative results focus on the presence of planning efforts related to equity, technology, and the equity impacts of technology. Table 13 provides an overview of the MPOs included in the study as well as abbreviations that will be used throughout this section.

3.3.1. Incorporating Equity & Environmental Justice

In terms of equity, 42 percent (22) of the plans assessed did not include a substantial discussion of transportation equity considerations. A substantial discussion of equity requires more than just

mentioning the term “equity” but could include a definition of equity for their region or a policy, planning action, or research item related to equitable transportation. In addition, only half of the plans assessed included their EJ analysis, or results from it, within the main planning document. While that is not an indication that no EJ analysis is undertaken, it may indicate priorities or lack of resources when the analysis is not presented in a public-facing document that is also used to determine federal funding allocations. The long-range plan document is often presented at the culmination of the public engagement process for the plan so not providing an overview of the EJ analysis limits the ability for the public to comment on this part of the planning process. It is important to note that out of the 42 percent, almost half (10) of the MPOs were in the smallest population bracket of 140,000 and under. These agencies will have significantly smaller programs and may often rely more heavily on the state department of transportation or a consultant for assistance with their planning documentation. Figure 4 shows the full results of the qualitative equity coding.

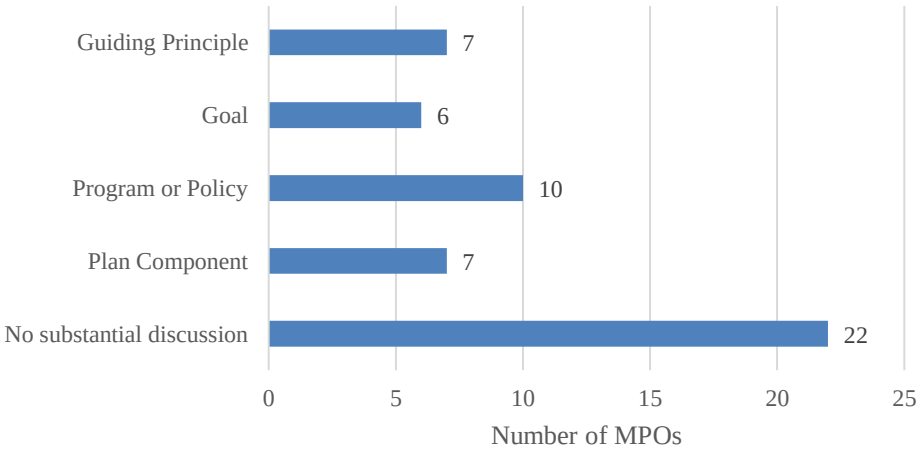

Figure 4. Equity Coding

Outside of not including equity within the RTP, most MPOs have a program or policy related to equity that shows a focus beyond just including equity as a discussion point. Equity programs can focus on a certain subset of projects that have a specific focus on equity issues, such as accessibility for equity priority communities or reducing bias in the transportation system or can be a broader effort that assesses the equity of the full plan. Broader efforts can be enshrined as a policy that leads the MPOs efforts on equity. For example, CRTPA has a community program that focuses on providing effective and accessible transportation for equity populations (Capital Regional Transportation Planning Agency, 2015). Including equity in the project prioritization process can be another example of an equity program or policy. Only 37 percent of RTPs assessed include some form of equity metric in their project prioritization process. Including equity as a guiding principle focuses on the entire plan rather than just a program or projects or a standalone project. CDTC is developing their new plan with an equity lens, which intends to "analyze all transportation policies through an equity lens to eliminate negative impacts to underserved and marginalized individuals and groups" (Capital District Transportation Committee, 2020). This shows a commitment to an equitable long-range plan and a focus on equity in all projects and policies. Not every MPO or plan has reached the stage where they can include equity as a guiding principle or even define a program or policy, but MPOs do recognize the need to consider underserved communities in transportation planning. Equity as a plan component can simply be a discussion of equity considerations in an auto-dominated culture or can be a requirement to measure equity impacts in projects moving forward. Finally, including equity in the goals section signals a commitment to improve planning in this area in future efforts; this can be because research and community engagement needs to be conducted or the MPO is working on the best way to incorporate equity into the plan.

3.3.2. The Technological Future

Technology is not necessarily a new area for transportation planners to consider, but smaller regions may not have focused on those investments in the past or needed to consider technology impacts to their transportation system. As technology becomes a greater part of daily life, even smaller MPOs are having to consider emerging, potentially disruptive, technologies as well as those that have served the transportation system for years. This coding focused on technology, both established and emerging forms. Out of the plans assessed, only 29 percent did not include a substantial discussion of broad technological impacts to their transportation system and/or plan. Figure 5 shows the results of the qualitative coding for technologies in the plans assessed.

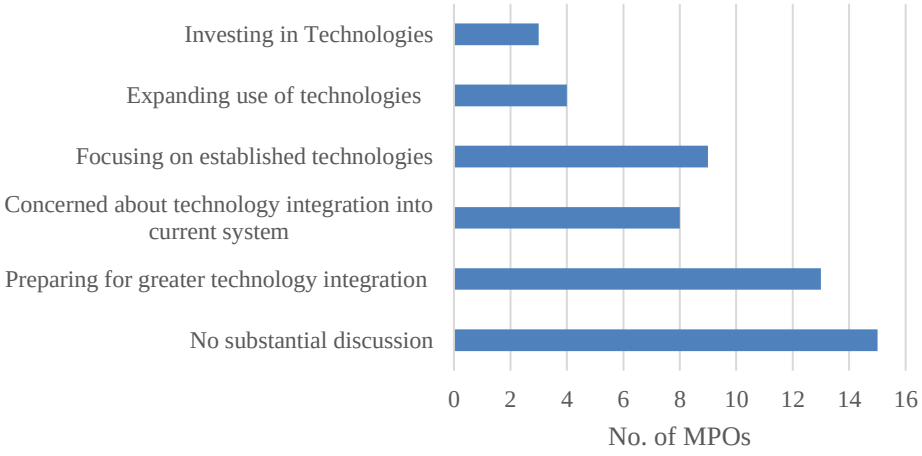

Figure 5. Technology Coding

The discussions of technology ranged in terms of both scope and depth; while most MPO's acknowledge technologies and the likely increase in investment in this area, 15 percent were

concerned about their regions preparedness in terms of infrastructure and the current transportation system. These MPOs ranged in size showing that population did not play a huge role in whether the MPO showed concerns over their transportation systems ability to effectively integrate new technologies. Most of the plans in this category mentioned the uncertainty and unknowns surrounding technologies, but also expressed a concern that current planning efforts would not be sufficient, and more research needed to be done to prepare themselves and the current infrastructure. The theme of uncertainty and an inability to predict the future of transportation technologies was common across those who were choosing to focus on established technologies as well. This is not surprising considering the "hype cycle" of technologies and how previous estimates of autonomous vehicle introduction have proven to be highly optimistic (Madrigal, 2018). 25 percent of MPOs are preparing for greater technology integration; these MPOs have commonalities with those that are focusing on established technologies and concerned about integration but are taking a more optimistic view and attempting to increase technological integration. Tri Cities Area discussed a number of "change drivers" and acknowledged the need to conduct research to move their region forward, while MCAG emphasized the need to remain flexible in both the approach to transportation planning and the key stakeholders involved in the process (Crater Planning District Commission, 2017; Merced County Association of Governments, 2018). Finally, the MPOs that are embracing technologies in a greater sense were split into expanding the use of technologies throughout their system to investing in emerging technologies to solve "wicked" problems in transportation. The MPOs that are expanding the use of the technologies fell into the smallest population bracket suggesting that the MPOs have not previously prioritized technology projects but are moving in that direction. For example, Wichita Falls included technologies in several of their "strategies" suggesting that

ITS and similar technologies would be a larger part of their project moving forward. Those investing in new technologies tended to be larger MPOs that would have the capacity to test new solutions as well as the available funding. MTC is planning to invest $17 million in a suite of technologies that will improve efficiency and SCAG has plans to leverage technology innovations to improve environmental outcomes and access to services (Metropolitan Transportation Commission, 2017; Southern California Association of Governments, 2020). Overall, the feelings toward technology varied, and not just by population size, some smaller regions are choosing to embrace and expand their use of technologies while others are focusing on the technologies they have established in their area. Few MPOs seem to have an overall strategy regarding technology, but this seems directly tied to uncertainties surrounding emerging technologies and when they may enter the transportation system.

Emerging technologies clearly play a large role in MPOs thoughts on transportation technologies as a whole; the promise of AVs, AI, and other advanced developments captured the imagination of many in the transportation world. However, these technologies have yet to bring the vast changes that have been forecasted, but that does not mean that they will not eventually alter the way we travel and interact with the built environment. MPOs are taking note of emerging technologies with 62 percent including some discussion of AVs, similar to the pilot study which saw 70 percent mention AVs. Again, following the trend of the pilot study, less MPOs mentioned CVs with only 44 percent discussing that technology. Figure 6 shows the results of the qualitative coding for the emerging technology category.

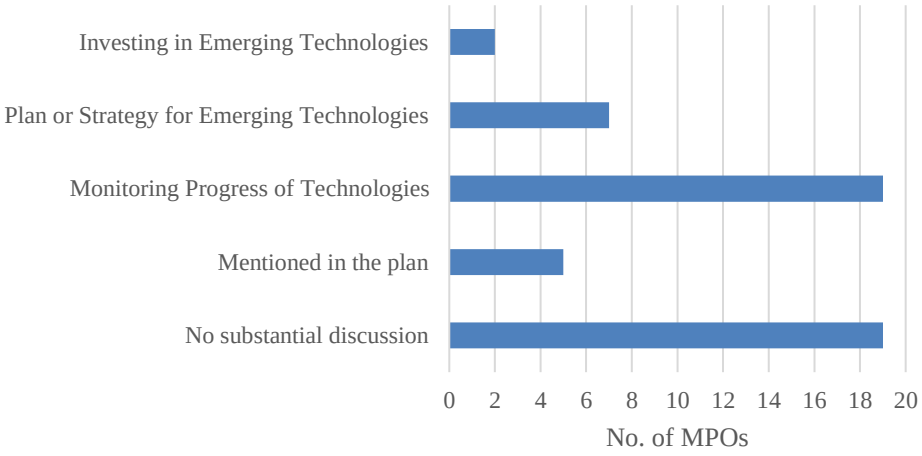

Figure 6. Emerging Technology Coding

Less than half of the plans (19) had no substantial discussion of emerging technologies, showing their increasing relevance to MPOs of all sizes. Almost 90 percent of the plans that did not include a substantial had a population under 600,000, which does indicate that MPOs with the funding and the need (in terms of congestion and increased traveling public) are more likely to be discussing and investing in emerging technologies. Outside of not discussing emerging technologies, the majority of MPOs (37 percent) are still monitoring their progress. The conversation a few years ago indicated that AVs would already be among us by the year 2021, but this not materialized as promised. Many MPOs understand that planning is difficult in such an uncertain environment and spending of transportation dollars should be focused on investments that are sustainable and will serve their region over a long timeframe. This has led to this continuation in the monitoring category; the pilot study in 2018 found that 6 out of 20 MPOs or 30 percent were monitoring the progress of emerging technologies. A/GFTC reported that

they would “continue to monitor emerging transportation technology, including C/AV and alternative fuels, and provide relevant information to member municipalities as appropriate.” The MPO will also focus their Unified Planning Work Program funds on research that will assist their member communities with integrating emerging technologies (Adirondack – Glens Falls Transportation Council, 2018). Efforts that differ from monitoring progress but do not quite reach the level of investment are focused on a plan or strategy related to emerging technologies. SLOCOG has a robust discussion of both the potential benefits and the potential costs of technology, especially in terms of the need for planning for their introduction. Their RTP notes that there is a potential to reclaim physical space and reorient how we view the urban environment if planned for effectively, if not “technologies will decide in their absence” (San Luis Obispo Council of Governments (SLOCOG), 2019). This emphasizes a need to plan for transportation technologies as well as how the goals of the MPO will direct their strategy for deployment. SLOCOG presents a promising practice in terms of how technology planning should be conducted as well as understanding the urgent need for such planning efforts. Finally, some MPOs are investing in new technologies; not always with an overall plan or strategy in place, but often testing the potential of these technologies to complement or improve their current network. Only larger MPOs are focusing on investing in new technologies, such as SCAG who are upgrading their ITS architecture to support CAVs, as well as identifying test sites for those vehicles.

3.3.3. Will the Future with Transportation Technologies be Equitable?

Discussions of equity and technology set a baseline for how the MPO views both where their potential vision for an equitable transportation lies as well as how technology may fit into their

network. However, an equitable technological transportation system is a step further. The plan evaluation results show that most MPOs are just entering the technology investment space; most of the direction and investment so far has appeared at the state level on major highways and interstates. This is set to change as technology becomes more integrated into societies and both new and established technologies expand and develop. MPOs have an opportunity to introduce technological developments in an equitable and just manner, as well as ensure that these investments improve the transportation system for those that currently receive the least benefits from transportation projects. The plan evaluation assessed the efforts toward equity both in terms of more established technology and technology more broadly as well as emerging technologies. The results show common trends in terms of equity of both established and emerging technologies. Interestingly, one MPO discussed the equity of emerging technologies but not established technologies. The discussion around justice and equity in terms of transportation technologies has focused on those seen as major disruptors to the status quo, but equity impacts can be seen in traditional ITS investments, such a signalized stops and automatic street lighting (Tanaka et al., 2021). The results of the qualitative coding are presented in Figure 7 and show a promising, if limited, trend in considering both equity in established and emerging technologies.

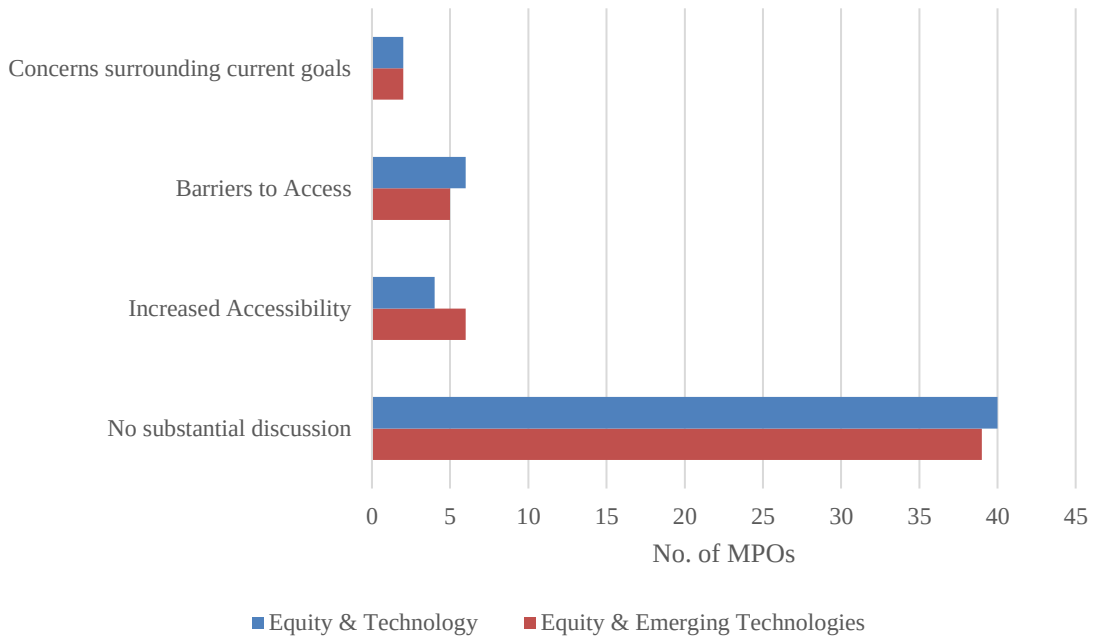

Figure 7. Equity Impacts of Technology Coding

The majority of MPOs still do not discuss the equity implications of emerging technologies to a meaningful extent with 75 and 77 percent of plans falling into that coding category for technology and emerging technologies, respectively. This shows a slight increase from the pilot study where 20 percent of the plans discussed the equity of emerging technologies. Considering 71 percent of plans included some discussion of technology and 63 percent at least mentioned emerging technologies, it is concerning that so few include the equity impacts. However, those that have concerns over technology integration may not be considering the potential equity impacts when their investments for the short-term will be focused in other areas. For example, two MPOs mentioned that technologies may disrupt their current goals relating to equity. FMMetroCOG spoke of the need to maintain public transportation service, acknowledging the potential for CAVs to reduce ridership and threaten transit. Metroplan also noted concerns over diminishing revenue for transit that would lead to service reductions; any reduction in public

transit will impact already underserved and transportation-equity populations (Clark, 2017; F. Zhao & Gustafson, 2013). Even if technologies can provide benefits to the traveling public, barriers to access should be considered. One of the core equity concerns, as discussed previously, is inaccessibility of certain technological advancements by (already) underrepresented and underserved populations. Around 10 percent of MPOs discussed barriers to access for technologies as a whole and emerging technologies specifically. SJCOG and RTC of Washoe County both mentioned the cost barrier to accessing emerging technologies; even if priced to support low-income populations, the method of payment could pose a barrier to the un- and underbanked. SCAG and MTC broadly mentioned barriers, but also indicated barriers through the cost-prohibitive nature of certain technologies, such as CAVs and even micromobility. While focusing on cost-accessibility is key to ensuring an equitable deployment, MPOs should be considering access equity in terms of spatial deployment and accessibility for disabled populations and the elderly. Although these would be included in "equity concerns", only a few plans mention possible accessibility barriers instead focusing on the potential for increased access for senior populations and individuals with disabilities. METRO noted issues with digital literacy for older populations as well as issues with wheelchair accessibility that have become more pronounced as shared mobility services have played a larger role in the way individuals travel (Portland METRO, 2018). 10 percent of plans mentioned the possibility for increased accessibility through technology. For example, MCAG wants to explore the possibility of using technology to alleviate the first mile last mile problem with transit services. Most MPOs mentioned the likelihood of increased mobility for those who do not or cannot drive without delving into the details of additional hurdles to accessibility for senior and disabled populations. While it is true that these technologies have the potential to increase mobility, these technologies

need to provide for a range of different circumstances including language barriers, digital literacy and accessibility considerations, modifications or support for individuals with a variety of disabilities, as well as financial accessibility (Allu et al., 2018; Cordts et al., 2021; Hwang et al., 2020; Vogels & Anderson, 2019). Overall, the discussion of equity as it relates to technology remains limited especially in terms of the barriers to access for these technologies. Although the discussion is limited, it is not non-existent. Some of the larger MPOs are exploring these equity challenges and searching for solutions. Both PACTS, SCAG, and MTC offered some discussion in this area; noting the challenges for low-income, people of color, and people with disabilities traditionally in the transportation system and how new technologies will not automatically present a solution. Lessons learned for larger MPOs projects and research could provide key information for smaller MPOs in the future.

3.3.4. Planning for Transportation Technologies

The overall results of the content analysis indicate a spectrum of views in long-range transportation plans regarding technology emerging technologies. In terms of benefits, MPOs range from optimistic about the ability of transportation technologies to solve or alleviate certain problem to concerned about their disruptive effect. In terms of investment, MPOs tend to be either focused on currently available technologies or utilizing a strategy that funds all technologies, including emerging solutions such as CAVs. A framework was developed, shown in Figure 8, to present the overall sentiment expressed in the plans toward transportation

technologies.[4] Four groups were identified: Pragmatist, Technological Optimists, Cautious Adopters, and Futurists. Pragmatist MPOs remain cautious about the benefits of technology and are taking a more measured approach by focusing on currently available and more established investments. Caution may not always be the driving force behind limited investment but could play a role in how and what those MPOs choose in terms of transportation technology projects. Technological Optimists tend to be more focused on the future and believe that technology can alleviate some common transportation problems, but these MPOs are still focusing investment on established technologies. This could be due to limited funding available and project selection and prioritization that focuses on known entities rather than gambling on emerging technologies. Cautious Adopters are testing and piloting new technologies or investing in certain projects but remain wary about the potential additional costs to such investments. Finally, Futurists are planning agencies that view technologies optimistically, overall, and are choosing to strategically invest in emerging technologies. The framework was developed to see how beliefs surround technology and the possible benefits and costs related to equity. The MPOs in highlighted in green included a discussion of the equity implications of technology within their plans.

[4] The plans without enough discussion of technology to rank on each spectrum sit along the axis for that category (essentially gaining a rating of 0 for that category).

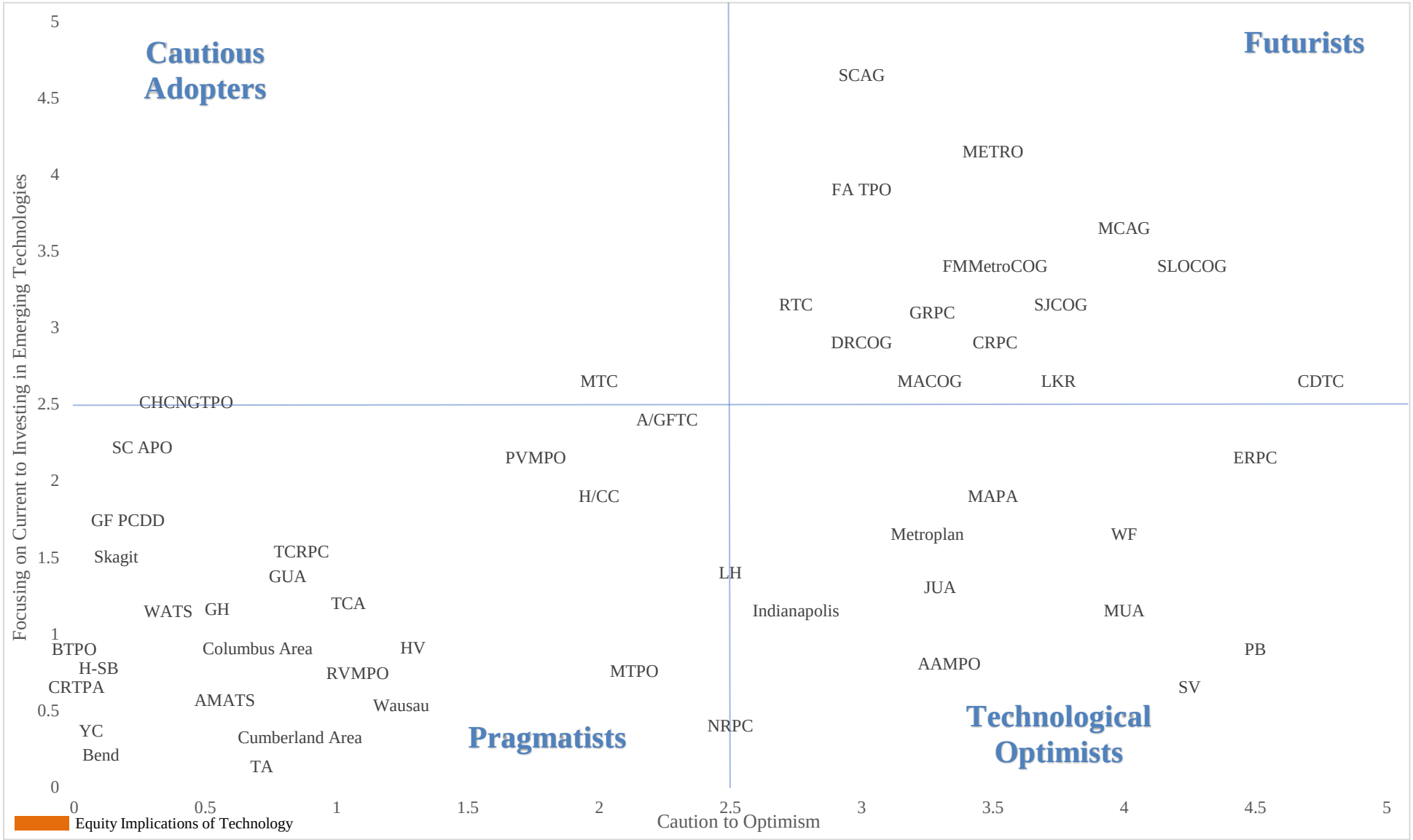

Figure 8. Planning for Technology Framework

The framework shows that most of the MPOs in the study remain focused on current or established technologies. MPOs that remain cautious of new technologies have a greater tendency to be focused on established technologies, but even those considered Technological Optimists appear to be waiting to better understand the impacts and the public opinion surrounding emerging technologies. Only two MPOs fell into the category of "Cautious Adopters"; typified by investing in emerging technologies but showing some caution in terms of the purported impacts or overall benefits. Most of the MPOs that were investing in emerging technologies had a more optimistic view, which then led to pilots, tests, or implementation of new technological solutions. However, showing caution or a critical eye toward new technology investments could help MPOs to reduce costs and focus narrowly on those technologies that will really benefits their region. Each MPO has unique regional challenges that will benefit from a different mixture of solutions that will ultimately include some technological component; however, no one approach, or one technology can be applied or recommended for all regions.

Connecting the technology framework to equity shows that each category has at least one MPO considering the equity implications of technologies. Futurists were the most likely to consider the equity benefits and costs either of technology. This speaks to sound planning as the Futurists are already investing, to some degree, in emerging technologies. Investment without a consideration of equity and justice has the potential to lead to harm and is how many of the previous transportation harms have been enacted

on disenfranchised communities. Those investing in emerging technologies, but not yet discussing equity considerations, tend to be in the earlier stages and are funding research or developing a technology strategy. Despite that, it would be useful to understand their thoughts regarding how to deploy technologies to address current equity concerns for their communities as well as the potential for unintended costs or harms. Pragmatist MPOs and Technological Optimists that discuss equity could be showing their commitment to understanding the full impact before testing new transportation technologies. Overall, the framework analysis shows the varied picture when considering the equitable and just deployment of transportation technologies; exercising more caution without considering equity does not necessarily lead to equitable outcomes. As MPOs move into the future, projects that involve technology should be viewed through an equity lens to ensure that that optimism remains founded.

3.4. Discussion

The results of the plan analysis present the complicated picture of equitably deploying technology; planners and policymakers must evaluate *both* the benefits and the costs to populations that have previously suffered harm from transportation investments. Choosing not to invest out of an abundance of caution may lead to delayed benefits for groups that require them to move toward a just transportation system. While rushing ahead with too much optimism can lead to unjust deployments of technologies that might otherwise have been just. MPOs and other planning agencies must balance these factors and ultimately decide what is best for their region; however, each MPO is

working with their own definition and considerations of equity within transportation. Planning agencies have different resources, capacities, knowledge bases, and differing needs from their communities that must be addressed. These factors offer a nuanced lens in which to review the results of this study; the discussion section will focus on reviewing the potential causes for a lack of discussion regarding equity and technology as well as provide the key takeaways from the plan evaluation.

The plan evaluation sought to assess the extent of technology discussion, especially in terms of emerging technologies, and how planning agencies are considering the equity implications of these new developments. The results showed only minor changes from the pilot study in 2018; this was a new sample of MPOs with a variety of different characteristics, but this shows that the patterns viewed in the pilot seem to occur in other MPOs as well. Plans are considering the impacts of technology and making progress in terms of determining projects or potential investment needs with 71 percent of plans substantially discussing technology and 63 percent including some discussion of emerging technologies. Just over half of the plans discussed equity and their MPOs definition of equity or justice. This shows a marked reduction from the pilot study results where 80 percent of the MPOs including some discussion of equity. While the discussion of transportation equity and justice was more limited in this evaluation, the equity of transportation technologies was discussed in 27 percent of plans representing a slight increase from the previous 20 percent. The plans that discussed equity but not the equity of technology tended to be from smaller MPOs, which could connect more to

their commitment to technology investments or the extent to which technology is included in their program of projects. MPOs often work with limited resources and if technology projects are still limited in their region, research or planning toward equitable deployment may still be in the early stages. Despite this, it is important to note that more MPOs included a discussion of both current and emerging technologies than substantially discussed equity. This seems to highlight a stronger focus on technology than equity, which will ultimately lead to an inequitable deployment of transportation technologies. Many of the recent harms felt by underrepresented and underserved communities in transportation can be attributed to planning without those communities' needs in mind. Both the intended and unintended consequences of transportation planning and decision-making have led to the inequitable system we move through today; the very need for an equity and justice lens to transportation decisions derived from this. Without careful planning, strong equity considerations, sound community engagement, and a reckoning with the racist and ableist underpinnings of our current system; the introduction of new transportation technologies will create more problems than they solve.

The lack of equity discussion, especially in relation to transportation technologies, could be due to several factors. A lack of resources or capacity to truly evaluate these issues through an equity lens is potentially a leading factor for smaller MPOs. Smaller MPOs will focus on smaller and more typical transportation projects with their limited funding. There is also a consideration of the best use case for certain transportation technologies;

rural or less dense regions may struggle to justify an investment in micromobility or an emerging technology pilot when their residents would not be able to easily use or access these services. The analysis and framework showed that most MPOs are focused on more established technologies even if they view emerging technologies or technology generally optimistically. This optimism may be tempered by a lack of practical applications and case studies of these technologies that planners can review and determine whether it would be a good investment for their community. Planners do not want to waste funding on technologies that are eventually made obsolete or those that do not gain full public acceptance. While a number of studies do exist relating to the public acceptance of AVs, these remain largely hypothetical as no large-scale deployment of AVs has occurred (Bansal et al., 2016; Bansal & Kockelman, 2017; Hohenberger et al., 2016; Jardim et al., 2013; Kyriakidis et al., 2015; Penmetsa et al., 2019; Schoettle & Sivak, 2014). Limited implementation of emerging technologies can lead to those concerns over waste of funding. Agencies may want to wait until these technologies have been better established; however, that could lead to scenarios where these technologies are focused on single occupancy vehicles or personal travel rather than transit. While all these factors could play a role, equity and justice still need to be far greater components of transportation technology planning as well as transportation planning.

Assessing the long-range plans of 52 MPOs in the U.S. for the inclusion of technology and equity has highlighted three main trends; (1) MPOs are more likely to discuss

technology than equity within their plans; (2) while technology is important to these agencies, the focus tends to remain on established technologies with limited investment in emerging transportation technologies; and (3) there is a lack of discussion on the equitable deployment of transportation technologies in long-range planning documents. While technologies can often provide solutions to certain transportation problems, most of the major issues facing transportation today will require far more than just technology. Ensuring a more just and equitable system that dismantles the racist underpinnings and barriers to mobility and accessibility cannot be achieved through technological solutions alone. Worryingly, technology has the potential to exacerbate current harms and further marginalize and underserve groups that have not historically, and still do not, benefit from transportation decision-making and investments. Even planners that are considering the equity impacts of transportation technologies must ensure they are taking a balanced approach; one that assesses the potential benefits against the costs and reaches out to their underserved and underrepresented populations to discuss how the technology may impact them specifically. This research has also highlighted the gap between MPOs that require more research into technology and those that have completed the research and have moved to testing and piloting potential solutions. MPOs with greater experience can provide lessons learned and vital knowledge for smaller planning agencies. Research that is conducted and case studies that are completed to assist an individual MPO can provide insight on limitations, costs, and applicability to agencies that are considering similar projects. This would assist in both moving those agencies toward investing in emerging technologies as well as

assessing the equity impacts of their current and planned investments. Knowledge banks or databases could be crucial to ensuring the equitable deployment of technology across the U.S. by providing evidence-based technological solutions as well as an equity analysis of transportation technology investments.

3.5. Conclusion

This study aimed to address how regional planning agencies, the MPO, are planning for equitable technology in transportation through a plan evaluation assessment. The results of the assessment show that MPOs still have room for growth in terms of considering the equity implications of both current and emerging technologies despite progress being made since 2018. Technologies, especially emerging technologies, have the power to vastly change the transportation landscape. Those changes must consider the potential equity implications if we are to build a more just transportation system moving forward. The fact that most MPOs in the study are focusing on current technologies offers an opportunity to embed equity into the process before emerging technologies become a greater focus, as these developments are likely to have broader and deeper impacts on transportation. In addition, the optimism about technology raises questions related to the potential costs and negative implications of new developments. MPOs should not forgo technologies due to potential downsides, but there needs to be greater consideration about the full range of impacts to reduce the burden of the transportation disenfranchised. This research has highlighted areas of need, especially for smaller and mid-sized MPOs, such as processes for greater knowledge sharing and more nuanced

and specific research on the needs of different EJ and Title VI populations. However, the study is limited in scope to 52 MPOs across the U.S.; these present a cross section in terms of population but does not consider the year of plan development or potential differences due to states being more rural or urban. Future research must consider the different factors that can impact planning efforts toward both equity and technology, such as MPO budget, staffing levels, additional resources, and current technology investment levels. Technologies will become a greater part of transportation and our overall mobility in the coming years, if these introductions are to be equitable and just, we must plan for them accordingly.

4. LOOKING AHEAD: AN ASSESSMENT OF PLANNERS' INTENTIONS AND CONCERNS REGARDING TRANSPORTATION TECHNOLOGIES & EQUITY

Transportation technologies promise to change, disrupt, revitalize, and permanently alter our current transportation system, but how will these changes impact those utilizing the transportation system as well as those who aim to plan and improve it? While technology may provide a solution to some of the wicked problems in transportation, it will also bring the potential for further, and deeper, inequities in how we currently move and interact with our environment. Understanding how we are planning for this eventuality and how we can ensure benefits to underserved populations rather than costs is crucial to creating a more just transportation system in the future. This research aimed to understand the intentions of planners toward emerging technologies, to determine whether there was a strategy to technology investment, and ultimately whether equity was considered in the planning process and how equity can be incorporated into a technology strategy. A survey of planners at Metropolitan Planning Agencies (MPOs) across the U.S. was conducted to delve into these questions and find out what the perceived equity challenges and benefits of transportation technologies might be as well as how this connects with both equity and technology planning separately. Results showed that planners and their agencies are focusing to a greater extent on equity and making improvements to how they measure and define this throughout the planning process. Technologies, while important for all, are often the focus of larger agencies that have the resources and capacity to invest. Most agencies are still focusing on ITS and

planning and preparing for emerging technologies. Finally, planners noted a range of possible equity benefits and challenges arising from technologies; often these benefits and challenges overlapped. The potential for technologies to increase accessibility and suffer from barriers to access provides an opportunity for planners to direct the deployment of these innovations to ensure the former and reduce potential for the latter.

4.1. Planning for Disruptions

Not all planning efforts can, or need to be, formalized. Emerging areas, changing demographics, economic stability can all be reasons to remain flexible. The traditional planning documents created by regional agencies and required by the federal government often do not leave room for a great deal of flexibility. In order to be eligible for federal funding, projects must be included in planning documentation (Sciara & Wachs, 2007). Investing in emerging technologies or even technological solutions, as they can be expensive, requires strong justification and knowledge that it is the right solution for the region. These conditions can constrain planning efforts and even the long-range planning document that is considered more visionary because they still must be grounded in planned and designed projects. This makes it difficult to justify and secure funding for projects that involve newer and unproven innovations, especially in small to mid-sized regions. While greater flexibility and the creation of living documentation would assist planners in dealing with uncertainty, disruptions, and the everchanging transportation environment; planning must still operate within the constraints of the formalized process to secure federal funding (Lyons & Davidson,

2016; Pastor & Benner, 2015). Although planning for technology or other potential changes to the urban transportation environment may be missing from formal plan documents, MPOs tend to be closely monitoring these new developments to ensure they are ready for their eventual deployment.

Emerging transportation technologies, especially in the form of autonomous vehicles (AVs), are being monitored closely by MPOs, but that does not always translate into the regional transportation plan (RTP). In 2016, only one of the 25 largest MPOs discussed AVs in their RTP (Guerra, 2016). However, interviews with those MPOs showed that planners were following developments in the technology but felt it was too early to include anything in their plan documents. While MPOs do not want to be caught off guard, they also do not want to make undue assumptions about the potential deployment and full-scale implementation of AVs in their region. A review of plans completed in 2018 and 2019 showed a vast increase in AV mentions and discussion in RTPs from the larger MPOs across the U.S. 41 out of 52 included some discussion and 12 included policies related to AVs (McAslan et al., 2021). This increase shows the importance of considering technology developments both in and outside of formal planning documentation. The four-to-five-year planning cycle of the RTP leaves a great deal of room for growth and change in the intervening years, which needs to be considered when planning in transportation is dealing with rapid changes. For example, micromobility, in the form of e-scooters, burst into cities without warning in 2017 leaving most cities scrambling to develop adequate rules and regulations (Cross, 2020).

As companies and the public sector continue to innovate and utilize new technologies, the importance of a dynamic planning process grows. This dynamic process must consider all possibilities in terms of emerging technologies, and one that still seems to be lacking in the RTP is a discussion of the equity considerations of transportation technologies.

The importance of equity is rapidly increasing in urban planning, and especially transportation planning. Evidence of previous injustices remain, and work must be done to reset the scales and ensure an equitable and just transportation system for all. Initiatives are underway at the federal level to incorporate racial equity into project planning through grant programs and a recent executive order, which acknowledges the harm done to Black communities through the development of the interstate highway system that continues today with expansion and maintenance efforts (Buttigieg, 2021). MPOs have long tackled these issues through Title VI and Environmental Justice requirements (Cambridge Systematics, 2002; Clinton, 1994; Twaddell & Zgoda, 2020b); however, the recent social and cultural changes have brought new urgency and a chance to move beyond just the requirements. Inclusion of equity in the project prioritization process allows for more targeted investment in programs and projects that benefit underserved populations (Twaddell & Zgoda, 2020b; Williams et al., 2019). Performance measures for MPOs were mandated under MAP-21, but many agencies have developed their own measures to understand the impact of their transportation plans and investments (Grossman, 2018; Hartell, 2017). While MAP-21 did not include

a specific equity performance measure, MPOs that are focused on creating a better transportation system for all have developed their own measures. The renewed focus on equity and justice in transportation arrives at a crucial moment for society, but especially for the planning practice as the coming years promise a great deal of change in the transportation system.

The benefits of emerging technologies, such as connected autonomous vehicles (CAVs), have been thoroughly explored due to their potential to improve safety, increase accessibility, and reduce environmental harms (Anderson et al., 2014; Clewlow, 2019; Fagnant & Kockelman, 2015, 2014; Greer et al., 2018; Penmetsa et al., 2019). These benefits could fundamentally alter the transportation experience for certain groups by allowing them easy access to travel without having to drive themselves, especially important for senior populations and individuals with disabilities. However, improvements for those populations, and many others, are not guaranteed. Concerns arise over barriers to access, the distribution of benefits, and privacy. Financial, physical, and spatial barriers to access exist when considering new technologies such as micromobility, CAVs, and electric vehicles (EVs). The initial purchase cost of an EV can price low-income individuals out of the market, and the used electric vehicle market remains limited (Fleming, 2018; MacArthur et al., 2018). In addition, payment systems must accommodate a range of different circumstances to support the unbanked and underbanked (Golub et al., 2021). Physical characteristics of these vehicles can burden people with disabilities by failing to accommodate for visual, auditory, cognitive, and

ambulatory impairments (Allu et al., 2018; Claypool et al., 2017; Cordts et al., 2021; Fink et al., 2021; Hwang et al., 2020; Kuzio, 2021). Finally, spatial access to supporting infrastructure, such as ITS and EV charging stations, is crucial if underserved communities are expected to benefit. Investments should be careful considered and take into account environmental justice communities and their needs if equity is to be a goal with transportation technologies.

4.2. Methodology

This research utilizes a survey to understand how planning agencies are thinking about technology beyond their plan document. The aim was to understand planner and agency intentions both today and as they look toward the future to understand whether we are planning for an equitable future with transportation technologies or not. The survey intended to address the following questions:

- What are metropolitan planning organizations intentions toward (emerging) transportation technologies?
- What are planner's intentions regarding equity in transportation, both today and in the future?
- How do they intend to incorporate equity considerations into their technology strategy?

4.2.1. Survey Conception & Design

A survey method was chosen to complement previous studies that have undertaken analysis on plan documents and investments. The survey instrument was then designed with the gaps or questions formed through plan and investment assessments of transportation technologies. Through the literature review and the results of previous studies, the research questions were developed to gain greater insight into how emerging technologies play into equitable transportation as well as develop guidance or lessons learned that can be a resource for MPOs and other transportation planning agencies across the U.S.

Emerging technologies, such as AVs, connected vehicles (CVs), micromobility, and even artificial intelligence and blockchain, are often sold as "solving" transportation problems, such as congestion, improving safety, and efficiency (Bullock, 2019; Fagnant & Kockelman, 2015; Greer et al., 2018; Jianjun et al., 2016). However, most regions have unique aspects to these problems and there often is not a "one-size fits all" technological solution that can be applied. The first research question intended to understand where MPOs are focusing their efforts and investments in transportation technologies, as well as whether these efforts amount to a technology strategy. Understanding how MPOs are considering technologies differently can provide a better understanding to how equity can be incorporated into those efforts.

While equity has been a part of transportation planning for decades, often through environmental justice and Title VI requirements, there has been an increased focus in

recent years on prioritizing equity and justice in transportation (Leahy & Takesian, n.d.; National Academies of Sciences, 2020; U.S. Department of Transportation, 2021a, 2021b). MPOs may be altering or reorienting their approach to equity, equity and environmental justice analyzes, and what constitutes a just transportation system in the wake of this shift in focus. The second research question hoped to better understand how equity and justice are considered at the MPO level and if any changes are on the horizon that could help or hinder the equitable deployment of transportation technologies as well as equity in transportation.

The final research question aimed to understand the planner's thoughts and intentions in the areas of emerging technologies and equity. As previously noted, formalized planning documents are often constrained by resources, time, and the need to be flexible to changing conditions. Emerging technologies, especially AVs, can be volatile in terms of development timeline and therefore introduction and integration into the transportation system (Madrigal, 2018). Long-range planning documents deal with the tension of needing to consider these developments while remaining flexible regarding projects and investment. Due to this, planning documents do not show the full scope of efforts being made by planning agencies (Guerra, 2016). The survey was designed to uncover some of these efforts and to highlight the difficulties in planning for transportation technologies through an equity lens.

4.2.2. Sample and Distribution

The survey was aimed at the main transportation planner at an MPO; however, MPOs can have specialist positions, such as Technology Planner or Equity Planner, which were also targeted to provide specific insight into each planning area. A contact list was developed using MPO websites and the MPO database provided by U.S.DOT (U.S. Department of Transportation, n.d.). The survey was also distributed through the Transportation Research Board's Standing Committee on Metropolitan Policy, Planning, and Processes and the Standing Committee on Equity in Transportation. The survey was sent to all MPOs with valid contact information.

4.2.3. Survey Instrument and Analysis

The survey instrument had three sections to address the three different elements of planning being assessed: technology, equity, and the equity implications of technology. The technology and equity questions establish as baseline for the MPOs current understanding and planning capacity toward each planning component with the final section connecting the two efforts. Definitions of concepts and terms such as environmental justice and emerging technologies were provided to improve the comparability of responses from different agencies. The instrument utilizes a mixture of closed and open-ended questions to collect basic information for quantitative analysis as well as rich contextual data related to technology and equity. The full survey instrument with rationale for inclusion is provided in Appendix C. The questions were developed to

address the research questions; specifically in terms of how planners view the equity of emerging technologies that might not translate into formalized planning documentation. In addition, the emerging technology focused responses may provide insight into promising practices, how to effectively track and monitor technology investments, and avenues for strategically planning technology projects.

The survey results provide a mixture of quantitative and qualitative data; the multiple choice or closed questions will be presented quantitatively with some basic descriptive statistics and the open-ended text responses will be qualitatively evaluated. The qualitative results will present themes, or an overview of the responses provided. Insights into planning in different regions and for different population sizes are determined where possible.

4.3. Results

There are 402 MPOs in the U.S. and the survey received 122 responses from 110 MPOs. The 2010 Census population of these MPOs ranged from ~55,000 to ~12 million. The results showed that while responses did vary, and some respondents noted the challenge of planning for technology at smaller MPOs, clear patterns did emerge in terms of the potential benefits and challenges those agencies foresee with equitable technology.

4.3.1. Technology in Transportation Planning

Most respondents, 53 percent, identified ITS as their main focus in terms of technology; only 13 percent indicated that electrification was their core focus, 11 percent answered

emerging technologies, and 24 percent selected other. In terms of the respondents who indicated that they had a different focus, some noted that they had no main focus at this time or that they were planning for all technologies mentioned. A few mentioned a combination of the three technologies showing that regions are trying to ensure they are ready for all possible technological changes. Outside of the three technologies, focuses included big data and performance metrics, bicycle and pedestrian related technologies, micromobility, broadband access, and a greater range of alternative fuels. Considering that ITS is a technology that has developed over the past few decades, it is unsurprising that many regions are still focusing on upgrading and maintaining these systems. ITS can provide several benefits in terms of congestion and the environment for different regions, as well as better preparing a region for more connected vehicle technologies. Emerging technologies remain in a state of flux in terms of large-scale deployment, which can lead to hesitancy regarding large investments.

Each MPO will have a different focus within the technology group also, but a key component of effective technology investment is understanding current assets and gaps in the system. MPOs were asked whether they maintained an inventory of technology projects or components in their system. 68 percent of MPOs do *not* maintain a technology inventory, which can create problems when new investments are being planned and programmed. This is especially important considering that the majority of MPOs are focusing on ITS, which often has more components and is harder to track retrospectively. Only 21 percent of those without an inventory indicated that they were planning to create one in the future. The MPOs that do maintain an inventory generally

tend to provide this to the public (62%) and often develop them through surveys of their member organizations. MPOs referenced coordination with higher level agencies, such as the DOT, as being effective in helping to establish and develop these inventories as well as potentially engaging consultants to assist with the work. In terms of tracking the technology projects and components, a GIS tool or software is suggested to provide the information in a spatial format. MPOs that are hoping to develop such an inventory should start with clear spatial and project description information in their Transportation Improvement Program (TIP). Each project with a technology component should be identified for ease of management and a survey can be conducted to try and account for historical projects. Maintaining a coordinated database after these efforts is crucial to an accurate inventory; this can be completed in coordination with the regional planning process or ITS architecture development and tracked using GIS.

Technology inventories provide a baseline from which to plan but plans then need to be created that focus on technologies. The results of the question related to specific technology plans follow the lack of technology inventories at the MPO level. Only 17 percent of MPOs create specific technology plans with 23 percent planning to do so in the future. Although it is important to plan for technology, MPOs often have limited capacity, either budget or staff, to create additional plans. These MPOs would benefit from expertise and knowledge sharing from other institutions on how to incorporate some technology planning best practices into their current plan documents, such as the

TIP or RTP. Figure 9 shows an overview of the different types of technology planning documents created.

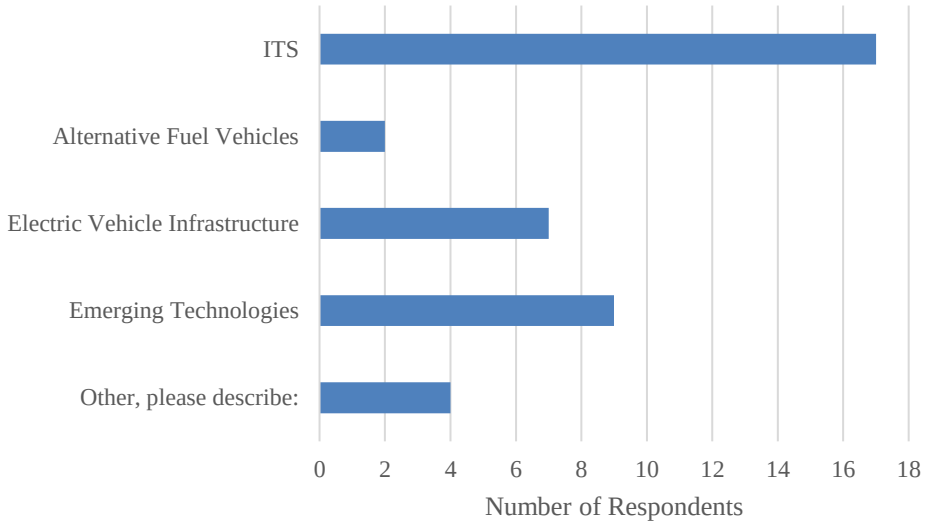

Figure 9. Technology Plans Developed by MPOs

The most commonly developed technology plan was for ITS, which aligns with the main focus of most of the MPOs. 23 percent of respondents selected that their MPO develops an emerging technology plan. Emerging technologies are still in the initial stages of deployment and many MPOs do not want to be "caught out" by a larger scale introduction; planning and research documents can help MPOs in knowing how prepared their region is and what investments they can and should make. Around 18 percent of respondents stated that an electric vehicle infrastructure plan exists at their MPO. As EVs increase their market share, the importance of infrastructure to support charging becomes increasingly apparent. Recent legislation at the federal level and the priorities of the current administration are increasingly that importance even further (DeFazio, 2021; The White House, 2021). Other plans included shared mobility, an all-

encompassing “smart region” plan that includes each of the technologies mentioned, and a micromobility plan.

4.3.2. Equity in Transportation Planning

The survey asked several questions related to equity and equity planning efforts, these questions delved into ongoing changes that may not be reflected in the planning documents, as well as assessing the common populations that are now included in equity or environmental justice analyzes. Beyond low income and minority populations, 90 percent of respondents to the survey include additional populations when conducting an equity analysis. Figure 10 shows the populations included in equity analyzes by MPOs.

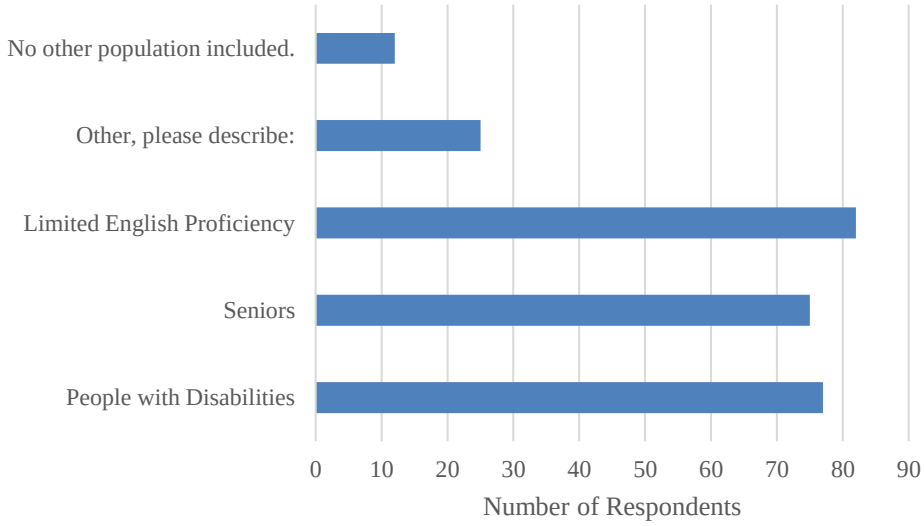

Figure 10. Equity Analysis Populations

The most common additional populations considered are those covered by Title VI, people with disabilities and English language learners, commonly known as limited English proficiency. 25 respondents do include other populations, these ranged from

zero-vehicle or transit dependent households to veterans to free school meal populations. Others noted including female head of household with children under 18, youths or children, native populations, females, and the LGBTQ+ community. A few MPOs noted including additional Title VI populations such as foreign born. Spatial characteristics were also noted with food deserts and housing affordability considered by two different respondents.

Moving beyond the equity analysis is crucial to a more just transportation system, the equity analysis is designed to ensure that underserved populations do not receive an undue burden from transportation and that they share in the benefits. However, justice requires a focus on the systemic and institutional barriers that impact transportation. Projects must be designed with equity and justice in mind to address these shortcomings, not simply evaluated to ensure that no further harm is perpetrated. The first step for many planning agencies is to include equity in their project prioritization or selection frameworks (Twaddell & Zgoda, 2020b; Williams et al., 2019). 72 percent of respondents to the survey now include equity within their project prioritization process with 16 percent planning to do in the future. This represents a small but important step in creating a more just transportation system.

Another important factor in advancing equity is measuring the impact of equity planning efforts; several measures are generally considered by MPOs, including dollars invested in environmental justice communities or the percent of projects located in those

communities. Measuring equity, however, is complex. Investing in a community is only equitable if the community wants the project and it directly benefits those previously harmed by transportation decision-making and investments. Figure 11 presents an overview of the performance measures selected by respondents to the survey.

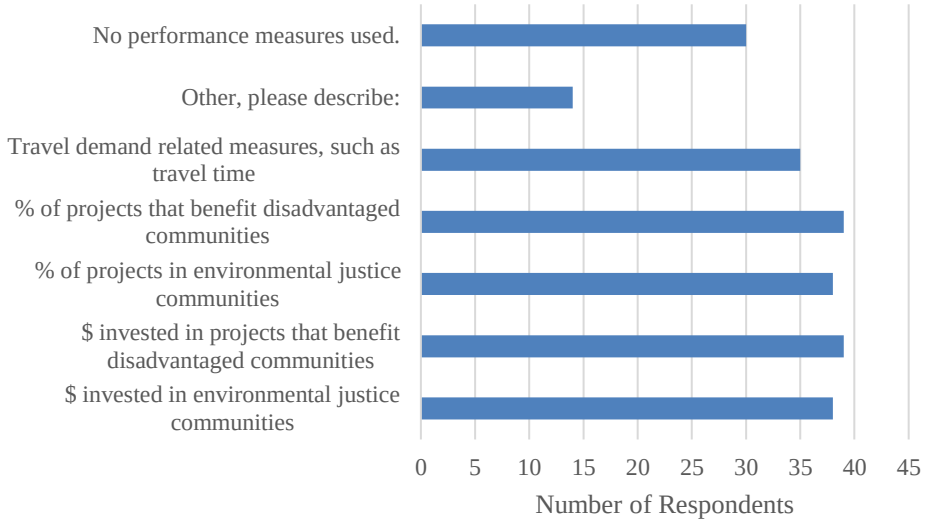

Figure 11. Equity Performance Measures used by MPOs

Approximately 25 percent of MPOs do not utilize performance measures for their equity planning efforts. While measuring the performance of equity can be challenging, it is important to ensure that these efforts are having the desired effect. The most used performance measures were dollars invested in, and the percent of projects that *benefit* equity-priority communities. While further research would be needed to determine how "benefit" is measured, this shows a shift toward focusing on the needs of equity-priority communities and not just spending money in those communities. As equity increases in importance in transportation planning, it will be important to ensure those measures

remain the most common. Other measures tended to be accessibility focused, but some did focus on safety, transit availability, and environmental impacts.

2020 brought the onset of a global pandemic, a greater focus on climate change, and showed the increasing need for racial equity throughout all institutions in the U.S. and most of the Western world. These profound events and cultural shifts will not have escaped planning agencies across the country, and the survey sought to assess how this may have impacted equity planning at the regional scale. Of those responding, 63 percent indicated that their equity planning had changed in the last year with 34 percent saying it had remained the same, and 3 percent indicating an unfamiliarity at this time with the changes. Table 9 shows the results of the qualitative coding.

Table 9. Coding Themes for Changes to Equity Planning Efforts

Theme	Number of Respondents
Project Prioritization and Decision-making	12
Planning Principle or Goal	4
Funding Allocation Change	2
Shift in focus to impact rather than $	5
Extended EJ analysis and/or Research	25
Increased Public Engagement	8

Several themes emerged for the text responses, but the focus was often on extending or improving their equity analysis to better reflect the goals and needs of their region. This often requires additional research to understand how to improve and how other regions have addressed this issue. The themes show that planners are increasingly assessing their equity planning efforts and addressing where change is needed. The increase in equity within project prioritization and decision-making was another common thread among the responses, which when coupled with increased public engagement should lead to better project selection for transportation-equity communities.

4.3.3. Equitable Technology in Transportation Planning

Survey respondents were first asked to assess whether transportation technologies would be a net negative or net positive, on a scale of 0 to 100, for their regions and then the same question was posed specifically for equity or EJ populations. The average rating for transportation technologies was 70.5 and only 25 respondents changed their response when considering EJ populations. Respondents to the initial question may have had those populations in mind already, however. The average rating for the impact of transportation technologies to EJ or equity populations was 57. Although a limited number of planners altered their answer when considering equity-priority populations, those that did believe that the benefits of transportation technologies are not as clear cut for those groups.

The final questions centered on the equity benefits and challenges of transportation technologies as well as whether MPOs were testing any emerging technologies with equity in mind. Planners were asked to consider the equity benefits and challenges of transportation technologies for their regions. Answers varied and often truly considered the regional challenges or potential benefits due to the unique characteristics of their region. However, common themes did emerge that discussed accessibility in terms of access to more locations than previously as well as improved access for people with disabilities, the impact to transit, safety, the environment, as well as economic changes related to access to opportunity or increased employment, and the improvements that technology could bring to planning. Table 10 presents an overview of the themes addressed in the survey responses.

Table 10. Equity Benefits of Transportation Technologies

Theme	Number of Respondents
Accessibility	59
Transit	8
Safety	12
Environment	17
Economics	9
Planning	6

Many responded that new technologies, such as AVs, could increase accessibility by providing more responsive service to those who cannot drive. This was the most common benefit mentioned by respondents with them noting the potential for increased access to all modes as well as better service provision for underserved populations. Micromobility was seen as a way to solve last mile problems for transit riders as well as offering an additional mode of travel. Transit was another area that planners felt could benefit from AVs, especially in creating micro transit or more demand responsive services. Safety is strongly associated with an increase in CAVs; although the technology is not ready to handle all driving situations, the assumption is that these vehicles will reduce crash rates and provide for a safer system overall. In terms of the environment, respondents noted the potential for improved air quality. Low-income and minority neighborhoods tend to have worse air quality, so any improvement should hopefully occur first in those areas. Economic benefits were related to the potential for reduced costs due to automation, but more commonly were related to access to opportunity. Providing better transportation options and improving the effectiveness of the system with technologies should allow for better access to jobs, education, and healthcare. Finally, six respondents noted potential improvements to transportation planning with access to more data to understand equity impacts as well as the ability to provide information to the public faster and more effectively.

Equity challenges related to transportation technologies were far more varied and often connected to the potential benefits. This crossover indicates a strong need for effective

research and planning and policy actions when implementing technologies in any region. Table 11 shows an overview of themes and subthemes identified in responses to regional equity challenges of transportation technologies.

Table 11. Equity Challenges related to Transportation Technologies

Themes	Subthemes	Number of Respondents
Financial		**46**
	Cost to Agency	17
	Cost to Consumer	23
Safety		**3**
	Vulnerable Populations	3
Barriers to Access		**47**
	Broadband/Smartphone Access	10
	Technological Literacy	5
	Inclusion of Disabled Populations	2
Governmental		**10**
	Political Buy-In	4
Planning for Equitable Deployment		**16**
Land Use		**5**
	Gentrification	3
Public Acceptance		**6**

Themes	Subthemes	Number of Respondents
Impact to Other Modes		**11**

Subthemes were included to address the more specific concerns that planners had, for example, financial considerations related both to cost to the agency and cost to the consumer. Cost to the agency presented an equity challenge because respondents were unsure whether planning could successfully direct an equitable deployment of technology, or any deployment of certain technologies, without significant infrastructure and other investments.

The main theme from the responses concerned barriers to access new technological developments as well as financial implications. The cost to the consumer also represents a barrier to access, and so those presenting such a cost as a barrier were coded within both categories. Concerns over cost to the agency often related to EVs and AVs; respondents understand that large scale deployment of these technologies require investment in infrastructure on the part of the public sector. Constrained budgets can hamper efforts to build out this infrastructure even if the agency believes they could use these technologies to benefit their underserved populations. Costs to the consumer related to EVs, AVs, micromobility, and shared mobility services and often related to the cost to the agency. The high upfront cost of EVs, and potentially AVs, prices out a great deal of the communities that MPOs serve. Micromobility and shared mobility services

could be deployed by the private sector, which would hinder efforts to ensure access for low-income communities. Concerns related to the unbanked and underbanked were noted when current ride hail and micromobility operations often require a credit or debit card to utilize their services. Overcoming these issues was seen as crucial to the equitable deployment of transportation technologies.

Other barriers to access included access to broadband or ownership of a smartphone, technological literacy, and the inclusion of disabled populations when designing and implementing established and new technologies. Broadband access and smartphone ownership were often linked together with the perception that new services will require a mobile device, and access to the internet, to call for a ride or to receive the full benefits of increased information from the transportation network. Broadband access was also linked to cost in terms of increased data plan charges. Similarly, planners were concerned about the level of technological literacy required to fully engage with new services and access additional information. Technological inclusion is also a concern; if systems are not created with visual, auditory, and cognitive disabilities in mind, these individuals will be locked out of new services enabled by technology. This barrier related to both the software and hardware utilized as autonomous shuttles or vehicles must be accessible for everyone. Access can even be impaired by surrounding infrastructure, which when linked to concerns over cost to the agency, have serious equity implications.

Governmental and planning concerns often linked back to financial considerations; the need for political "buy-in" is important if planning agencies are to have the necessary funds to ensure equitable deployment. Concerns over a two-tier system emerged where certain roads or modes lose priority when new technologies arrive in their area. Reduced ridership on transit due a switch to vehicle travel, either EV or AV, would hurt the limited revenue that transit agencies collect as well as reducing the incentive to invest in transit as well as other alternative modes. Common EJ issues related to public engagement and acceptance were noted in terms of effective planning; not only is community buy-in important, but planners must ensure that technology projects benefit traditionally underserved communities. Few respondents discussed safety, but those that did referenced vulnerable populations, such as bicyclists and pedestrians. While AVs may reduce crashes involving multiple vehicles, the challenge of pedestrian and bicycle identification remains. Finally, concerns related to land use, sprawl, and gentrification were raised both for micromobility, in terms of gentrification, and EV and CAVs, related to sprawl and loss of economic opportunity.

The survey closed with a question relating to emerging technology pilots with the hope of finding equitable technology planning being put into practice. 28 respondents indicated they had a current or planned pilot involving technology and 23 indicated that the project included an equity component. Respondents were presented with four options as well as "Other"; multiple equity components could be selected. 61 percent indicated a spatial equity component with the project occurring in an equity community. 48 percent

included research on impact of the technology to equity populations. 43 and 30 percent respectively had goals or target for benefits to underserved communities and participation in the pilot by these groups. Only 13 percent selected other, with most of the responses indicating a spatial equity component. Respondents were asked to provide details of the pilot and the equity component and Table 12 shows an overview of the project types mentioned.

Table 12. Overview of Pilot Project Types

Project Type	Subtype	Number of Pilots
Micromobility		10
	e-scooters	4
	e-bike share	5
Micro-transit		3
Mobility Hubs/Services		4
Smartphone Apps		2
Smart Traffic Lighting		2
Autonomous Vehicles		5
	transit pilot	2
	dedicated lanes	1
Safety/Vision Zero		1
Clean Energy		1

The equity components generally fell into one of three categories: financial, spatial, and economic. Financial involved reduced cost for low-income users of the service as well as ensuring that the service did not require a credit card or bank account. Spatial equity relates to the specific location of the project in EJ or equity communities. Finally, two pilots noted the expansion of economic opportunity for transportation-equity groups through improved accessibility.

4.4. Discussion

Equitable technology is clearly a consideration for planners at MPOs across the U.S., but there are variations in how equity is being considered as well as how emerging technologies are perceived. 25 respondents believe that when considering underserved or transportation-equity populations alone, the benefits of transportation technologies to their region are, overall, reduced. Others may have considered equity when weighing the overall positives and negative of technologies, but there was still a decline from an average of around 71 to 57. This response highlights the need to plan for the equitable deployment of technology; respondents noted how previous transportation disruptions had disproportionately impacted equity populations and that changes in the future seemed likely to follow that pattern. The concerns highlighted the uphill struggle that agencies have when juggling political and financial issues; fears over buy-in and lack of funding seem likely to, again, impact the already underserved populations in the U.S.

The consideration of equity in transportation planning is increasing and many agencies seem to be altering their current practices and policies to better plan for an equitable and just future in transportation. This reflects recent research and shows a marked change from the mid-2010s (Duthie et al., 2007; Kuzio, 2019; Manaugh et al., 2015); environmental justice and equity analyzes are moving beyond the basic requirements to include multiple populations and use a more holistic approach. Many MPOs are focusing not just on investing in previously underserved areas but investing in projects that benefit those communities. Despite EJ requirements remaining vague at the federal level, MPOs seem to be implementing new policies and practices that place a higher priority on equity as well as using better measures of success, such as including equity in their project prioritization process, expanding public engagement efforts, and including more nuanced analysis techniques (Golub et al., 2013; Karner, 2016; Karner & Niemeier, 2013a; Twaddell & Zgoda, 2020b). Making progress in equitable transportation planning is crucial if these techniques are to be applied to the deployment of technology; establishing a baseline understanding of the equity issues within a region will also allow planners to connect technological solutions to their current problems.

While there is still an opportunity to plan for an equitable deployment for emerging technologies, most MPOs remain focused on existing technologies, such as ITS. Caution toward emerging technologies could be for several reasons, but survey responses did indicate that a lack of funding and concerns over public acceptance have led them to focus on more traditional investments. Although this does provide more time for

research, pilots to determine challenges for underserved populations, and to plan for implementation with equity in mind; existing technologies also need to be viewed through an equity lens. ITS will form the backbone of a connected and autonomous transportation network, so where and how these investments are being made is important to both equity and justice. The purpose of ITS should also be strongly considered, an investment that increases surveillance could harm BIPOC communities far more than it helps (Benjamin, 2019; Guerrero-Ibanez et al., 2015; Zuboff, 2018). Similarly, if the environmental benefits of technologies are to be realized, investments in electrification must occur in low-income communities. Agencies should also consider the upfront cost of electric vehicles for the consumer; investing in charging infrastructure is only worthwhile if the community members can afford to switch to an EV. In addition, the electrification of transit should begin in EJ communities to ensure those who have been harmed the most receive the environmental benefits, or harm reduction, first.

When discussing the possible equity benefits and challenges in terms of emerging technologies, themes overlapped. The possibility for technology to both improve or deepen inequities depends on decisions surrounding implementation and integration into the current system; planners have the opportunity at this juncture to ensure that equity is front and center in their emerging technology projects and investments. Areas that were highlighted through the survey as needing greater attention where: accessibility, safety, planning, and economics or land use.

Increases to accessibility are only possible if barriers to using and interacting with technologies are reduced. These barriers include financial, physical, and spatial aspects of utilizing technology. Private provision of new mobility services raises cost concerns for low-income users; agencies can work with private companies to ensure equitable access or develop their own services. Issues related to the unbanked and underbanked should also be considered; anxiety over attaching a credit or debit card to these services can deter even those with a bank account, but often "underbanked", as they do not have the financial cushion to weather identity fraud, from utilizing ride hailing or micromobility services (Golub et al., 2021). A few of the pilot programs are incorporating these concerns into their deployment and testing potential alternatives for payment, including cash. Physical barriers impact people with disabilities; while technology can assist in the efficiency and effectiveness of demand responsiveness service, by providing online booking, vehicle tracking, and faster service, systems and vehicles must be designed with a range of disabilities in mind. Ambulatory, auditory, visual, and cognitive disabilities all require different designs to enable a smooth and easy user experience. Some of these design changes will even conflict; those with cognitive disabilities may suffer under changes that improve the experience for those with visual and auditory disabilities. These conflicting design elements must be considered and should be customizable to ensure access for all to new technologies. Spatial barriers relate to the location of investments and the populations they then benefit or harm. Planners have a direct role in considering the spatial aspects of technology investment and should ensure spatial equity through their transportation programs.

One of the purported key benefits of CAVs is increased safety, but safety in the sense of reducing vehicle on vehicle collisions (Anderson et al., 2014; Fagnant & Kockelman, 2015). So, while CAVs may increase the safety of the roadways for the driving public, those who move around by foot or bicycle could have more to fear. Although a survey of vulnerable road users found that they were less concerned over safety with AVs that might be expected, this was prior to the Uber self-driving car crash that killed a pedestrian in Arizona (Madrigal, 2018; Penmetsa et al., 2019). Detection and avoidance of vulnerable populations is a core safety concern, but it is also an equity and justice issue (Hoffmann, 2016). Black, Indigenous, People of Color (BIPOC) are more likely to face traffic violence when biking or walking as well as feeling unsafe due to excessive enforcement of regulations (C. Brown, 2021; Butler, 2020; Herbert, 2021). This is only exacerbated by the current limits of technology such as facial recognition that regularly misidentify non-white faces (Benjamin, 2019; Buolamwini & Gebru, 2018). Regions that are focusing on making improvements to non-automobile modes of travel must consider the safety risks to these populations when introducing more vehicles, through both EVs and AVs, and more "intelligent" vehicles, such as CAVs.

The impact of AVs to urban land use has been heavily debated in recent years, initial thoughts were that reduced spacing between vehicles could reduce congestion but the likelihood of "ghost" trips with no one riding in the vehicle would only increase congestion and then sprawl (Childress et al., 2015; Fagnant & Kockelman, 2015, 2014;

Fraedrich et al., 2019; Gruel & Stanford, 2016; Thakur et al., 2016). Increasing congestion and sprawl is undesirable in urban environments and planner are right to be concerned about this and the reduction in more efficient modes, such as transit. Increased sprawl exacerbates access to opportunity for low-income populations as commutes increase to access affordable housing. Concerns that technologies can increase gentrification are contrasted with the potential increase in accessibility and economic opportunity as more transportation options are made available to those who do not drive. Ensuring implementation that complements the current network rather than overloading or contributing to sprawl will require planning and policy actions to direct the usage of new technologies, such as EVs and CAVs.

The contrasting nature of the potential benefits and challenges present an opportunity for planning, but it will not be easy for planning to ensure that benefits not harms are felt by underserved communities. Current planning processes will need to focus on equity to a greater extent, which is happening at MPOs, as well as allowing for greater flexibility. Big data and new technological tools can help planning better assess equity, but it should not be a replacement for strong community engagement effort that asks what the community wants and how transportation can provide it. Engaging with communities about the need and use of technologies in transportation should counteract past trends in transportation development, which is a concern for certain planning agencies. Although political buy-in and governmental will is needed for planning agencies to effect true

change, technology can be used as a tool for improving equity when incorporated in a way that serves those communities.

4.5. Conclusion

The results of this research represent a subset of planners at agencies across the U.S.; the research sought to understand how planners were thinking and preparing for emerging technologies, especially when considering equity implications. While the survey did not receive responses from all agencies, it does present interesting trends in technology and equity planning as well as providing insight into how agencies are planning for the equitable deployment of transportation technologies in the future. Planners are clearly considering equity when preparing for technologies, but an understanding of the nuances and concerns of underserved populations is required to ensure that the perceived benefits come to fruition. Challenges relating to public acceptance and political will need to be addressed through strategies at all levels of government with an understanding that those at the local level are often the project implementers and holders of community knowledge. Breaking down barriers will require a coordinated effort between the public and private sector to address the different challenges and needs of underserved groups. Overall, planning for equitable technologies must include a utilization of all the available resources in terms of research and testing or technology as well as involve effective collaboration between a myriad of actors, especially underserved communities. Future research must determine the success of different pilots and planning efforts; in terms of those specifically aimed at equity and technology separately as well as those that

incorporate equity and technology together. Lessons learned and promising practices will arise through collective knowledge of a problem; the consideration of equitable transportation technologies show areas that need attention as well as pilot programs and performance measures that are actively trying to address those areas. A better understanding of the efficacy of these efforts will help MPOs of all sizes in planning for an equitable deployment of transportation technologies.

5. SUMMARY - PLANNING FOR THE TECHNOLOGICAL FUTURE IN TRANSPORTATION

This dissertation asked, “are we planning for an equitable future with transportation technologies?” and as expected, there is no one clear answer to that question. Each MPO has a different region to consider with differing needs, demographics, budgets, etc. Despite this, clear trends in planning for technologies, and planning for equitable technology, did emerge. The Lessons Learned section will detail the common threads that emerged from the three studies as well as areas where they diverged. Challenges and Limitations will synthesize the different issues that arose during each study and consider possible changes or new approaches as this research is expanded. Finally, the Areas for Future Research will discuss new questions that arose throughout the research and determine places that warrant a new or different approach. Planning for equitable technologies is not complete and both planners and policymakers will need a deeper understanding of how and why to do so if the future of transportation is to be just.

5.1. Lessons Learned

Planning for the technological future in transportation will require a considered and expanded effort to incorporate equity and justice, planning must move beyond “fairness” in the distribution of benefits and costs to removing the institutional blocks and barriers that perpetuate the inequitable system we have created. This research has helped to highlight the areas where working is ongoing and progress is being made, but it has also shown how planning is falling short and exposed aspects of the process that are ripe for

change. The results of the case study of the Bay Area and the plan assessment of 52 MPOs indicated the same broad trends; a heavy focus in process rather than outcomes, equity not being prioritized in the process, and often a lack of real consideration of the equity impact of new transportation technologies. However, the survey offers a different perspective. Responses showed that MPOs are in the midst of making changes and altering their approach to equity, issues of equitable and just technologies are being discussed and considered, and there is an understanding that planning must play a strong role in implementing and driving technological change in their region. Despite this, there is still a hesitancy to truly engage with new technologies, often due to political and financial barriers, as well as a limited understanding of their current technology inventory and how they intend to expand it. This section will dive deeper into the lessons learned from the three studies before presenting some key recommendations for moving forward.

For many years, involving underserved populations within the planning process has been the core focus of environmental justice efforts, especially in transportation (Arnstein, 1969; Forester, 1999; Golub et al., 2013; Innes & Booher, 2004; Innes & Gruber, 2005; Karner & Marcantonio, 2018). However, the lack of clear guidance or a framework on translating engagement and public participation into action that can then be measured through equity analyzes has meant that while equity in process may be improving, it does not ultimately lead to equity in outcome. The case study of MTC especially highlighted this disconnect through the BART Oakland Airport Connector project; the

project conducted extensive outreach but still failed to meet environmental justice requirements and was ultimately subject to a legal challenge (Mayer & Marcantonio, 2009; Roth, 2010; San Francisco Bay Area Rapid Transit District, 2010). The plan assessment presented further evidence with planning documents only discussing environmental justice under their public engagement or participation overview rather than presenting performance measures, analyzes, or prioritization matrices that included equity. This signals that EJ is a checklist item for MPOs that are required to show evidence of equitable public participation, planning processes, and project analysis. Instead of truly grappling with how their transportation programs and projects are impacting the underserved communities, MPOs instead work to meet requirements. The lack of a framework at the federal level exacerbates this issue and could be leading to the focus on actionable items, such as participation, rather than reaching that holistic understanding of community needs and what would constitute an equitable program of projects. Reaching such an understanding requires dedicated outreach, research, scoping, design, and planning studies that often do not fit into the restricted transportation planning timeframe. Rather than just monitoring the process, the work of environmental justice must consider the outcomes and then make process adjustments as necessary. MPOs will require a great deal more time and resources to complete such an effort; the results of the survey showed a true desire to improve planning for equity, but also highlighted the challenge of doing so in their current environment.

While the work of creating an equitable and just transportation system is long and complex, technological developments are happening at a rapid rate. This further complicates efforts to reckon with the historical injustices inherent in urban planning, and especially transportation planning, by forcing planners to assess how technologies can break those institutional injustices as well as how they might further complicate them. The case study focusing on MTC shows that technology projects can suffer from many of the same issues as traditional transportation projects; a lack of thoughtful consideration of equity impacts and undeniable harm to underserved communities when their needs are not considered in project design, construction, and operation. The key difference is the amount of data, research, and project evidence for traditional transportation projects versus those that are technology focused. In addition, many technologies are being developed outside of the public sector by private actors that often consider the profit motive before all other considerations. Introducing private actors into transportation can reduce the burden on state and local governments that are often responsible for maintaining and operating the full transportation system, but it also cedes control over certain aspects of system to the private sector. Planners are currently facing a renewed call to focus on equity while also having to monitor new and ever-expanding mobility options that range from AVs, to micromobility, to mobility-as-a-service. Understandably the consideration of the equity of these technological developments remains limited as planners work to address competing societal issues, such as systemic racism, climate change, and economic instability.

While the case study and the plan assessment highlight the problems arising when planning for equitable transportation technologies, the survey indicates promising practices that are occurring at MPOs across the U.S. of various sizes. Most respondents that utilize equity performance measures are including a focus on outcomes as well as process. This shows a shift in how we perceive equity in planning and how that should translate into practice, which has largely been uncovered over the past few years as societal changes have highlighted systemic and institutional problems. While equity performance measures are focused on outcomes, those that are changing their equity planning currently or have over the last year, still seem focused on public engagement. Eight MPOs mentioned improving public engagement processes while only five noted a shift to focusing on outcomes. Realistically a combination of the two efforts is required to build a more equitable transportation system, but in recent years, public engagement has received attention seemingly to the detriment of translating the knowledge gained from those efforts into equitable transportation plans. Engagement efforts need to meet people where they are at, to ensure true engagement, as well as emphasizing the outcomes of projects and establishing a vision for a just transportation future in their region.

Results from the survey suggests a nuanced understanding of the equity of transportation technologies at the regional level; respondents understood the challenges in providing access to all, ensuring benefits are realized for underserved communities, and no additional harm is perpetrated. Although this understanding exists, many of the

challenges related to overall planning capacity to ensure equitable deployment. Concerns related to budget limitations, political buy-in, and resource constraints. MPOs, especially in small and mid-sized regions, believe their communities will not immediately benefit from technological improvements. Transportation technologies can be viewed as a dense urban transportation solution rather than a development that can benefit all. Greater resources will need to be directed to small agencies to ensure that no community is left behind or harmed by new transportation technologies.

Planning for emerging technologies is taking shape but it is often uneven and resource dependent. While smaller MPOs may see technologies are a future problem, the expansion of AVs, EVs, and artificial intelligence will not be constrained by political borders for long. As these technologies become more prevalent, infrastructure changes will be required across the U.S.; not just limited to dense urban environments. Establishing specific policy and planning guidelines at the federal level for both equity and technology would improve overall planning practice as well as help to address the disparate efforts currently being made at the regional level. Greater oversight of private development of technology can reduce the burden on state and local entities by providing broad safety, environmental, and equity standards for new transportation technologies. While each region will need to coordinate implementation and usage of technology, overall standards for design and operation at the federal level reduces the workload on smaller planning agencies. Another way to reduce the burden to planning agencies is to provide greater opportunities for knowledge sharing especially from large

to small agencies. The survey highlighted the number of pilots ongoing at different MPOs; the results, promising practices, and lessons learned should be widely disseminated from these efforts to guide other agencies when considering transportation technologies. Overall, ensuring that each community can effectively prepare will require extensive knowledge sharing, a specific understanding of community concerns and hopes surrounding transportation technologies, and an open dialogue with private sector actors that are designing and implementing AVs, micromobility, or mobility-as-a-service platforms. While pressure from the public can influence private actors to reduce barriers to access for underserved groups, planners are uniquely positioned to direct the equitable deployment of transportation technologies in their region. The results of this research should provide one resource in developing strategies for equitable technology deployment.

5.2. Challenges and Limitations

Each study within the overall dissertation had its limitations and challenges; however, some limitations were common across the three studies. Limitations included the differing sample sizes across the three studies, issues with data collection and data availability, as well as issues with measurement in terms of both measuring equity and evaluating the effectiveness of planning efforts. The overall limitations will be presented in this section with a discussion of the different reasons for maintaining the research design as well as steps taken to address issues that arose.

While the different sample sizes allowed the dissertation to scale naturally and present different viewpoints, the case study results cannot be generalized to all MPOs. However, insights can be gleaned from all three studies despite them offering a subset of the entirety of MPOs. The case study allowed for a deeper analysis of project level impacts from technology, but the region chosen does present a more advanced planning agency that has the capacity and resources to program more technology projects. The plan assessment presented an analysis that included small and midsized MPOs rather than just the larger MPOs in the U.S. (Guerra, 2016; McAslan et al., 2021). A stratified random sample based on population size was utilized after the results from a previous pilot study indicated that size had a greater impact than region on differences in planning for emerging technologies (Kuzio, 2019). In the future, this study could be expanded to include more MPOs, which would allow for greater statistical analysis as well as providing a broader cross-section of planning agencies. Finally, the survey attempted to reach all MPOs in the U.S. and received responses from 110 different MPOs of 402. The response rate was only 27 percent, but it provides a baseline that can be expanded upon in future research. The initial hope was to be able to triangulate data on the case study subject, MTC, but no survey response was received from the agency. Each study can be expanded to provide greater insights into different regional responses to emerging technologies as well as the different potential benefits and challenges.

Data availability issues occurred in both the first and second studies; identifying projects with a technology component proved difficult utilizing publicly available

documentation. Without technology inventories, it is difficult to conduct an evaluation of the equity of past technology investments but most MPOs are still in the early stages of developing these inventories, and they are not always available to the public. This lack of accounting can also cause problems for planners when hoping to invest in new technologies, as there is no solid foundation for the current technology components in the system. In addition, the plan assessment utilized the regional transportation plan, the long-range plan for MPOs, to ensure validity and consistency across the study. However, MPOs often create a variety of different reports and plans that may have contained relevant information to equitable technologies. In ensuring an accurate comparison between MPOs, these plans were not reviewed. Future research should include a review of additional documentation to understand the differences between the technology discussion in the RTP and these plans or whether these plans are replacing any discussion in the long-range plan. Beyond plan documentation, demographic, financial, and institutional data can be difficult to obtain at the MPO level. Most MPOs do not conform to other political boundaries, such as cities or counties, instead they represent a greater region that often incorporates several cities and/or counties. Data presented by the MPO cannot always be directly compared with another MPO depending on data source, collection method, as well as the year the data is collected. If data at the regional level is unavailable, even from the MPO, it limits the application of accurate statistical methods to research at this level.

Issues with measuring equity are common as measurement aims to convert impacts to individuals that can differ in a variety of ways into a number that can be aggregating and collating to provide a generalization or overview. Equity is far more nuanced that most transportation metrics, it is much harder to measure the impact limited mobility has on an individual or group of people than it is to measure the reduction in congestion or a reduction in pollutants. When considering the equity of transportation technologies, additional factors beyond whether the project provides another transportation option or reduces travel times for underserved populations are required. Technology introduces concerns over privacy, surveillance intended to improve traffic flow can serve to criminalize individuals, new barriers to access arise and those barriers can also conflict for different populations (Benjamin, 2019; Claypool et al., 2017; Cuellar et al., 2018; Hwang et al., 2020; Kuzio, 2021; Zuboff, 2018). These impacts cannot always be reduced to a number that is easily analyzed and assessed against other metrics; however, research needs to develop a more comprehensive framework for evaluating the equity of transportation technology projects. Measures should utilize both qualitative and quantitative data, understand that the data points in this case are humans, and account for the variety of different equity impacts that can arise from transportation projects. Finally, these measures should consider the systemic racism that exists throughout our institutions and work to dismantle these institutional barriers to justice.

5.3. Areas for Future Research

Further research is necessary in determining a complete picture of planning for emerging technologies as well as moving from planning to deploying or implementing equitable technology solutions. Expanding on this research necessitates an assessment of equity measures to develop a tool or framework to assist MPOs and other agencies in determining equitable technology strategies. Acceptance of new technologies, such as AVs, must be understood from an underserved populations perspective. Beyond just acceptance, research should focus on how underserved groups wish that technologies could be incorporated, how they could best serve these populations, as well as highlighting any disconnect between these thoughts and that of transportation planners. Network analysis would assist in determining the different actors and decision-makers involved in planning for emerging transportation technologies.

Measuring the equity of transportation projects, and especially projects that introduce new solutions or emerging technologies, is a complex process that many MPOs cannot undertake. Equity, justice, and access for all requires an understanding of the diverse needs of each population that is underserved, underrepresented, and disadvantaged by transportation. No one measure or framework will apply to every situation or even every region; the needs and goals of each community must be considered when determining equity and justice. While it is impossible to reduce equity to a simple measure, flexible frameworks can provide a baseline for understanding the different equity impacts, asking the important questions during public engagement sessions, and ensuring that people are

not treated as just numbers. This dissertation has provided a starting point to develop those frameworks, which would consider regional challenges, resource constraints, and community need.

Current literature on acceptance of AVs and adoption of EVs often does not present the results in terms of race and ethnicity or for zero vehicle households (Adnan et al., 2018; Bansal & Kockelman, 2017; Hardman et al., 2016, 2018; Hulse et al., 2018; Jardim et al., 2013; Penmetsa et al., 2019). While the studies do provide information on income levels and acceptance, the results often focus on the high acceptance levels for wealthier individuals rather than exploring the nuance of low-income individuals lack of acceptance (Golub et al., 2021). In addition, the acceptance and barriers to senior populations and people with disabilities regarding autonomous vehicles is growing within the literature (Claypool et al., 2017; Cordts et al., 2021; Faber & van Lierop, 2020; Fink et al., 2021; Hwang et al., 2020; Kuzio, 2021; Milakis & van Wee, 2020; National Center for Mobility Management, 2018). Broader research on transportation technology acceptance such as automation, electrification, and increased use of artificial intelligence is still needed to provide a more detailed picture of the differences in acceptance and how the different technologies are perceived. Recent research into the differing attitudes between users, urban planners, and developers regarding autonomous vehicles in Sweden offers insight into the power of focus groups in determining and comparing opinions across groups (Strömberg et al., 2021). Focus groups that bring together the private sector, planners, policymakers, and underserved groups would assist

in determining design standards, planning protocols, and establishing baseline policies that promote equity in transportation technologies.

In conjunction with conducting focus groups to better plan and prepare for emerging technologies, network analysis would present a clearer picture of the key decision-makers and collaborators in the area of transportation technologies. Social network analysis has been used in planning to assess the role of planners in environmental and hazard mitigation planning (Lyles, 2015). While social network analysis has its critiques (Dempwolf & Lyles, 2012), it can be useful in determining the different actors at play within transportation planning as well as determining which stakeholders lead to equitable policy and planning actions. Utilizing these techniques alongside focus groups and stakeholder interviews can assist planners and researchers with understanding the role of the private sector and community members in planning for an equitable future with transportation technologies.

The impact of the new Executive Order 13985 "Addressing Racial Equity and Support for Underserved Communities through the Federal Government" is yet to be seen. However, this increased focus on equity should yield improvements in data collection and standards, as well as provide more resources for planners at the state and local level. After the executive order actions have been implemented, further research will be needed to determine how this has impacted the inclusion of equity in transportation as well as in terms of the equitable deployment of technology in transportation.

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APPENDIX A

MATERIALS RELATED TO STUDY 1

Study One Conception & Overview

The first study aims to understand how current and past transportation technology investments have impacted environmental justice and equity communities. The idea stemmed from the fact that while there is an increasing focus on technologies as new developments, such as AVs, occur, there needs to be a better baseline understanding of how technology is currently impacting these communities. The initial approach focused on spatial equity with the premise that technology investments need to be in proximity or accessible to these communities. The next section details the various approaches to measuring equity, including the use of spatial analysis techniques. The research intended to compare three MPOs with differing population sizes and in different regions across the U.S. Throughout the course of the research, it became clear that detailed data on technology projects and projects with a technology component were difficult to locate at a regional level. Most project descriptions do not include enough detail to conduct rigorous analysis of impact, even spatially. After data from additional MPOs, outside of MTC, was collected, it was clear that true comparisons could not be made due to differences in project detail and the lack of clear technology projects at small and mid-sized MPOs. The study then shifted to focus on MTC and utilize a case study approach. The case study analysis focused on spatial equity initially, but again data constraints limited the ability to truly measure and document accessibility for certain technology projects. Different projects also necessitated different impact boundaries, which was

taken into consideration in this research. Although the different "reach" of transportation and transportation technology projects were considered, spatial equity still appeared to be a missing a large piece of the puzzle, whether and how these projects *impacted* the communities of concern. Delving deeper into impact is difficult when analyzing over 50 projects, so five projects were selected from each category for a thorough review. Again, data constraints were an issue. Project details could only be found on larger projects or those that garnered media attention, so smaller projects that have a greater impact on communities of concern can be difficult to thoroughly analyze. For example, the purchase of electric buses by AC Transit has clear environmental benefits, but *who* is benefitting from that investment? While it was not possible to accurately assess the benefits of that specific purchase, AC Transit has a plan that focuses their electric vehicle deployment to communities of concern first before general expansion. This shows that a smaller investment, if correctly implemented, can provide greater benefits to these communities. The extension of the research to include these project examples provided nuance and shows the complex nature of measuring equity.

This appendix addresses additional methodological considerations and especially addresses the limitations of spatial equity analysis that occurred during the course of the research. There are multiple ways to measure equity, and this is an area that is receiving greater consideration today than previously, but each method has challenges. The limitations and future research section address the challenges and argues for more nuances measures of equity when considering transportation technology projects. A tool

is needed that can address the nuance of equity for regional planners, such as MPOs, especially a tool that accounts for racial injustices and the inherent inequitability of the current transportation landscape.

Extended Methodology

MPOs are tasked with completing environmental justice (EJ) reviews of their transportation plans and programs. This directive began with a 1994 Executive Order by President Clinton that mandated the inclusion of EJ as a goal for every federal agency and eventually led to rough guidance from the U.S. Department of Transportation (DOT) and other federal level transportation organizations (Clinton, 1994; Karner & Niemeier, 2013b; U.S. Department of Transportation: Federal Transit Administration, 2016). EJ reviews required some form of equity analysis to ensure a fair distribution of transportation benefits and costs from a proposed program of action; normally the regional transportation plan (RTP). However, the lack of strict guidance has led to numerous approaches to these equity analyses that are required under the Executive Order and subsequent federal announcements. Traditional approaches rely methods that focus on spatially inequitable exposures, but a range of different methodologies have been proposed academically. These range from spatial modeling using geographic information system (GIS) tools combined with spatial analysis to adapting activity models for equity purposes. Although some of these analysis methods do not specifically focus on the equity of investment; they offer a proxy to understand what constitutes an equitable program of investment.

Approaches to Equity Analysis in Practice

All MPOs are required to perform an equity analysis; however, how they perform that analysis is largely at the discretion of the MPO. The lack of guidance has led to numerous approaches with varying levels of intensity, but most of the analyses follow a similar three step approach (Cambridge Systematics, 2002; Karner & Niemeier, 2013a). The first step is to define the target populations; this involves determining the equity-priority communities that are located within the region. Typical populations to be included are low-income, minority, disabled, and the elderly. A percentage threshold is set for each traffic analysis zone (TAZ) to then define that as a community of concern or EJ community. The second step is to determine equity metrics; commonly used metrics to determine benefits include accessibility or access to jobs and activity sites, travel time, safety, or metrics to assess impact that focus on costs or harms, such as noise and pollution. Finally, the MPO must assess equity to determine whether their plan results in a fair distribution of benefits and costs. This is not a straightforward process due to the various definitions of equity within transportation, as well as the lack of definition at the federal level (Martens et al., 2012; Taylor & Tassiello Norton, 2009). Often, the approach taken assesses whether the plan leads to equal benefits for both high-income and low-income groups using the travel demand outputs from the base year versus the forecasted year. This approach provides an easily adaptable framework for most MPOs, but there have been several other methods proposed.

Alternative Approaches to Equity Analysis

Equity analyses by practitioners are often constrained by a lack of time or resources to conduct in-depth studies. Alternative approaches have been suggested in the literature that aim to provide a better overall understanding of the equity impacts of transportation investments as planned by regional entities. These include developing a measure of accessibility that can be applied to understand fairness or access across a region, a spatial approach that focuses on GIS and spatial clustering analysis and using activity-based models to disaggregate impacts to different groups.

Measuring accessibility using a cumulative opportunity approach uses the number of essential destinations available within a set travel time; this can then be split by mode to show the difference between transit and automobile access (Golub & Martens, 2014). Since many equity populations are transit dependent, this provides a better understanding of how an investment program will impact them than just assessing whether the change in aggregate travel time is the same for high and low-income neighborhoods (El-Geneidy et al., 2016). Once the accessibility measures are created for each TAZ within the plan area, an assessment of the fairness of access can be made by determining differences in accessibility between transit and automobile travel as well as between TAZs for the same mode. The result would be an access ratio that assesses the two differences and determines whether the planned investments move the ratio closer to one (resulting in greater equality or fairness) or not.

Most equity analyses focus on the RTP, which is the long-range planning document created by an MPO; however, this is not always an exact representation of the funded projects or could contain more projects than the eventual budget will allow. RTPs do present a fiscally constrained budget to avoid such issues but planning and programming of projects is not exact and cost overruns can occur. The transportation improvement program (TIP) is created in addition the RTP to show the programmed projects that received funding through the MPO. A spatial analysis of actual investment patterns may not help to ensure equity at the current stage but can speak to projects that have provided greater benefits to historically underrepresented and underserved communities previously. Spatial analysis techniques can show the impact of a transportation investment across a geographic region by setting mile radius limits depending on the type of project (bike or pedestrian improvement versus a highway expansion) (Klein, 2007). This will show the likely full impact of the investment and whether the benefits and costs are being spatially distributed; this form of analysis does not necessarily consider the improvement to accessibility however, which limits its ability to show whether there are true benefits to communities of concern.

Finally, efforts have been made to test whether activity-based models could be used in the pursuit of equity analyses; one core concern lies with whether these models accurately reflect travel behavior and whether they can be disaggregated to understand different group behaviors (Basta, 2016; Bills et al., 2012; Bills & Walker, 2017). Although there are still some methodological issues with these models, such as not

showing equality in tests of distribution (when compared against actual data), the general shapes of the distributions appear similar and the relative differences between the high and low-income groups that were sampled appear to match after testing of the model. This seems to indicate that activity-based models could be adapted to provide a scenario analysis of equitable investment.

Limitations and Issues in Equity Analyses

Each of these methods has limitations and issues; methods used in practice suffer from fuzzy guidelines and a non-standardized procedure. In addition, these methods are not exhaustive, and other research has used estimation models to determine how state funds are distributed locally (Pasha, 2018). The different definitions of equity that can be arrived at by an MPO reduce the ability to replicate the methodology between agencies and even within agencies due to staff turnover. This method can fail to incorporate accessibility for their populations by not considering mode of transport and the differences in accessibility between equity and non-equity populations. However, creating accessibility measures by TAZ and mode for each transportation plan could be time-consuming and resource intensive for many smaller MPO staffs. Although resource scarcity is an issue, there is a need to link equity analyses with performance assessments if these methods are to be practically used to evaluate alternative scenarios rather than just justify current investment plans (Karner, 2016). Finally, assessing the impact of the TIP can provide insight into the reach of certain projects, but there should be a

consideration of whether these projects improve accessibility for equity populations rather than just being geographically close to them.

Limitations & Future Research

The previous section detailed potential methods in the literature for measuring equity, and this study focused on a combination of spatial and investment equity. While conducting the research, it became clear that the limited quantitative data available on technology projects, especially data specific to the technology component, necessitated a deeper engagement with some of the projects to understand the results of the quantitative analysis. The spatial investment analysis approach had given too much weight to the amount invested in an area without considering the potential impact; initial conception of the study had intended to categorize projects as "positive" or "negative" from an equity standpoint, but in practice, those categorizations are complex. Project information included in the TIP is extremely limited and so the exact location could not always be determined, let alone the potential consequences to equity of the investment. The TIP only provides a summary of the project that, unless directly related to technology, can be difficult to discern the possible impacts during construction or implementation and then after completion. This first study further affirmed the need for rich, qualitative data in addition to quantitative elements when considering equity. The methodology was limited by a lack of project specificity, data on performance measures and outcomes, as well as lacking comparisons across the U.S. Additional efforts in this area should be expanded in scope; both in terms of the number of MPOs assessed and the equity components or

demographics considered in the analysis. Future research must also work to create an effective and easy to implement tool for agencies, such as MPOs, to understand the equity of their projects – especially those that involve technology. A flexible system that can be altered depending on project type would allow an MPO to make assessments on larger projects as well as smaller investments if time and resources allowed. Any tool should incorporate both qualitative and quantitative data to ensure the nuance of equity in transportation can be captured; a few key elements to consider are public or community need, disruptions both during and after project completion, as well as the need to reorient our transportation system to remove institutional barriers and the uncover racial underpinnings of systems.

APPENDIX B

MATERIALS RELATED TO STUDY 2

Study Two Conception & Overview

While plan evaluations are common across the disaster mitigation, sustainability, and climate change planning fields; transportation has seen limited application of the approach. The second study aimed to utilize plan evaluation techniques to grapple with the complex questions surrounding equity and technology in transportation plans; in addressing how we are planning for an equitable future with transportation technologies, it is important to assess what is being formalized in plan documents. Regional transportation plans provide a sense of the long-term direction of an MPO, the vision and goals for a region, and ultimately shows investment priorities. The focus of a plan, as well as how certain elements are incorporated, speak to how the transportation system will change or maintain the status quo in the years to come. As the plans directly relate to federal funds because projects requesting such funds must be included in both the RTP and the TIP, these plans reflect the impact of dollars invested in transportation. Therefore, this study wanted to understand how transportation technologies fit into that framework; are technologies being discussed? And more importantly, is there a consideration of the equity impacts of technologies – in terms of economics, accessibility, mobility, and more. If there is no discussion of the equity of transportation technologies, is this because there is a lack of consideration of transportation equity. All these questions led to the development of a framework that was presented in the second study of this dissertation and will be explore further in this appendix through an

extended methodology and further results. In terms of the overall research design, this study helped to assess the "Present" or the current efforts being made by planners in terms of emerging technologies, as well as offering another set of data to help triangulate around the problem of equitable transportation technologies in planning.

Extended Methodology

The extended methodology will provide a review of the literature related to plan evaluation as well as specific evaluation of transportation plans that drove the framework created for both the pilot study and the second study in this dissertation. The pilot study methodology is also presented here as it relates to the creation of the plan evaluation framework for the second study in this dissertation.

Overview of Plan Evaluation

Plans are created and implemented across cities, regions, and states to varying degrees of success, but that success is rarely measured or assessed. Plan evaluations focus on the intentions of the plans and the policies that being proposed by the local government or transportation agency. Most plan evaluation has focused on comprehensive plans, disaster mitigation, or sustainability issues (P. R. Berke, 1996; P. R. Berke & Conroy, 2000; P. R. Berke & French, 1994; Lyles et al., 2016); however, transportation plans have been assessed for certain component parts, such as the environmental justice analysis or social equity (Golub & Martens, 2014; Karner, 2016; Karner & Marcantonio, 2018; Karner & Niemeier, 2013a; Manaugh et al., 2015; Marcantonio et al., 2017).

In evaluating a plan, there should a consider of the plan alternatives, the plan as a package, and the outcome following the implementation of the plan (Baer, 1997). However, most plan evaluations focus on the plan as a package by using state of the practice metrics to develop evaluation protocols (P. Berke & Godschalk, 2009). This shows the priorities and strategies being utilized by the government or agency and how they intend to pursue their goals. The consideration of plan alternatives can only be researched if alternatives are available, and plan implementation studies have been scarce in the past (Baer, 1997; Lyles et al., 2016; Talen, 1996). However, recent research has assessed progress made toward the policies and goals mentioned in the plan as a way of understanding its performance (Lyles et al., 2016). In addition, recent research in climate adaption has shifted the focus onto implementation (S. Woodruff, Bowman, et al., 2021; S. Woodruff, Meerow, et al., 2021). The focus on the plan as a package is largely a focus on the perceived quality of the plan.

Plan quality evaluations typically begin with criteria or a framework for evaluation (P. Berke & Godschalk, 2009); these frameworks can assess compliance with local laws and regulations by finding specific policies the plan includes, as well as research protocols that are often looking for planning items that reflect a theoretical imperative or standards determined for the area of planning. The general elements that are expected from a "good" plan are internal consistency, such as a strong fact base and process for monitoring and evaluation, and external quality that emphasizes coordination with outside agencies and compliance (P. Berke & Godschalk, 2009; Hoch, 2002). Plan

evaluations are a form of content analysis that use a systematic method to locate specific areas or planning efforts within the documentation. This form of content analysis generally relies on a pre-determined coding scheme that can either be directed or deductive depending on the area of study. Directed content analysis uses key concepts and keywords derived from theory and research rather than the documents or plans themselves (Hsieh & Shannon, 2005). This allows researchers to understand how plans are applying theoretical concepts or best practices that have been identified within the literature. The validation of results in plan evaluation has relied on content analysis techniques to maintain reliability and validity. The plans should be evaluated by more than one coder where possible and then a measure of inter-coder reliability is used; the generally accepted standard is Krippendorff's alpha. Krippendorff's alpha is considered the optimal measure of inter-coder reliability for plan evaluation style research as it allows for multiple coding options, assesses the coders independently, adjusts for agreement by chance, and can be used on different levels of measurement (Stevens et al., 2014).

Overall, assessments of a good plan go beyond plan quality, but assessing the plan as a package does provide an idea of intent and in terms of transportation, often an understanding of where investments will be made throughout the region (Beth Farquhar, 2005; Lowe, 2014; Lowe & Hall, n.d.). Assessing performance of a plan requires an analysis of progress made toward goals, which can be found most often in transportation improvement programs. Currently, transportation suffers from limited analysis of plans

and plan objectives; often focusing on environmental justice, specific equity concerns, or new developments in transportation (Golub & Martens, 2014; Guerra, 2016; Karner, 2016; Manaugh et al., 2015; McAslan et al., 2021). The overall quality and performance of transportation plans is under-researched outside of these areas and does require further investigation.

The introduction of emerging technologies, as well as the continued investment in current technologies, require strong planning to integrate them into existing systems, especially in terms of ensuring equitable deployment. Developing a strong understanding of where planning stands in terms of transportation technologies is an initial step in developing frameworks and promising practices for integration and deployment. The thoughts, intentions, and potential applications regarding transportation technologies by planners and planning agency can be gained through reviewing official documents and plans. This research focused on long-range plans and their inclusion of technology and key equity and justice components. The long-range plan, or regional transportation plan (RTP), was selected due to the time frame that the plan considers as well as the detail generally provided in these plans. Since many emerging technologies are in the pilot stages and not fully integrated into the transportation system, the 20 years, or longer, time frame of the RTP allows planning agencies to discuss the potential of technologies without committing resources prematurely. The review of RTPs utilized a plan evaluation approach that drew on a previous study as a pilot, the transportation literature, as well as the plan evaluation and content analysis literature more broadly.

Pilot Methodology

Before creating the final framework and conducting the plan evaluation, a pilot plan evaluation was conducted using summative content analysis. Summative content analysis uses keywords derived from the literature and those found within the documents themselves (Hsieh & Shannon, 2005). The RTP was selected as the document for evaluation as it is the most comprehensive and long-range plan that an MPO is mandated to create by the federal government (U.S. Department of Transportation: Federal Transit Administration, 2016). The guiding questions and keywords drove the content analysis by locating areas of the plan with pertinent information. Once those areas were located, an MPO could be coded as to whether they included social equity, emerging technologies, or the implication of those technologies on equity in their plan. Excerpts were collected at that stage for qualitative coding, which investigated how the MPOs included each planning effort in their RTP. This pilot represented an exploratory study to determine the state of the practice in terms of social equity and emerging technologies within long range planning documents. Previously, Guerra found that only one MPO in the top 25, by population, mentioned AVs within their plan; this research aimed to expand beyond AVs as well as determine whether social equity implications of these new technologies was being considered.

The plans were selected based on several characteristics; year of plan adoption, population served by the MPO, and geographic region. Plans adopted in 2016 or 2017 were chosen to maintain consistency considering this study focused on emerging

technologies. The RTP is updated on a four to five year basis, which can lead to a wide range of plan adoption cycles (Federal Transit Administration, 2016). A population threshold of 250,000 was established as this is the threshold for an MPO to become a Traffic Management Area (TMA). MPOs in TMAs receive greater funding and have the capacity to complete more advanced plans (*PART 450—PLANNING ASSISTANCE AND STANDARDS*, 2016; Federal Transit Administration, 2012; U.S. Department of Transportation: Federal Transit Administration, 2016). Finally, the sample of plans represented all four of the U.S. Census Regions, five plans for each region: Northeast, Midwest, South, and West. The geographic regions provided a cross-section of the U.S., and the opportunity to assess regional differences. Plans were randomly selected from the population of MPOs that met the criteria for year of plan adoption and population. Kuzio (2019) includes the full MPO sample information.

Three focus areas were selected and then guiding questions drove the framework for assessing plans. The first area, social equity, sought evidence of planning for disadvantaged communities that improved overall accessibility, mobility, and outcomes from transportation decisions. If evidence of social equity planning was present, such as explicit mentions or equity or planning for transportation disadvantaged groups or communities, the plan would receive a code of "1". Planning should reference a positive equity change; aiming to improve transportation outcomes for the disadvantaged populations in their region (Bullard, 2003; Kristoffersson et al., 2017).

The second area, emerging technologies, aimed to find evidence of new developments such as AVs. Planning in this area is complex as there is no clear timeline for deployment and implementation as well as no precise method to understand public use and acceptance (Fagnant & Kockelman, 2015; Guerra, 2016). Despite this, MPOs must be proactive in preparing for their introduction; the framework sought mentions of these technologies only. For example, if an RTP included a section on Emerging Technologies or Autonomous Vehicles, it would be coded "1". The guiding questions and the key search terms, as well as other planning efforts, such as goals or projects, can be found in Kuzio (2019).

The final area is evidence of planning for equitable technology. Since this intersection is emerging, the RTP is less likely to incorporate it. Initial efforts could be in the form of considering the negative impacts of emerging technologies, such as a reduction in jobs, or positive actions, in terms of increasing mobility for the elderly. An attempt to connect social equity with emerging technologies, such a discussion of disparate impacts or possibilities for improved outcomes, would receive a code of "1". If no evidence of planning could be found for each of the three focus areas, the plan would receive a code of "0" for the area in question. The full framework for the pilot study can be found in Kuzio (2019).

The keywords were selected from a thorough review of the literature on both social equity and emerging technologies. Terminology differs across regions and fields; so, there are different names or terms for a similar concept. In order to understand how social equity might be referenced in a transportation context, a review of transportation equity, sustainability, and social equity literature was conducted. This provided the keywords used to search for social equity in the plans, including mentions of the concept, but also target populations. An MPO could be targeting their low income or minority population for improved accessibility through several metrics, but not put that under a heading of equity. Therefore, keywords were included that searched for target populations, such as low income or minority (Boschmann & Kwan, 2008; Guerra, 2016; Manaugh et al., 2015). Understanding the depth of technology planning required separate searches for transportation technologies, with their own keywords. These included IoT, which while not transportation exclusive, are key to the operation of CVs and eventually AVs (Meyer et al., 2017). Even terms that cross the boundaries between equity and these technologies arose such as accessibility, and so were included (Boschmann & Kwan, 2008; Deboosere et al., 2018; Guerra, 2016; Litman, 2003; Manaugh et al., 2015).

The study involved the collection of passages from each RTP by searching each keyword in order. Any relevant passages were collected and set aside for coding. Multiple passages were collected when separate relevant passages were found within the document. If no evidence of planning was found, the MPO received a code of 0 or “Not

Included in the Plan". Next, each focus area was assigned a code according to how the planning effort was incorporated into the plan. This process was emergent, since from the outset the research was intending to see whether MPOs were planning in these areas and then understand how they were planning. The results of this pilot study informed the plan evaluation framework for the final analysis of plans; in conducting the small review of 20 planning documents, further refinements were made, and new questions assessed about the quality and breadth of transportation plans.

Extended Results

This section will provide an overview of the quantitative evaluation score, where collected, as well as broad overview of the inclusion of each planning element (equity, technology, and equitable technology) in the plans. Table 13 provides a guide to the abbreviations used throughout the second study and within this extended results section.

Table 13. Metropolitan Planning Organization Abbreviations

Metropolitan Planning Organization	State	Major City	Abbreviation
Skagit MPO (SMPO)	WA	Mt. Vernon	Skagit
Williamsport Area Transportation Study (WATS)	PA	Williamsport	WATS
Yellowstone County Planning Board	MT	Billings	YC
Wichita Falls MPO	TX	Wichita Falls	Wichita Falls

Metropolitan Planning Organization	State	Major City	Abbreviation
Bannock Transportation Planning Organization (BTPO)	ID	Pocatello	BTPO
Longview-Kelso-Rainier MPO	WA	Kelso	LKR
Columbus Area MPO (CAMPO)	IN	Columbus	Columbus Area
St. Cloud Area Planning Organization (APO)	MN	St. Cloud	SC APO
Bend MPO	OR	Bend	Bend
Jackson Urban Area MPO	TN	Jackson	JUA
Policy Committee of the Erie Regional Planning Commission	OH	Sandusky	ERPC
Goldsboro Urban Area MPO	NC	Goldsboro	GUA
Lake Havasu Metropolitan Planning Organization	AZ	Lake Havasu City	LH
Wausau Metropolitan Planning Organization	WI	Wausau	Wausau
Sierra Vista Metropolitan Planning Organization	AZ	Sierra Vista	SV
Cumberland Area MPO (CAMPO)	MD	Cumberland	Cumberland Area

Metropolitan Planning Organization	State	Major City	Abbreviation
Albany Area Metropolitan Planning Organization (AAMPO)	OR	Albany	AAMPO
Great Falls Planning and Community Development Department	MT	Great Falls	GF PCDD
Rio Grande Valley MPO	TX	Harlingen	H-SB
Adirondack/Glens Falls Transportation Council (A/GFTC)	NY	Glens Falls	A/GFTC
Tri Cities Area MPO	VA	Petersburg	TCA
Housatonic Valley MPO	CT	Brookfield	HV
Rogue Valley MPO (RVMPO)	OR	Central Point	RVMPO
Nashua Regional Planning Commission (NRPC)	NH	Nashua	NRPC
Fargo-Moorhead Metropolitan COG (FMMetroCOG)	ND	Fargo	FMMetroCOG
Metropolitan Topeka Planning Organization	KS	Topeka	MTPO
Tuscaloosa Area MPO	AL	Northport	TA
Regional Transportation Commission of Washoe County (RTC)	NV	Reno	RTC

Metropolitan Planning Organization	State	Major City	Abbreviation
Chattanooga-Hamilton County/North Georgia Transportation Planning Organization (CHCNGTPO)	TN	Chattanooga	CHCNGTPO
Florida-Alabama Transportation Planning Organization	FL	Pensacola	FA TPO
Tri-County Regional Planning Commission (TCRPC)	MI	Lansing	TCRPC
San Luis Obispo COG (SLOCOG)	CA	San Luis Obispo	SLOCOG
Capital Region Transportation Planning Agency (CRTPA)	FL	Tallahassee	CRTPA
Anchorage Metropolitan Area Transportation Solutions (AMATS)	AK	Anchorage	AMATS
Michiana Area COG (MACOG)	IN	South Bend	MACOG
Greater Hickory MPO	NC	Hickory	GH
Hernando/Citrus County MPO	FL	Brooksville	H/CC
Gulf Regional Planning Commission (GRPC)	MS	Gulfport	GRPC
Merced County Association of Governments (MCAG)	CA	Merced	MCAG

Metropolitan Planning Organization	State	Major City	Abbreviation
Capital Regional Planning Commission (CRPC)	LA	Baton Rouge	CRPC
Metropolitan Area Planning Agency (MAPA)	NE	Omaha	MAPA
San Joaquin COG (SJCOG)	CA	Stockton	SJCOG
Pioneer Valley MPO (PVMPO)	MA	Springfield	PVMPO
Metroplan	AR	Little Rock	Metroplan
Capital District Transportation Committee (CDTC)	NY	Albany	CDTC
Memphis Urban Area MPO	TN	Memphis	MUA
Indianapolis MPO	IN	Indianapolis	Indianapolis
Palm Beach MPO	FL	West Palm Beach	PB
Portland Area Comprehensive Transportation System (METRO)	OR	Portland	METRO
Denver Regional COG (DRCOG)	CO	Denver	DRCOG
Southern California Association of Governments (SCAG)	CA	Los Angeles	SCAG
Metropolitan Transportation Commission (MTC)	CA	Oakland	MTC

The plan evaluation framework did initially include a quantitative element that was being conducted with the assistance of an additional coder. The quantitative evaluation utilized two coders to enable a more thorough review of the plans and reduce the likelihood that planning, or policy elements, would be missed during the data collection and plan evaluation process. The protocol collected data on both the presence of planning efforts, through the quantitative coding process, and details regarding those planning efforts, by collecting excerpts of the plan for qualitative coding. The quantitative coding used a 0, 1, 2 system to determine both the presence of a certain planning effort and to indicate where additional details or analysis had been included in the plan document. 30 of the 52 plans were quantitatively assessed by both coders with the codes reconciled at the end of the process, the remaining 22 plans were quantitatively assessed by one coder. The results are presented by population and the MPOs in italics were only assessed by one coder.

Table 14. Quantitative Summary Results

MPO	Population	Equity	Technology	Emerging Technologies	Equitable Technology
Lake Havasu Metropolitan Planning Organization	55,280	0	1	1	0

MPO	Population	Equity	Technology	Emerging Technologies	Equitable Technology
Sierra Vista Metropolitan Planning Organization	56,070	1	1	0	0
Albany Area Metropolitan Planning Organization (AAMPO)	57,721	1	1	0	0
Longview-Kelso-Rainier MPO	65,796	0	1	1	0
Great Falls Planning and Community Development Department	68,818	0	1	0	0
Bannock Transportation Planning	73,190	0	0	0	0

MPO	Population	Equity	Technology	Emerging Technologies	Equitable Technology
Organization (BTPO)					
Cumberland Area MPO (CAMPO)	75,091	0	0	0	0
Columbus Area MPO (CAMPO)	76,794	1	0	0	0
Policy Committee of the Erie Regional Planning Commission	82,976	0	1	1	0
Bend MPO	84,249	0	1	0	0
Wausau Metropolitan Planning Organization	84,831	1	1	1	0
Goldsboro Urban Area MPO	92,964	1	1	0	0

MPO	Population	Equity	Technology	Emerging Technologies	Equitable Technology
Jackson Urban Area	98,294	1	1	1	0
Wichita Falls MPO	109,139	1	1	1	0
WATS	116,102	0	1	1	0
Skagit	116,901	0	1	0	0
Yellowstone County	126,372	0	1	0	0
St. Cloud Area Planning Organization (APO)	130,191	1	1	1	0
Adirondack/Glens Falls Transportation Council (A/GFTC)	143,664	0	1	1	1
Tri Cities Area MPO	154,407	0	1	1	1

MPO	Population	Equity	Technology	Emerging Technologies	Equitable Technology
Harlingen-San Benito	156,063	1	1	0	0
Rogue Valley MPO (RVMPO)	167,859	0	1	0	0
Metropolitan Topeka Planning Organization	168,233	1	1	0	0
Tuscaloosa Area MPO	194,656	0	1	0	0
Fargo-Moorhead Metropolitan COG (FMMetroCOG)	199,592	1	1	1	1
Nashua Regional Planning Commission (NRPC)	205,775	0	1	1	0
Housatonic Valley MPO	224,621	0	1	0	0

MPO	Population	Equity	Technology	Emerging Technologies	Equitable Technology
Merced County Association of Governments (MCAG)	255,366	0	1	1	1
San Luis Obispo COG (SLOCOG)	269,637	0	1	1	0
Anchorage Metropolitan Area Transportation Solutions (AMATS)	289,011	0	1	1	0
Hernando/Citrus County MPO	313,992	1	1	1	0
Greater Hickory MPO	365,651	0	1	0	0
Capital Region Transportation Planning Agency (CRTPA)	367,384	1	1	0	0

MPO	Population	Equity	Technology	Emerging Technologies	Equitable Technology
Gulf Regional Planning Commission (GRPC)	370,692	0	1	1	0
Regional Transportation Commission of Washoe County (RTC)	412,326	1	1	1	1
Florida-Alabama Transportation Planning Organization	434,625	1	1	1	1
Chattanooga-Hamilton County/North Georgia Transportation Planning	436,669	1	1	1	0

MPO	Population	Equity	Technology	Emerging Technologies	Equitable Technology
Organization (CHCNGTPO)					
Tri-County Regional Planning Commission (TCRPC)	464,234	1	1	1	0
Michiana Area COG (MACOG)	464,490	1	1	1	0
Metroplan	621,397	1	1	1	1
Pioneer Valley MPO (PVMPO)	621,823	1	1	1	0
Capital Regional Planning Commission (CRPC)	661,042	1	1	1	0
San Joaquin COG (SJCOG)	685,306	1	1	1	1
MAPA	754,062	1	1	0	0

MPO	Population	Equity	Technology	Emerging Technologies	Equitable Technology
Capital District Transportation Committee (CDTC)	823,239	1	1	1	1
Memphis Urban Area MPO	1,077,697	1	1	1	0
Palm Beach MPO	1,320,134	1	1	1	1
Portland Area Comprehensive Transportation System (METRO)	1,499,844	1	1	1	1
Indianapolis MPO	1,557,962	0	1	1	0
DRCOG	2,827,082	1	1	1	0
Metropolitan Transportation Commission (MTC)	7,150,828	1	1	0	1
Southern California	18,051,203	1	1	1	1

MPO	Population	Equity	Technology	Emerging Technologies	Equitable Technology
Association of Governments (SCAG)					
Totals		**30**	**49**	**33**	**13**

The table shows that results in terms of whether equity was included within the plan, if there was a mention of any technology searched for (technology broadly, electrification, or ITS), a mention of any emerging technology (AV, CV, electric micromobility, etc.), and whether equity impacts of technology were discussed in the plan. Table 15 presents an overview of the results by the population categories used in the sample.

Table 15. Quantitative Results by Population

Population	Equity	%	Technology	%	Emerging Technologies	%	Equitable Technology	%
<150,000	8	*44%*	16	*89%*	9	*50%*	1	*6%*
150,001-250,000	3	*38%*	8	*100%*	3	*38%*	2	*25%*
250,001-600,000	7	*58%*	12	*100%*	10	*83%*	3	*25%*
600,001-1,000,000	6	*100%*	6	*100%*	5	*83%*	3	*50%*
1,000,001-2,000,000	3	*75%*	4	*100%*	4	*100%*	2	*50%*
>2,000,000	3	*100%*	3	*100%*	2	*67%*	2	*67%*

The results indicate that larger MPOs tend to include a greater discussion of equity than smaller MPOs in the sample. However, in terms of technologies such as electric vehicles and ITS, only two MPOs in the entire sample did not mention them within their plans. This shows how important technology is becoming for transportation but does suggest that greater efforts need to be made to increase the discussion and inclusion of equity by smaller MPOs. Emerging technologies saw a slight decrease in mentions and overall, larger MPOs seem to have a greater focus on these new developments. Finally, discussion of the equity impacts of technology increased as the population did. While

these results did not speak to the specificity or the quality of the mention, as the qualitative coding process attempted to do to a greater extent, it does seem to highlight the power of capacity and resources in terms of planning for equitable technology.

Limitations & Future Research

The second study does not present an overall assessment of plan quality but speaks to the incorporation of equity, technology, and equitable technology in plans. The results present a cross-section of the status of RTPs or long-range plans. Limitations of the research were related to data collection efforts, small sample, and limited generalizability due to a cross-sectional approach. Future research would address each of these issues and provide a more robust understanding of how planning for transportation technologies currently stands as well as how it has evolved.

As previously noted, the results do present a cross-section or a "point-in-time" analysis as it analyzes the long-range plans that have been formally adopted. Although there are movements toward more living documents in planning that can better adapt and change as transportation does, the rules and standards that apply to metropolitan planning organizations still follow a rigid cycle of short and long-range plan timelines. Developing our understanding of how the importance of equity and technology has changed over time would require a deeper analysis of plans in a longitudinal design. In addition, this research could help to determine when discussions of equitable technology

began as well as how these discussions have developed as technologies have advanced and changed in recent years.

The plan evaluation study focuses on a small sample of 52 MPOs, which represents around 13 percent of all MPOs in the U.S. In addition, the sample focused on representing the population differences of MPOs across the U.S., so a greater number of smaller MPOs were included in the sample than in other transportation plan evaluation studies. This allowed for more nuance in terms of planning across the board rather than at larger MPOs, but the trends cannot be easily compared to other evaluation studies and might differ greatly from the patterns found at larger agencies. Future research should expand the sample of plans assessed to provide a full picture of the level of equity, technology, and equitable technology planning at MPOs.

Finally, this research intended to incorporate a quantitative evaluation that investigated the impact of population size served, budget, MPO staff, and demographic characteristics on the plan evaluation score. Due to limitations in data collection and the necessity of a second coder, the quantitative evaluation remains incomplete. Future research would address these questions and provide a better understanding of what can drive a better inclusion of equity; for example, is there greater racial diversity in the city that has led to increased equity efforts? Or is the population generally younger and affluent, so equity has not been considered to the extent necessary? In terms of technology, this may be related to MPO budget; is there capacity to complete the

research and testing required to understand which technological solutions could benefit their region? A quantitative evaluation utilizing regression analysis would start to answer some of these questions and provide an understanding of how to move forward in better planning for equitable technology in transportation.

APPENDIX C

MATERIALS RELATED TO STUDY 3

Study Three Conception & Overview

The third study intended to provide an additional data source for answering how we are planning for equitable technology in transportation; a survey was chosen to understand how planners across the U.S. view the issue as well as provide an added dimension that is missing from plan documents. As previously noted, formal planning documents have multiple constraints that can lead to limited incorporation of new and emerging issues, as well as those that are currently in flux. The survey asked questions that directly involved how planners were considering technology, especially in terms of the equity benefits and challenges. The instrument was developed through a consideration of the results, limitations, and gaps identified in the previous two studies. In addition, the third study aimed to provide a greater breadth of data by contacting all 402 MPOs across the U.S. This concluded the design by adding the "future" element as well as again increasing the scale of the study.

Survey Instrument

The questions were developed to answer the research questions developed specifically for part three, or paper three, of the dissertation as well as to address gaps identified from part two. One of the research questions for part three aimed to understand the planner's thoughts and intentions in the areas of emerging technologies and equity. Formalized planning documents are often constrained by resources, time, and the need to

be flexible to changing conditions. Emerging technologies, especially autonomous vehicles, can be volatile in terms of development timeline and therefore introduction and integration into the transportation system (Madrigal, 2018). Long-range planning documents deal with the tension of needing to consider these developments while remaining flexible regarding projects and investment. Due to this, planning documents do not show the full scope of efforts being made by planning agencies (Guerra, 2016). Therefore, the survey results will provide an additional layer of context toward equitable technology planning. Table 16 details how the questions from the survey instrument connect to the research questions, the data format of the responses, and how that will contribute to answering the research question.

Table 16. Survey Development Overview

Research Question	Survey Question(s)	Data/Answer Format	Contribution to Research Question
What are metropolitan planning organizations intentions toward transportation technologies?	Will new transportation technologies be a net positive or net negative for your region?	Sliding scale from Positive to Negative.	Provide a baseline in terms of general perception of transportation technologies. This will be linked to equity and technology later in the survey.

Research Question	Survey Question(s)	Data/Answer Format	Contribution to Research Question
	Do you have any current or planned pilot tests for emerging technologies, such as autonomous vehicles or shuttles, connected vehicles, or micromobility?	Binary (yes/no).	Assesses the current stage their MPO/agency is in regarding emerging technologies. This will also link to equity and technology in a later question.
What is their technology investment strategy and/or goals?	What is your region's main focus in terms of technology projects and investment?	Selected choice (3 options + Other).	Baseline for current "main" technology focus at the regional level. Results will be analyzed by MPO size to assess differences in focus.
	Does your agency maintain an inventory of technology	Binary (yes/no).	Understanding the current inventory and level of investment is

Research Question	Survey Question(s)	Data/Answer Format	Contribution to Research Question
	projects/technological components of the transportation system?		key to developing a strategic plan.
	Is there a plan to create or start the process of documenting technology projects/components?	Binary (yes/no).	Follow up from previous question.
	Is the inventory available to the public?	Binary (yes/no).	Measure of transparency as well as a follow up from previous question(s).
	What was the process involved in developing the	Open-ended text. Qualitative review of	Follow-up from previous question. Themes and promising practices

Research Question	Survey Question(s)	Data/Answer Format	Contribution to Research Question
	inventory? And how is it maintained?	responses with coding for themes.	will be collated. This will be translated into practitioner focused material/advice.
	Does your MPO complete a technology plan?	Binary (yes/no).	One of the initial stages of planning for emerging technologies is research. This will determine aid in determining what stage of the planning cycle MPOs are in as well as provide insight into strategy for investment.
	What types of technology plan do you complete?	Selected choice (4 options + other, please describe).	Will refer to main technology focus. Establishes where MPOs are investing their resources in

Research Question	Survey Question(s)	Data/Answer Format	Contribution to Research Question
			terms of research, which should signal future investment intentions.
What are planner's intentions with regard to equity in transportation, both today and in the future?	Environmental justice analyzes are federally required and cover low-income and minority populations; do you include other underrepresented or transportation-equity populations in those analyzes?	Selected choice (3 options + other, please describe).	Federal requirements for environmental justice focus on minority and low-income populations; however, some MPOs include additional populations. This question will address gaps from the plan evaluation.
	Is equity included in your project prioritization process or framework?	Yes, No, Planning to add in the future.	Recent research suggests that including equity in project prioritization is key to equitable

Research Question	Survey Question(s)	Data/Answer Format	Contribution to Research Question
			planning in transportation. This will show whether research is being adopted in practice and understand progress toward greater equity incorporation.
	What performance measures are used to evaluate the success of your equity planning efforts?	Selected choice (5 + other).	The environmental justice or equity analysis can appear to be a checklist item at times in the planning process. Evaluating success shows a commitment to equity and may provide promising practices

Research Question	Survey Question(s)	Data/Answer Format	Contribution to Research Question
			for other planners/agencies.
	In the last year, do you feel like your agency/organization's approach to equity planning has changed?	Open-ended text. Qualitative review of responses with coding for themes.	The conversation surrounding equity and justice in planning has increased over the past year. Many of the plans being evaluated were completed before these events and societal shifts. This question is directed at the "future" portion of the research question as well as addressing gaps from the plan evaluation.
How do they intend to	Previously we asked if you believed	Binary (Yes/No).	Analyzed against the established baseline

Research Question	Survey Question(s)	Data/Answer Format	Contribution to Research Question
incorporate equity considerations into their technology strategy?	transportation technologies would be a net negative or net positive for your region, thinking about the equity and environmental justice communities in your region, does your answer change?		from previous question. This question will speak to whether their technology strategy changes when considering these populations.
	Will new transportation technologies be a net positive or net negative for your EJ or equity populations?	Sliding scale.	Follow-up from previous question. This should give insight into how agencies will be incorporating equity considerations into their development. For example, a “positive”

Research Question	Survey Question(s)	Data/Answer Format	Contribution to Research Question
			response should lead to equity components into technology projects.
	What equity benefits do you foresee, for your region, with the introduction of new transportation technologies?	Open-ended text. Qualitative review of responses with coding for themes.	Themes will provide an overview of the potential equity benefits at a regional level. It should also provide insight into the focus of MPOs in terms of emerging technologies.
	What equity concerns or challenges do you foresee, for your region, with the introduction of new	Open-ended text. Qualitative review of responses with coding for themes.	Themes will provide common challenges that could be helpful for other agencies, especially smaller MPOs without the resources to complete

Research Question	Survey Question(s)	Data/Answer Format	Contribution to Research Question
	transportation technologies?		research into these technologies. It may also show gaps and areas where more practitioner-focused guidance is necessary.
	Do those pilots include any of the following components (*related to equity*)?	Selected choice (4 + other).	Follow-up from previous question on pilot studies. This is where intentions are translated to practice. Incorporating equity means understanding how new technologies will impact underrepresented populations. Including an equity component in a pilot project is the first step.

Research Question	Survey Question(s)	Data/Answer Format	Contribution to Research Question
	Please briefly describe the pilot project and the equity component.	Open-ended response. Qualitative assessment of responses.	Promising practices and concrete examples will be helpful for those in the planning field. This will provide more details on how equity is being incorporated as well as information for practitioners.

Extended Results

The extended results section will follow the order in Table 16 and provide results for each question.

Will new transportation technologies be a net positive or net negative for your region?

Table 17. Transportation Technologies Sliding Scale Response Overview

Minimum	Maximum	Mean	Standard Deviation	Variance	Count
20	100	70.48	17.08	291.82	112

Do you have any current or planned pilot tests for emerging technologies, such as autonomous vehicles or shuttles, connected vehicles, or micromobility?

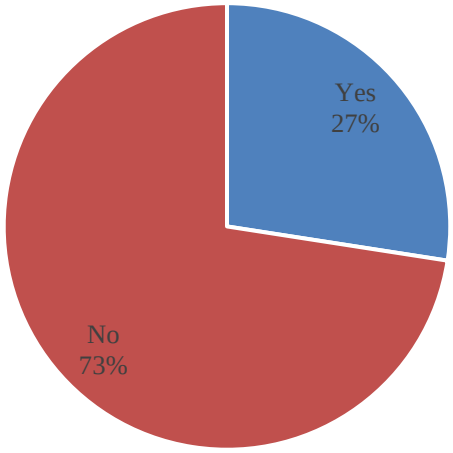

Figure 12. Current or Planned Pilots Response Overview

What is your region's main focus in terms of technology projects and investment?

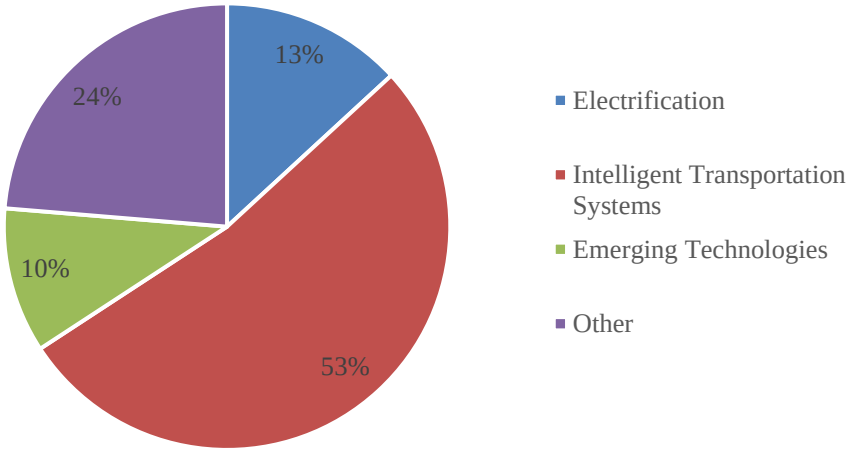

Figure 13. Technology Focus Areas Response Overview

Does your agency maintain an inventory of technology projects/technological components of the transportation system?

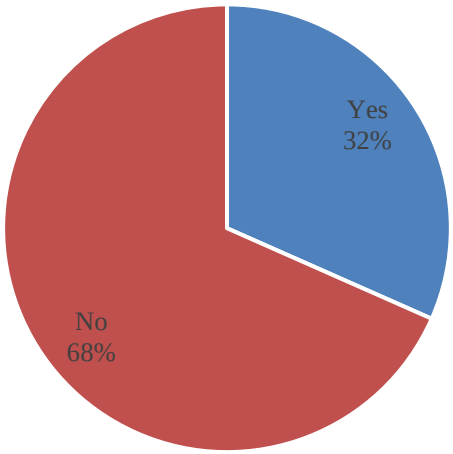

Figure 14. Technology Inventory Response Overview

Is there a plan to create or start the process of documenting technology projects/components?

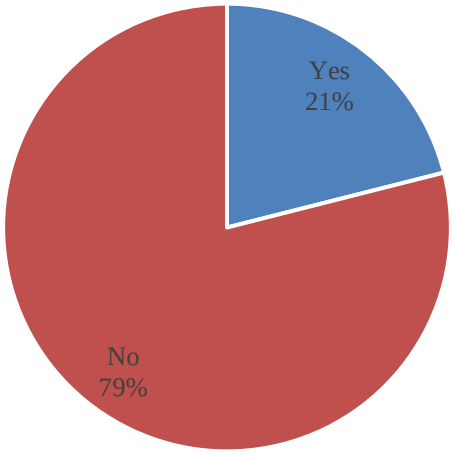

Figure 15. Technology Inventory Planned for the Future - Response Overview

Is it publicly available?

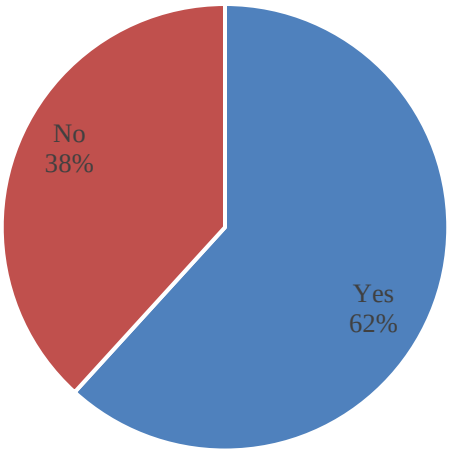

Figure 16. Technology Inventory Available to the Public - Response Overview

What was the process involved in developing the inventory? And how is it maintained?

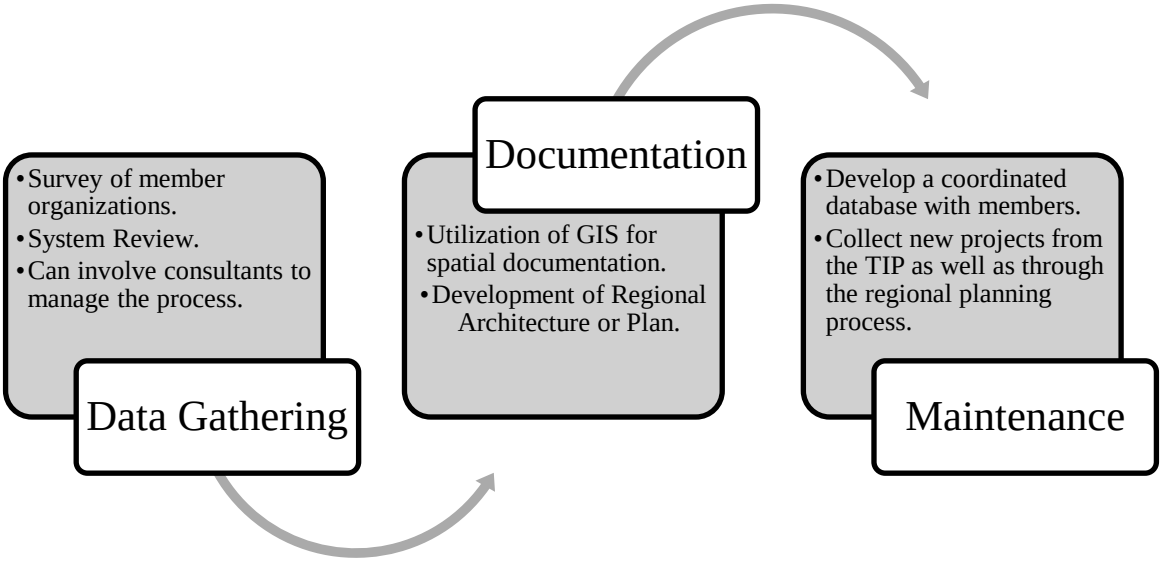

Figure 17. Technology Inventory Development & Maintenance Workflow

Does your MPO complete a technology plan?

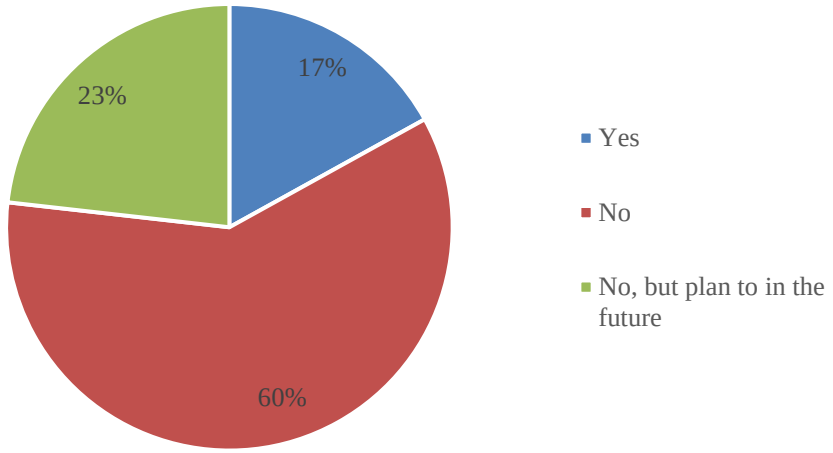

Figure 18. Technology Plans Response Overview

What types of technology plan do you complete?

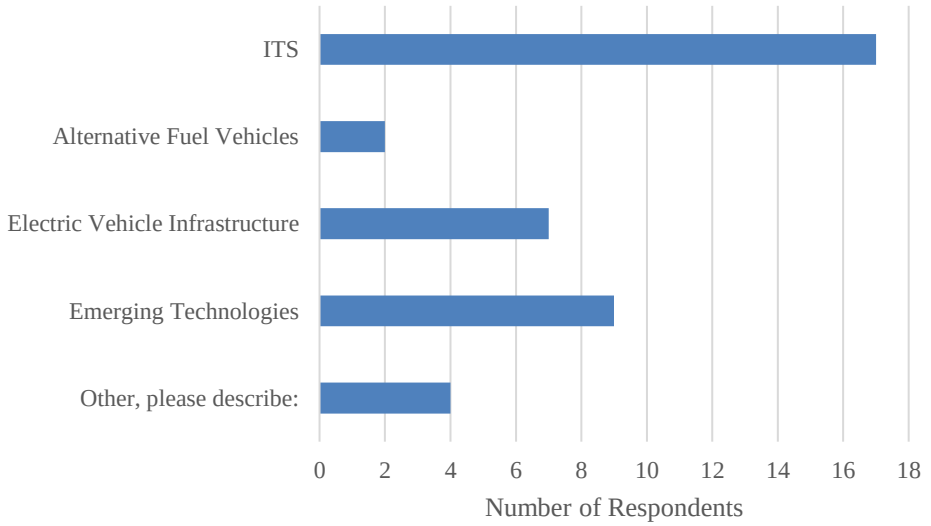

Figure 19. Types of Technology Plans - Response Overview

Environmental justice analyzes are federally required and cover low-income and minority populations; do you include other underrepresented or transportation-equity populations in those analyzes?

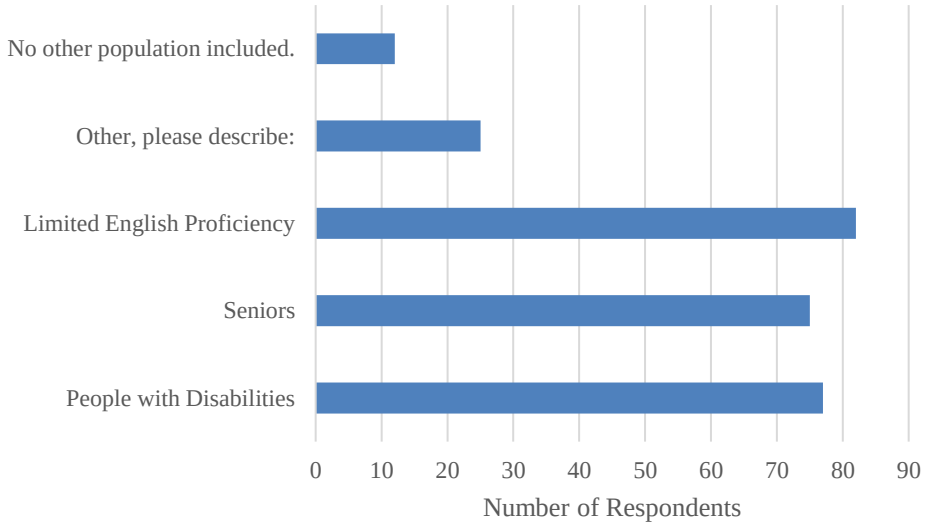

Figure 20. Environmental Justice Populations - Response Overview

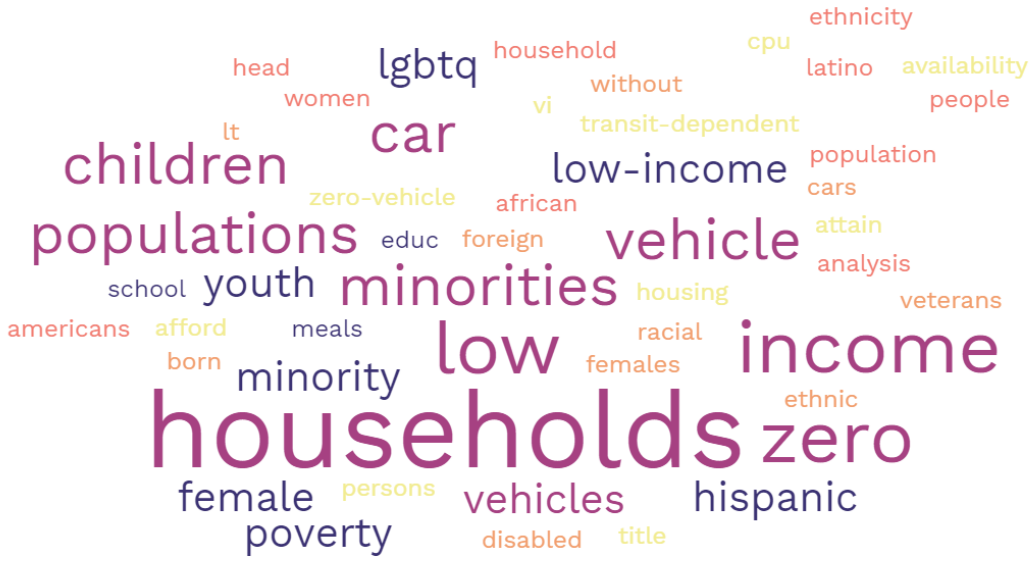

Figure 21. Environmental Justice Populations - Word Cloud of Text Responses

Is equity included in your project prioritization process or framework?

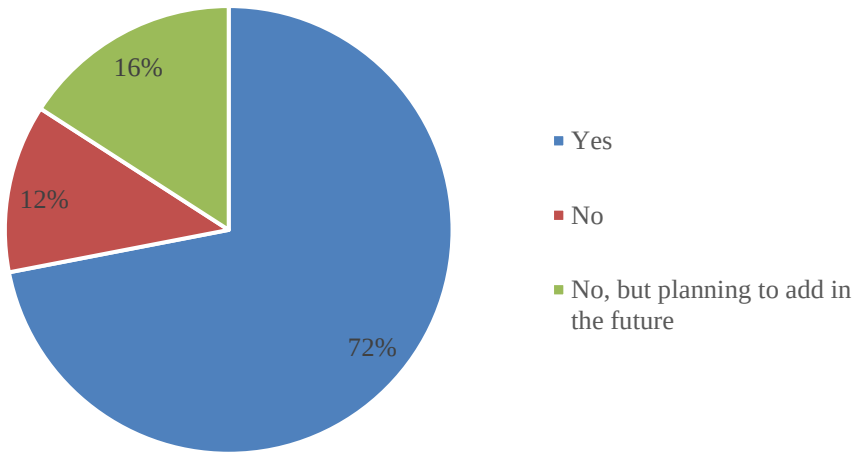

Figure 22. Equity & Project Prioritization - Response Overview

What performance measures are used to evaluate the success of your equity planning efforts?

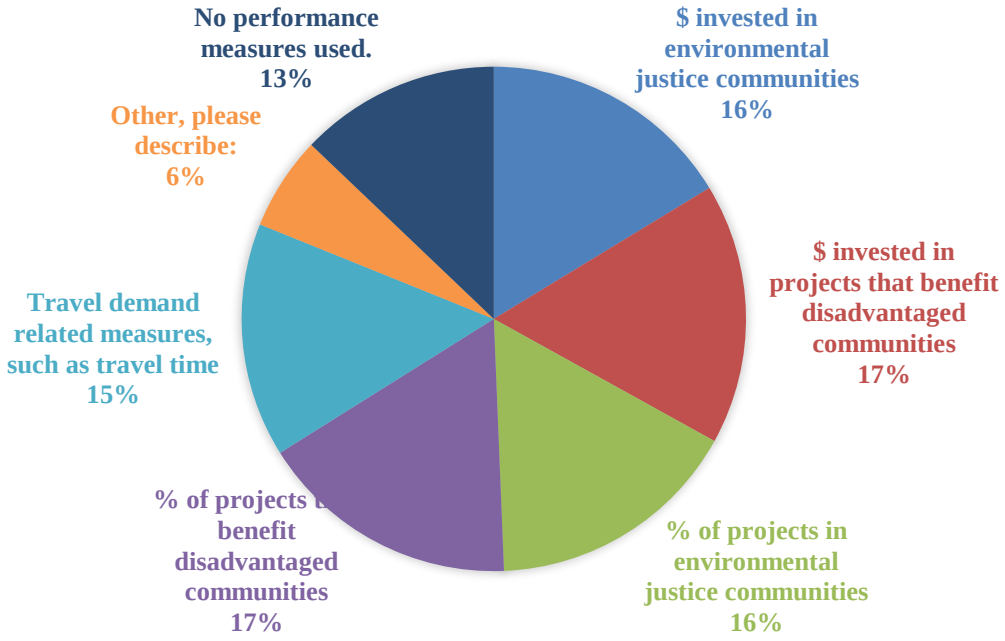

Figure 23. Equity Performance Measures Response Overview

In the last year, do you feel like your agency/organization's approach to equity planning has changed?

Figure 24. Approach to Equity - Word Cloud

Previously we asked if you believed transportation technologies would be a net negative or net positive for your region, thinking about the equity and environmental justice communities in your region, does your answer change?

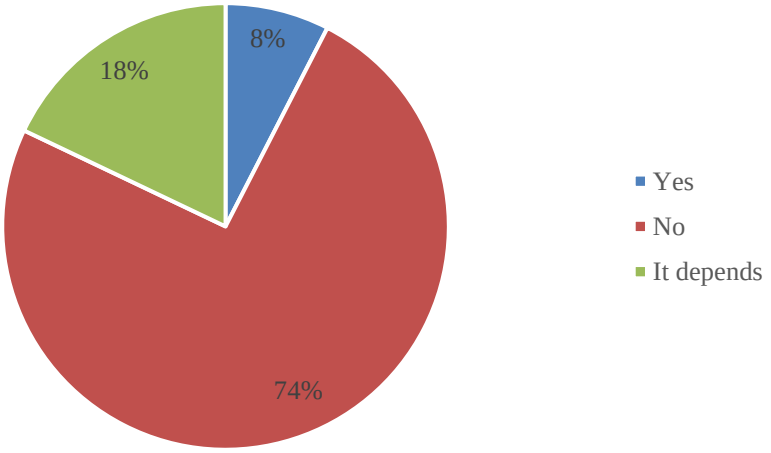

Figure 25. Transportation Technologies & Equity Response Overview

Will new transportation technologies be a net positive or net negative for your EJ or equity populations?

Table 18. Transportation Technologies & Equity Sliding Scale Response Overview

Minimum	Maximum	Mean	Standard Deviation	Variance	Count
20	91	56.96	18.66	348.04	25

What equity benefits do you foresee, for your region, with the introduction of new transportation technologies?

Figure 26. Equity Benefits Word Cloud

What equity concerns or challenges do you foresee, for your region, with the introduction of new transportation technologies?

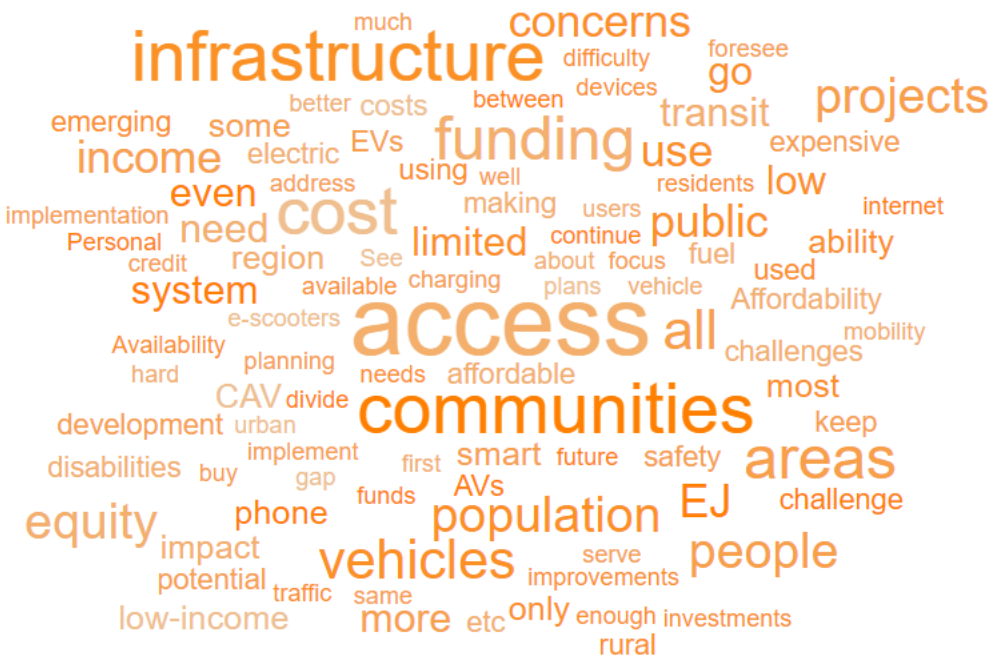

Figure 27. Equity Challenges Word Cloud

Do those pilots include any of the following components (related to equity)?

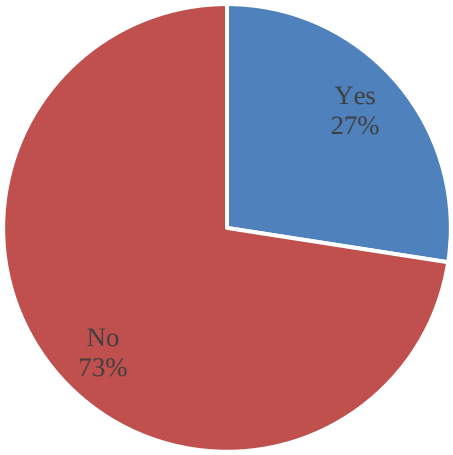

Figure 28. Equity Component in Pilot Project

Please briefly describe the pilot project and the equity component.

Figure 29. Equity Component of Pilot Project Word Cloud

Limitations and Future Research

Limitations of this study can be directly addressed with additional research, especially an expansion of the survey as well as conducting focus groups and interviews to gain more nuance from the questions relating to the equity of technology. The survey instrument relied on open-ended responses due to the nature of the subject and a lack of survey research that has directly delved into this problem in the past. Open-ended responses allow for nuance but can often lead to survey fatigue and different understandings of the question at hand. This initial survey has provided a solid overview of the issue from the perspective of planners but has room for both improvement and expansion. A survey instrument that includes more directed questions based on the responses and initial results of the survey could provide additional nuance and context, especially in terms of the equity impacts of technology. The questions were intentionally broad in this effort to capture the full range of experiences, thoughts, and intentions in the area. Additional research should also consider in-depth interviews of MPOs that are conducting extensive research or work in this area; promising practices should be shared with other agencies to reduce the impact of limited capacity when possible. This would also allow for a more detailed consideration on the topic of equitable technology, which is best discerned through qualitative research (Lincoln & Guba, 1985). Focus groups would add another dimension to this research by allowing planners to share ideas in a collaborative space, where the potential for more detailed responses is possible. Also, focus groups that included actors outside of planning, such as community members, policymakers, and

technology designers, would provide for rich conversation and qualitative data that could work toward a more equitable future with transportation technologies.