Living in the Arizona Testbed:

Mapping the Spaces and Work of Sociotechnical Imagination and Assembly

by

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ABSTRACT

Technology and society co-exist, influencing each other simultaneously and iteratively, in ways that are sufficiently interdependent that it can be hard to see where one ends and the other begins. A set of sociotechnical relations exist between and across society and technologies that structure the ways that people live and work. What happens to sociotechnical relations when technologies are introduced or changed? In this dissertation, I argue that key parts of the processes that link technological and social change occur in a liminal space between the invention of new technologies and their widespread adoption and integration in society. In this space, engineers, businesses, and users of new technologies imagine, explore, develop, and test new ways of weaving together technology and society in novel sociotechnical arrangements. I call this space between invention and adoption a testbed, which I theorize as an early phase of technological deployment where outcomes are explored and tested, and sociotechnical assemblages are imagined, assembled, evaluated, and stabilized. I argue that the testbed, which is often delimited in both time and location, should be understood, interrogated, and governed appropriately to anticipate and examine the possibilities of social disruption inherent in technological change and to design the relationships between technology and society to improve sociotechnical outcomes. To understand the testbed, I engage in a case study of the Arizona public autonomous vehicle testbed, leveraging a multi-method approach that includes public observations, interviews, a survey, and content analyses. Through this work, I analyze diverse aspects of the testbed and articulate how the work of testbed actors imagines, assembles, tests, and stabilizes sociotechnical assemblages and

futures. The dissertation builds on the insights gained from this investigation to evaluate the testbed and develop recommendations about assessing the space between technology invention and widespread adoption. Ultimately, this dissertation concludes that testbeds are key places where futures get made and so should be given greater attention by theorists of innovation and by societies confronting the societal and ethical challenges posed by new technologies.

I dedicate this work to my parents, Joyce and David Radatz, who taught me the meaning of hard work, perseverance, and kindness.

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CHAPTER 1

INTRODUCTION

"The Titanic remains a haunting image of technological complacency… [Engineering] is not, of course, an experiment conducted solely in a laboratory under controlled conditions. Rather, it is an experiment on a social scale involving human subjects."- Martin and Schinzinger 1996, 81

Technology and society co-exist, influencing each other simultaneously and iteratively, in ways that are sufficiently interdependent that it can be hard to see where one ends and the other begins. A set of sociotechnical relations exist between and across society and technologies that structure the ways that people live and work. People inhabit sociotechnical systems. For instance, transportation technologies shape mobility and social order, allowing for people to live and move around in the world in ways that are radically different than if they did not exist, even as the same technologies are shaped by the choices people make about which technologies to use—and how to use them. Transportation technologies, embedded in society amongst a sea of other technologies, help to orchestrate how people go to work, where people live, and how they access critical resources like food and healthcare. They are, fundamentally, part of who we are and how our societies work.

What happens to sociotechnical relations or systems when technologies change or are replaced? How do the social structures connected to technology change, and how will we know if they are changing for the better? For example, when the car was introduced in

the first half of the 1900s, changes occurred in government, infrastructure, and justice as the concept of a road was negotiated over several years, impacting lives and livelihoods (Norton 2011).

Space exists between the invention of new technologies and their widespread adoption and integration into society that is a place in which engineers, businesses, and users of new technologies engage these questions and explore and test possibilities for how technology and society might be interwoven. In this dissertation, I argue that this space, which is often delimited in both time and space, should be understood, interrogated, and governed appropriately, to anticipate and study the possibilities of social disruption inherent in technological change and to design the relations between technology and society to improve outcomes for diverse groups of people. I call this area between invention and adoption *a testbed*, which I theorize as an early phase of technological deployment where sociotechnical outcomes are explored and tested (see Table 1). The testbed, I assert, is not just a testbed of a technology, but a place where the imagined sociotechnical configurations are assembled and evaluated before the scaling of such assemblages that eventually become settled.

Table 1

The Space Between Invention and Adoption

	Invention	Testbed	Adoption
Explanation	Assembling and testing technological prototype devices & imaginaries	Assembling, testing, and stabilizing prototypes of sociotechnical configurations and their fit into larger social, economic, environmental, and technological landscapes.	Scaling sociotechnical assemblages that are established.
Examples of Activities/ Features	• Invention • Prototyping • Designing • Construction	• Simulations/trials • Public testbeds • Living Labs • Early Adopters	• Widespread adoption • Normalized • Pervasive

To understand this space, this dissertation will examine the case study of the autonomous vehicle (AV) testbed in Arizona. This testbed is public, meaning that it is not only a test of the technology but also a test of the social future of living alongside and with the technology—a test, if you will, of possible future sociotechnical relations or systems. The Arizona metropolitan Phoenix area, a testbed for autonomous vehicles, currently engages in testing autonomous futures on public streets. Leveraging this case, this dissertation will explore the concept of a testbed as an intermediary stage in the innovation system that connects the construction of anticipatory sociotechnical imaginaries of the future with the building of users and nonusers, simultaneously overlaying future possibilities onto the real lived experiences of people who live within the testbed. To ensure that social futures, not just technological futures, are being built responsibly (meaning both that the testbed itself, as an overlay on real people's lives, as well as the processes of building futures within the testbed, are managed responsibly), the testbed must become a site of analysis in responsible innovation research. This

dissertation investigates how leaders, institutions, and discourses in the testbed develop and encode automated mobility futures and then uses this knowledge as a way to articulate responsible innovation strategies for testbeds, both broadly and in relation to driverless vehicles in particular.

This dissertation is a study about what happens after a technology is invented and before it adopted, looking specifically at how people and materials in a testbed craft and encode future sociotechnical relations. How technologies, which are still emerging and in flux, are negotiated alongside society in this test environment is crucial to understand because social values and risks are simultaneously being determined. Specifically, in Arizona, more attention should be paid to autonomous vehicle testing to build better social outcomes for the inhabitants, both now and in the future, that could enable more equitable, safer, and just sociotechnical societies.

Let me offer an example. One of the questions at stake when configuring the sociotechnical relations between any new technology and the society into which it comes into being is what risks that technology will be allowed to create and how those risks will be distributed across different groups of people. This question is of particular concern with automobiles, which are highly dangerous technologies (Wetmore 2004). Already, there has been tension in the testbed between the communicated value of why the technology should be tested in the public sphere and the reality of this integration of the emergent technology with the existing sociotechnical configurations of the city. In 2015, Arizona Governor Doug Ducey signed an executive order allowing for driverless vehicle testing on Arizona public roads, transforming the State of Arizona into a testbed of sociotechnical relations. As conceptualized here, a testbed is a place where sociotechnical

futures are tested out while under development. The executive order justified the decision, stating the "testing and operation of self-driving vehicles could produce transformational social benefits" (Exec. Order No. 2015-09, 2015). Nearly three years later, pedestrian Elaine Herzberg was killed in Arizona—a testament to the risk of testing driverless vehicles. Presently, autonomous vehicle design, building, and testing continue in Arizona.

This tension between innovation and safety was on display at "Let's Talk Self Driving: A Fireside Conversation with Waymo's Tekedra Mawakana," a 2019 public talk hosted by Arizona State University featuring government, university, and business leaders. This event served as a reminder of what is at stake by rapidly engaging in a sociotechnical transition through testing in public spaces. Mawakana described driverless vehicles as a risk "worth taking," in response to concerns about whether or not the process of developing and then testing driverless cars was too risky. The premise of taking risks to design a safer future is a common trope within the testbed and purports to move toward a future with fewer human-caused driving deaths and greater transportation accessibility. However, this vision of the future also carries with it a critical question: risks to whom? Unlike in a clinical trial setting, participants in the testbed do not consent to be there. They live there and, at least in Arizona, were neither informed nor consulted about the testbed's establishment. In Arizona, if a driverless vehicle hits a pedestrian, as was the case in Tempe in March 2018, that pedestrian did not actively consent to the risks of being in the testbed.

In the testbed scenario, the risk worth taking is not universally agreed upon by the participants in the testbed, but yet the risks are real and present to people living in the

testbed. To rephrase differently, people may not know or agree about how they are supposed to have relations with the new technology within the testbed. The *Let's Talk Self-Driving* event demonstrated different stakeholders and artifacts have power and make decisions between invention and adoption that impact the trajectory of those who live in the system by making assessments on values and weighing risks relative to the emerging technology's trajectory. Thoughtful assessments are needed in real-time to recognize what risks are worth taking, who gets prioritized, and what kind of lived experiences are being created both during testing and in the future, as a result of testing.

My dissertation interrogates how a technology gets revised and socialized before it enters into widespread use and adoption. It does so by analyzing diverse aspects and features of the testbed and activities within the testing environment and how those open up, make visible, negotiate, test, create, or close down different possible futures. Building on the insights gained from this investigation, the dissertation evaluates the testbed and develops recommendations about assessing the space between technology invention and widespread adoption.

To accomplish this work, one of the key questions examined is how different stakeholders in emerging sociotechnical systems construct users and nonusers. By exploring questions about who counts as a user or a non-user, to whom, and what those designations mean for how participation and risks in testbed activities and negotiations, the dissertation reveals how sociotechnical visions of the future, system artifacts, and decisions within the testbed shape the evolution of different people's identities and bodies in the move towards automated mobility futures. As technologies are tested and built, stakeholders are simultaneously building and testing social futures. The testbed is where

key questions are formulated and answers attempted and assessed by participants, such as: who are the users, how will the technology be used, and how will people live alongside it? By inquiring into how different actors are designing potential users and nonusers, the research presented in this dissertation helps to understand how discourses and designs deployed in the development and maintenance of the testbed impact not only the form that sociotechnical systems ultimately take but also how they were arrived at and how they ultimately shape inhabitants' well-being. By thinking about the testbed as a place situated between the sociotechnical visions of automated mobility and lived experiences of people, this dissertation provides insights into how to responsibly innovate as sociotechnical futures are being actively tested.

I systemically interrogate the designers and implementers of the driverless vehicle testbed environment in the metropolitan-Phoenix landscape. I accomplish this by examining various visions, spaces, and artifacts embedded in the system to understand what is included in the imaginary of automated mobility and how these visions are articulated, socialized, tested out, contested, negotiated, and ultimately shaped into the sociotechnical systems that emerge from the testbed to become a larger part of society. I use the testbed concept as the site of a unique kind of technological emergence that is also an overlay onto existing sociotechnical systems. The testbed is not just testing a technical device, but instead is doing the active work necessary to construct a future world in which the new technology exists among inhabitants and other technologies. The testbed is, in fact, a key part of the process of continuing the building of the technology itself, elaborating upon the prototypes emerging from the laboratory, as well as its supporting infrastructures and the new kinds of people who will live with the new

technology and their current and future lived experiences. Analysis of these simultaneous technological and social reconfiguration processes within the testbed has real-world implications for how to responsibly innovate with autonomous vehicle testbeds. It also can inform researchers on how to leverage sociotechnical imaginaries and theories of technological users and non-users for responsible innovation more broadly to improve the management of the space between invention and the attainment of a particular sociotechnical future.

Transformative Technologies: Literature Review on Creating Technologies, People, and Lived Experiences

Transportation technologies enable people to get to work, visit friends, pick up food, seek medical attention, and spend time with family. They are an ideal example to interrogate what happens if a technology is altered or replaced. Changes in transportation technologies disrupt how people engage in their daily lives, for better or for worse. It is essential to recognize autonomous vehicles are not just a change in technology but also a change in social order and sociotechnical relationships.

Autonomous vehicles are not the first vehicular technology to cause social transformations. Norton (2011) investigated how the city was transformed after the advent of the automobile in the 1900s and the subsequent fight over a city street's purpose. Are public streets for pedestrians or automobiles, and depending on the answer, how are they managed, and by whom? The initial roll-out of automobiles showcased how the new and evolving emergent technology had to negotiate with existing sociotechnical arrangements to find its place amongst a city ad people that were also evolving. Norton (2011) found "before the city could be physically reconstructed for the sake of motorists,

the streets had to be socially reconstructed as places where motorists unquestionably belong" (p. 1). In service of this argument, Norton traced how society had to grapple with who had the right of way and was at fault in automobile-pedestrian accidents. At first, accidents were the driver's fault and then became the fault of pedestrians, with the newly coined term "jaywalkers." In this historical retelling, automobile technology on roads resulted in both momentum and tension tied to values of safety, justice, efficiency, freedom, and commodification, reflected in local, state, and national policies governing transportation. It also spurred the creation of new enduring artifacts like parking lots, crosswalks, school safety patrols, playgrounds, chambers of commerce, and traffic engineers, all of which continue to shape the lived realities of people today, as well as new technologies to enable safe driving, like speedometers and horns (Norton 2011). The initial negotiation between the technology and society spanned several decades (Norton 2011) and involved the loss of considerable life as people figured out how to navigate the reconceptualization of roads.

In some ways, Norton (2011) could be interpreted as a story about a testbed. To interpret Norton's analysis would be to say that automobiles slowly made their way onto the streets when all the sociotechnical relationships had not been appropriately sorted out. It was exceptionally unclear the relationships that were supposed to exist between people, the road, and the car as the automobile and city were being refashioned. As a result, uncertain outcomes were omnipresent, and eventually, negotiation occurred that identified what counted as acceptable rates of accidental risks to participants and where responsibility was situated. Managing the space between invention and adoption, as this research documents, analyzes, and makes recommendations on the matter, would help

make sure such technosocial negotiations resulted in better outcomes for both the technology and society.

Within science and technology studies, one of the key tools for interrogating processes of sociotechnical change like that explored by Norton is the theorization of users and nonusers, which helps articulate who has access, interest, and capability of using a technology (Oudshoorn & Pinch, 2003). But this binary, one-dimensional language of users and non-users elides how stakeholders, such as for-profit businesses, advocacy groups, and government, define where and how users fit into and shape sociotechnical systems, not just how they interact with discrete artifacts. This dissertation goes beyond dichotomous conceptualizations of users and non-users and instead interrogates how the technological and social worlds are constructed in ways that alter lived experiences for diverse groups of people within emerging sociotechnical systems. In this research, I focused on how aspects (both social and technological) of the Arizona autonomous vehicle system construct the inhabitants of the testbed through their real and envisioned use and nonuse of the technology and then extrapolate this to investigate what this means for life in the system, in terms of daily lived experiences, access, opportunity, and futures.

In the following sections, I explore the concept of a testbed and construct a theory of testbeds. I explore how technologies and people get made and remade through co-construction within testbeds, how coproduction of technologies and society shape relationships between people and their environments, and how to leverage responsible innovation to improve such techno-social outcomes. The general perspective of this research is that the world is coproduced iteratively between technology and society

(Jasanoff, 2004). One slice of this coproduction occurs when designers create technologies, and then users and nonusers are created through design decisions (Oudshoorn & Pinch, 2003). Users can also interpret how to engage with the technology, which may be different from the designer's intent, and can shape its evolution (Kline & Pinch, 1996). Design decisions and interpretations create different lived experiences and futures for people, as some people get access to new opportunities while others may not have access at all (Garland-Thomson, 2011).

However, both people and technology also exist within a larger system of sociomaterial arrangements, collective experiences, and visions for the future. By looking at sociomaterial relations and networks broadly and collectively, a macro-social approach examining technologies in the context of a city can help clarify how different possible technological forms of life are enabled or disabled by the activities and negotiations that occur within testbeds. This research investigates how sociotechnical experiences and futures are assembled in an extensive regional innovation system where futures are actively tested out on public spaces in the testbed. The following section delves deeper into the nuances of testbeds and theories that help to articulate what goes on between design and adoption, including the creation of technology, envisioning of imagined users, adoption of real users, and implementation in largescale sociomaterial arrangements, alongside normative questions tied to value and power and enduring visions of the future tied to sociotechnical imaginaries.

Testbeds

Nothing is settled in a testbed: the technology has not achieved closure and the social relations to the technology are not matured and stable. It is essential to understand

precisely how the term "testbed" can be interpreted to grasp the fundamentals: what is being tested, by whom, where, and to what ends? The following section will leverage a broad definition of the word testbed to understand it as a place where sociotechnical assemblages are in development, while outlining a few examples of how testbed activity current occurs with the public, before suggesting a model for conceptualizing how testbeds work and why they matter.

This research takes a broad approach to the definition of the word testbed to allow flexibility in conceptualizing what, where, and how things are tested. Merriam Webster's definition of a testbed is "any device, facility, or means for testing something in development" (Merriam Webster, 2019). This definition has many pivot points for reinterpretation in different contexts. This definition provides flexibility both geographically and topically, as to the purpose and physicality of the testbed. Structurally, the shape of the testbed can take make forms. For instance, the definition allows for a testbed to be a technological tool used for simulations, a fenced-off proving ground facility, or any other strategies for testing a device. A testbed's shape can take many different forms and might be tied to its geography, infrastructure parameters, physicality, and political or social circumstances. Testbeds can exist physically, taking on the form of a testing warehouse, track, or proving ground. They might occur electronically in a computer simulation. They might also exist more broadly in a region where politics have allowed for testing in public spaces, as is the case in Arizona. The definition also has topical flexibility as to what, or who, actually gets tested in the testbed. The language of "something in development" brings additional definitional flexibility because it allows this research to understand a testbed where both technologies

and society can be tested in their development. For this research, an autonomous vehicle testbed is a place where sociomaterial arrangements can be tested to understand how identities and futures are being built, alongside the development of new technology.

The testing of innovations and the futures they might bring is not a new concept practically. People participate in focus groups to provide product feedback to companies, while others attend movie screenings to test alternate endings. Some people consent to participate in clinical trials for medical and pharmaceutical innovations, while others might live in a testbed for driverless vehicles. Each of these testing modalities brings different risks, opportunities, and obligations.

Testing can occur in less structured and more opaque ways than clinical trials or focus groups, where it is unclear what protections might be provided for people. Engineering certainly can have trials in a lab in a controlled environment, but when the engineering innovation goes out into the world, it becomes "an experiment on a social scale involving human subjects" (Martin & Schinzinger, 1996, p. 81). When testing occurs on a social scale, Martin and Schinzinger (1996) reminded readers, "the *Titanic* remains a haunting image of technological complacency" (p. 88). Martin and Schinzinger (1996) described that between the operator sailing the ship in a known iceberg-ridden area and designers having the boat equipped with one-fourth of the lifeboats needed, over 1,500 passengers died. The authors suggested, "imaginative forecasting of possible bad side effects" (Martin & Schinzinger, 1996, p. 122) could alter such outcomes, increase preparedness, and make designers, implementers, and users less complacent. A sterile, structured clinical space is not a prerequisite for a testbed environment, and the trials of the experiment will run regardless of whether or not there are members of the public

present. Whether the technology being tested in a ship's passage or medication trial, people are tied to these examples.

As a type of experimentation in the real world, the concept of urban living labs has also received some attention in academic literature. Urban living labs are similar in concept to a testbed and often seem to involve testing sustainable technologies. Such labs aim to develop strategies that can be scaled to help with broader geographic sustainability transitions. According to Steen and van Bueren (2017), urban living labs are characterized by learning, experimenting, and including meaningful participation from all stakeholders, including private business, government, and the public, and occur in a real use context environment. Their analysis of 90 urban living labs found the public was not fully involved in the co-creative process. Their research suggests many of these labs never fully met the criteria and represent traditional top-down approaches to development.

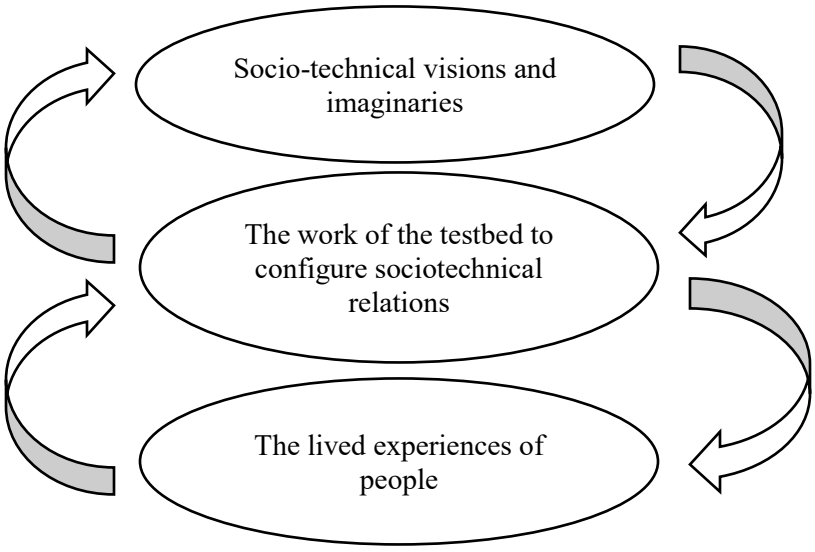
Testbeds are fueled by massive, transformative visions of the future, coordinating actors and resources toward an end goal. Engels et al. (2019) described testbeds and living labs as a tool to cultivate innovation geographically and result in beneficial transformations technologically and societally, but lack democratic accountability. A careful analysis of a testbed would "reveal how power, benefits, and costs get re-distributed, and competing visions for the future of society negotiated, in sociotechnical transformations" (Engels et al., 2019, p. 2). Engels et al., through their research and creation of a framework for testbeds, acknowledged testbeds are experiments on society, which different issues of power and control guiding its design. Knowing which stakeholders are involved in the testbed design and governance helps make sense of

transparency and control issues and varying visions for success. Critical to recognizing problems related to transparency and control is how testbeds are integrated into infrastructure projects, with an inability to withdraw consent in the testbed, as the line between test subjects and the public is inextricably blurred.

This research conceptualizes the testbed as a liminal space between visions of the future and lived experiences of people. In the testbed is where work is done to configure the particular sociotechnical relations of a technology. This testbed space, I argue, can influence and be influenced by both visions of the future and real lived experiences of people (see Figure 1). The following section will develop a theory of testbeds to explain how this happens, leveraging literature across technology studies to demonstrate how sociotechnical relations get negotiated, contested, and settled and why the process of forming sociotechnical arrangements matters for building desirable futures.

Figure 1

A Theory of Testbeds



Developing a Theory of Testbeds

Theorizing and subsequently managing testbeds enables futures to be built in more advantageous ways, because that is the place where emerging technologies take shape and where society is impacted. As new futures are being built, it is important to make sure that these futures are desirable. To understand how technologies form and impact society, it is necessary to understand how sociotechnical assemblages are negotiated, contested, and achieve closure in the testbed, and therefore how different people within testbeds interact with each other and with different ways of imagining and designing the technology. With knowledge, the testbed as a liminal space between invention and broad adoption can be managed to maximize outcomes through responsible innovation.

What is there to do about trying to maximize outcomes as a technology emerges? How are societies and technologies built and maintained well? As society and technology emerge together and create new relations, doing so critically, responsibly, and reflexively is vital to bringing about positive social outcomes and sociotechnical lived experiences. Responsible innovation attempts to orient designers and governors of science and technology to grapple with the complicated relationships between technologies and society. This research builds upon existing responsible innovation work to create strategies to manage testbeds specifically and the sites between invention and adoption more broadly. Stilgoe et al. (2013) described responsible innovation as "taking care of the future through collective stewardship of science and innovation in the present (p. 1570), made up of four dimensions: anticipation, reflexivity, inclusion, and responsibility. Guston and Sarewitz (2002) suggested the framework of "real-time technology

assessment" as an updated form of technology assessment that would improve the relationship between science and society, to enhance both simultaneously. The methodological suggestions include engaging in research program mapping, communication and early warning strategies leveraging mediums like newspapers, analogical case studies to help put the technology in historical context, and participatory research. Science-fiction can even help responsible innovation, as science fiction is human-centered, future-focused, imaginative, and resonates with meaning (Miller & Bennett, 2008). Indeed, science fiction helps impart the important lesson that "technologically enabled futures are also value-laden futures" (Jasanoff & Kim, 2015, p. 337).

To innovate responsibly, it is essential to recognize how sociotechnical decisions can worsen problems and alter morality. Wolbring (2011) suggested technologies should be designed and implemented with the awareness of how a technology might create a disabling experience. Even with transhuman techno-enhancements where people are expected to gain new abilities, this will create a new form of disability for the techno-poor. Additionally, Wolbring called for incorporating goal-based ethics into technology policy, which would include things like equitable access. These are all important considerations that motivate this effort to theorize testbeds and leverage them responsibly for beneficial social outcomes.

At the heart of the testbed is the creation and negotiation of sociotechnical assemblages, where the arrangements of people and technology are tested out and developed. In the testbed, the relationships between society and technology are imagined, built, and tested. The testbed is a place for seeking to build such assemblages, seeing

whether and in what form people are willing to attach themselves to different kinds of assemblages, and whether this can achieve closure of some sort.

The relations between technology and people are at stake in the testbed, because sociotechnical arrangements, and thus sociotechnical futures, are being imagined, performed, and reimagined. Actor-network theory (ANT) provides a useful way to understand how humans and nonhumans are tied together and how these sociotechnical arrangements make up the world. The following two examples found in Latour (1992) and Callon (1986) help raise awareness about the role of technological actors in building networks and systems that result in different sociotechnical outcomes. Callon introduced the "sociology translation" to trace human and nonhuman new, existing, and unfolding heterogenous relations agnostically. In the retelling of how scallops, fishermen, and researchers network together to answer the question, "does Pecten maximus anchor," Callon gave equal attention and weight to the role of the nonhumans in the story and how they make the story possible, giving the nonhuman actors a voice. This mapping of relations across humans and nonhumans is exactly what is decided in the testbed. Giving attention to both the technologies and the humans helps to carefully describe the assemblages being created there.

Latour (1992) asked the question, "Where Are the Missing Masses" through the title of his chapter in *Shaping Technology/Building Society* (Bijker & Law, 1992). The answer to the question of the missing masses is used to describe the influence of artifacts on people's behavior. Latour (1993) walked through a story where the world is composed of assemblages of human and nonhuman (technological artifact) actors. Latour used the example of the "wall-hole" to demonstrate how technologies are actors in how the world

gets made. When walls were put up to create a building, the walls prevented people from entering the building. A hinge would have to be developed to establish a door, allowing people to enter the building. Depending on how the hinge is built, the door might close very fast, resulting in the door closing too soon on people, or very slowly, letting in too much weather from the outside world. People were then used to holding the door open the right amount of time, but sometimes these people might miss work or be too expensive. When these human grooms failed to do their job, nonhuman technological grooms replaced humans and completed the task.

In this story, nonhumans and humans can do similar work, and their existence or lack of existence results in different possibilities. Although this is a lengthy summary of the evolution of something as simple as a door, this explanation orients this research to recognizing how relations between human and technological actors, no matter how mundane, evolve and create different outcomes. In the case of autonomous vehicle technology, people were the drivers and now the vehicles might be the driver, and as a result, this might solve some problems and create others.

To theorize the testbed, assemblages must be broken apart by first grappling with who is associated with the testbed and how. Technology studies literature provides a foundation for thinking about the roles of those associated with the testbed and technology, including designers, imagined users, and users. Then, these roles will be reassembled to illuminate how technology is developed and deployed within larger societal contexts, such as in cities and imaginations. Both the inner workings of how technologies and people come to be and how they manifest in society are key to

articulating the complexity of the testbed and how the testbed works to build and unbuild sociotechnical relationships.

Technologies are created by people who bring with them their values and conceptions of the world. Scholars have grappled with user construction at the design stage of a technology in an assortment of ways. When technologies are created, relevant stakeholders can compete to interpret a technology to influence the final stabilized form of the technology (Pinch & Bijker, 1984). Although Pinch and Bijker (1984) might not have spoken explicitly to how users are constructed, their introduction of the social construction of technology illuminated how technologies can take multiple forms and are designed in particular ways by groups of people. While technologies are being designed, they undergo "interpretive flexibility" where the technology is constructed and re-constructed by relevant social groups (Pinch & Bijker, 1984, 421) until they reach "closure" where the technology has stabilized (Pinch & Bijker, 1984, 421). A focus on the social construction of technologies orients us towards examining how technologies are physically designed for eventual users of the technology and how the concept of the technology can fluctuate. This is a particularly salient point in understanding the space between invention and automated mobility futures, because it provides a basic theoretical backdrop of recognizing that technologies can be changed by social groups, which can impact the ultimate trajectory of the technology and its users.

Designers enter the testbed with a set of imagined users for which they have designed the technology and the testbed is the place where the imagined users of the technology confront the actual users and non-users. Imagined users differ from actual users because they are imaginations of potential users located in the designers' minds that

motivate how the technology takes shape. These visions of prospective users include conscious or subconscious assumptions about what people want, how people operate, and how people should be impacted. In Woolgar (1991), the concept of user construction becomes a bit clearer: designers imagine future users and then build those imaginations into the technology, which sets constraints on how the technology can be used and by whom once designed. Akrich (1992) expanded upon this by postulating that not only are technologies designed for an imagined user, but that assumptions about these imagined users, such as their motives, morals, and tests, are also built into the technology.

Two examples clearly articulate how technologies are designed for imagined people, and done so at the possible exclusion of real people. In a very relevant example, Rose and Blume (2003) used the economy-class airline seat as a quintessential demonstration of how technologies are designed with a certain kind of user in mind. In an economy-class airline seat, these seats are built for people with a particular set of dimensions, which comes at the expense of others with different dimensions. For instance, a tall, rotund, or pregnant airline passenger might find these economy-class airline seats difficult or impossible to use and intended for someone else to access. These seats are built with technical dimensions to fit a particular body size while simultaneously designing them at the expense of others who fall outside these dimensions. Knowing who a technology is being designed for helps articulate who can access the technology and its associated outcomes.

By exploring the history of shavers, van Oost (2003) demonstrated how a specific imagined user guides the design strategy of a technology, and that these designs reinforce user identities and interests. Within a case study, van Oost explored the history of Philips,

a company that designs and sells electric shavers. Philips made the Ladyshave razor for women, and it was pastel, marketed as a cosmetic device, and had invisible mechanics, like screws. For men, Philips designed the Philishave, an electric gadget made to be more mechanical and able to be taken apart. Both the Ladyshave and the Philishave provide the same technological function of shaving, but Philips designed them for two different sets of imagined users, where the users are imagined with varying interests in design and perceived ways in which they would engage with the tool. As a result, these technologies reify and perpetuate stereotypes and cultural assumptions

The above two examples demonstrated how design impacts access while leveraging cultural norms and averages, and how relationships between people and technologies shape the lived experiences of people. It is also important to recognize that these relationships can shape the identities and entire futures of those within the system. Weber (1997) demonstrated, although cockpit design might appear to be an innocuous, gender-neutral issue, the design resulted in different futures for men and women. Cockpit design was geared toward male anthropometry specifications, which resulted in a technological bias where women and smaller statured men were less able to navigate the cockpit effectively. By designing the cockpit for the average male size, this impacted the professional futures of women trying to navigate this space. This is a very clear demonstration of how technologies can be designed with a specific user in mind, which can incorrectly draw upon cultural assumptions and anthropometric conceptions of average to exclude others who are pursuing their goals. Therefore, looking at better leveraging the space between invention and adoption futures can result in better outcomes for people related to not only their ability to access the technology, but their ability to, as

a result, access their goals and ideal futures, by paying attention to how imagined users and actual users get sorted out in implementation.

Technologies can also impact how people users relate to themselves. As another example, biomedical technologies change the relationship people have with their body and their identity. Zarhin (2018) explored how the continuous positive airway pressure (CPAP) machine enables users to feel disabled. In one way, they feel disabled without the machine, and for others, they feel disabled since using the device suggested a lack of normalcy. Similarly, Haddow et al. (2015) explore the relationship between technology and masculinity by investigating how biosensors in men with prostate cancer impact their perceptions of their masculinity. Some perceived the biosensor as stigmatizing, and for others, it made them feel as if the sensor transformed the body from an unhealthy body into a healthy one. Family identities can even be altered through sociotechnical relations. For example, through exploring fertility treatments, Thompson (2005) describes how new technologies have allowed families to address the medical problem of infertility to become mothers and fathers. However, these technological innovations can be seen as reifying heteronormative values, as some feminist scholars have noted. While some feminists recognize the potential for reproductive technologies to allow more women to have children, others find the technology to be an extension of male control (Thompson 2005). These biomedical examples demonstrate people have different relationships with technologies and that these relationships can impact their perceptions of their identity and the kind of person they are supposed to be in the world.

Furthermore, managing the space between invention and adoption of a particular technosocial future will have long-lasting consequences, because technosocial

relationships create and reinforce cultural norms. Gross and Blundo (2005) articulated how erectile dysfunction drugs reinforce cultural norms that describe the male body as broken if it does not perform sexually. This cultural norm suggests men are required to age well to maintain their masculinity and virility. Joyce et al. (2017) continued the critique of commodification and medicalization Gross and Blundo (2005) raised by articulating how the sociotechnical imaginary of ageism impacts perceptions of the elderly and results in new technological creations that reinforce the cultural concern of growing old. Ageism pervasively affects who is imagined and not imagined as users of different technologies. What is at stake in the design of a technology is not just that there are consumers to buy it; instead, it is that there are relationships built (or not) between technology and people that facilitate and prescribe lived experiences and identities. How these relationships are built, imagined, and established is a critical site of analysis to recognize opportunities to build better techno-social futures.

Not everyone, however, in the testbed explicitly influences the design of the technology, but those who are exposed to the testing can take an active role in how they engage with the technology in the environment. People are not just passively subjected to the design or testing of physical technology, as users can also alter their sociotechnical relationships in their resistance and modification to technologies. Nonusers resist, reject, or are excluded from a technology, and can include those for whom the technology was not designed or those who actively choose not to be a user (Oudshoorn & Pinch, 2003). Users can also resist a technology and redefine it. For instance, in Kline and Pinch's (1996) study, early rural resisters to the automobile referred to them as "devil wagons" and built social groups around their hatred for the new technology. Eventually, rural users

redefined the automobile and, therefore, their lived experiences with technology by using it to power equipment needed for their home and work life. Wetmore (2007) expanded upon the resisters to technology literature by working with the Amish to understand technology's role in their society, and why some technology is excluded from society while others are not. Through this research, technology is described as "value-laden tools" (Wetmore, 2007, p. 21) whose inclusion or exclusion can be made to align with a community's values. The resistance to technology is just as important to understand as the use of the technology, because such conflict illuminates social experiences and societal values. With the public testing of autonomous vehicles situated across cities, this Arizona testbed example will provide evidence of both those who want to engage with the technology and those who do not.

In between users, nonusers, resisters, and the technology exist another kind of sociotechnical role: mediators. Some relationships exist between people that impact user or nonuser relationships to technologies, which can occur through mediation. Mediators are a facet of the space between invention and the attainment of automated mobility futures because they translate information to potential users and nonusers, which can influence their relationship to the technology. Mediators, such as salespeople and advertisers, can exist between users and developers and help translate who and how people should be using a specific technology. Schot and de la Bruheze (2003) investigated the mediation between technologies, companies, market research, and potential users in the case of a snack developed by Unilever. Pinch (2003) also demonstrated salespeople were instrumental in making the Minimoog a technology that

would shape musicians and the rock and roll music they produced. Mediation can shape the perception, use, and design of the technology and user experience.

Another form of mediation occurs through narratives about how technology is developed and used within society. As an example, Fouché (2006) articulated how the African American community has been excluded from technology narratives, which has created an assumption of that community about how they contribute to technological innovation. Fouché (2006) recounted how the story of technology often ignores African American experiences with technology or otherwise describes technology as a way to control and regulate them as a social group. What is currently lacking is a retelling of African American experiences with technologies that recount technological ingenuity from historically marginalized groups. As a form of mediation, narrative building and storytelling translate how the social and technological relate to one another, which perpetuates ideas about how the world operates, whether accurate or not. In the testbed, how stories get told about how and how well the technology and society are assembling will translate to testbed inhabitants. Attuning to the mediators in testbeds can help clarify who and how they shape sociotechnical relations for different sociotechnical futures and to what ends.

The next key concept that needs to be explored to fully theorize the testbed is the relationship between the testbed, as a physical and temporal space, and the ongoing dynamics and structures of the sociotechnical entity that is the city, on which the testbed is overlaid. This is because people do not exist in singular relationships with one technology. People and technologies are tied to many other people and technology, while norms, processes/practices, history, and values are imbued across these complicated

sociotechnical webs. In theorizing the testbed, the testbed can be laid on top of the pre-existing sociotechnical assemblages of the city, while also trying to dismantle, reorganize, and newly generate strands and connections.

ANT recently expanded to help reinvigorate the study of cities. Cities are complicated places where the arrangement of relations between humans and technological artifacts construct lived experiences. A city is a place where technologies and society assemble and produce meaning daily. Farias and Blok (2016) aptly described the concept of a city as a "crucial site in which to explore all the key political problematiques of a hybrid, technoscientific world" (p. 574). Hommels (2005a) described cities as "gigantic living organisms" (p. 324) and "a 'seamless web' of material and social elements" (Hommels, 2005b, p. 15). Mumford (1967) described a similar type of organism situated in an urban space—the megamachine—where human and technical objects are part of structured and ordered systems for accomplishing certain ends. The city is a place where the social and technical come together to structure daily life and be a site of analysis to understand how networks of technologies and people assemble to create lived experiences.

As new technology is added into a testbed environment located on top of existing sociotechnical relations, broader societal configurations like practices, customs, and imaginations may be depleted or generated. The following two examples demonstrate how technological infrastructure in cities can structure social practices. In *Electrifying America*, Nye (1992) detailed how Muncie, Indiana lit up and changed in concert with technological advancements in electricity. In this historical retelling that focused on the lives of the people in the city, electricity brought new technological artifacts like trolleys,

amusement parks, and shopping, while simultaneously creating new jobs, providing escapism and culture, and integrating nationally. Increased access to electricity shifted power dynamics in factories from the shop floor to managers and promoted values like efficiency and speed (Nye 1992). Not everything is as energizing as electricity; indeed, Slota and Bowker (2017) bemoaned the lack of attention to infrastructure, which is "pervasive and ubiquitous" (p. 529), but yet taken-for-granted. For example, Slota and Baker (2017) cited Larkin (2013) to describe the relational and transformative importance of something as simple as roads as a site of fantasy where dreams are made real. Like individual technologies, built infrastructure has values and enables certain kinds of activities versus others. Indeed, transportation networks are the veins running through the city.

Guggenheim (2010) investigated the quasi-technology of buildings to understand their role in making the city. They are "mutable immobiles," where they are fixed and immobile as a technology, but their use can vary and change based on policy and legal interpretations (Guggenheim, 2010). Valderrama Pineda (2010) asked, "How do we co-produce urban transport systems and the city" (p. 123). In mapping out the transition between transportation systems while attuning to technological scripts, Valderrama Penda (2010) found the scripts created a divide between the old transportation system and the new one, making the newer innovation system irrevocable. The creation of the new system was political because the mayor appointed the CEO of the project and then had a robust public-private relationship. Furthermore, the structuring of the new system changed the way people traveled.

Seeing the world as a series of sociotechnical arrangements can reveal valuable insights into how people and artifacts co-construct one another to create lived realities. For the testbed, what occurs in the testbed will impact both the lived experiences of people now and in the future, creating potentially new opportunities or barriers. Technology studies that look at ableism demonstrate how sociomaterial relationships are assembled, who is participating in the assembling, and how they create societal disabling and abling experiences. Focusing on socio-technical arrangements, rather than isolated technologies, reveals where power is located and exerted within systems and where inequalities are created, which will be useful context for grappling with where power is located in testbed environments.

The disability literature provides helpful examples to demonstrate what is at stake in making sure sociotechnical assemblages are designed well and why intervention in testbed spaces can be valuable for generating more equitable, safe, and just societies. Actor-network theory (ANT) in an ableism context exposes how people with different abilities are discriminated against through relationships between human and nonhuman actants (Galis, 2011). Garland-Thomas (2011) introduced the language of "misfitting" to articulate the phenomenon where the world is built in a certain way, leading to the exclusion of certain kinds of people. Garland-Thomas described misfitting in particular to show how sociotechnical arrangements have been configured in ways that disabled bodies do not fit with such arrangements, resulting in a disabling experience. Similarly, Moser (2006) aptly explained the construction of disability by saying, "Ability and disability are located neither within people nor society, but in the particular sociomaterial arrangement of relations and ordering of practices that simultaneously produce the social,

technological, the embodied, the subjective, and the human" (p. 376). These arrangements demonstrate how people's bodies are judged as normal or abnormal, and how this implicit judgment leads to different kinds of experiences based on which category they fit in. This conception of "misfitting" or that sociomaterial arrangements can order the world in exclusionary ways is critical to this research, because a testbed is where these arrangements are built, tested, and evaluated. Being able to responsibly guiding these arrangements can upend existing and create new sociomaterial arrangements that increase access and equity.

How sociomaterial arrangements come together to create the different lived experiences, as suggested in Garland-Thomas (2011) and Moser (2006), can be exemplified in the story of money practices within the city. The way technology is arranged in a city can create a disabling practice, even in practices that seem rudimentary. Schillimeier (2010) told this story when tracing how money and money practices, like payment and exchange processes, in the city can disable the blind. The practice of exchanging money between a blind payer, cashier, and then back to the blind payer in the form of change creates a disabling experience.

Even in a testbed environment where something new is being implemented, the testbed may not upend exclusionary practices because it is situated on top of an existing set of sociotechnical relations. Technologies can be developed that continue to support the existing social and cultural norms. For example, creating technologies to retrofit bodies to make them "normal" reinforces the divide between what counts as disabled. Sadowski (2014) looked at the exoskeleton as a technology that gives people opportunities to walk on two legs, which reifies the cultural norm that walking on two

legs is the goal for which technologies can solve to fix people. Although the technology can help some people, it perpetuates the value of walking on two legs, imposing a suggested burden on other disabled members to purchase exoskeletons themselves, instead of accepting their own body. Such stories in the disability literature help illuminate how technologies can eliminate body diversity.

These examples tied to disability speak to the importance of looking at how technology structures lived experiences of people. By having the tested be the object of analysis, this research can look at how entire city life might be organized, while focusing on the envisioned users or non-users illuminates who becomes excluded. Surrounding and embedded in these arrangements are histories, values, visions, and power that influence their trajectories and eventual outcomes. The relationships between and across society and technology are not solely a byproduct of happenstance. Actors and their actions are not history, value, or vision-neutral.

Values are embedded in technologies that result in different outcomes. Noble (2018) explored search engines' hidden architecture and discovered the invisible architecture reinforced racism toward black women. Technologies have values imbued in them. Winner (1986) even went so far as to say technologies have politics. For example, the (mechanical) tomato harvester implemented in California, starting in the 1940s, ended up replacing (human) tomato harvesters, favoring large agricultural growers, and favoring heartier tomatoes. Winner (1986) mused:

> As far as I know, no one has argued the development of the tomato harvester was the result of a plot… What we see here instead is an ongoing social process in which scientific knowledge, technological invention, and corporate profit

> reinforce each other in deeply entrenched patterns that bear the unmistakable stamp of political and economic power. (p. 127)

Whether consciously or not, technologies and systems are designed to structure sociotechnical relationships in particular ways that impact lived experiences.

Assemblages of people and technology are imagined in the testbed and are made real. In the testbed, visions of hose society can be remade abound. As stated in *Dreamscape of Modernity: Sociotechnical Imaginaries and the Fabrication of Power*, Jasanoff and Kim (2015) wrote, "Science and technology have been involved in efforts to reimagine and reinvent human societies for close to two hundred years" (p. 321). Through this recognition, the concept of sociotechnical imaginaries has helped explain transformational sociotechnical visions. Sociotechnical imaginaries are collective visions (often national) for the future that describe social order and life based on the construction and actualization of a technological project (Jasanoff and Kim, 2009). Sociotechnical imaginaries, like aging (Joyce et al., 2016) and carbon-neutral energy (Tozer & Klenk, 2017), design technologies, mobilize stakeholders, and enable social futures. As an example, Bach and Kroløkke (2020) leveraged sociotechnical imaginaries as a framework to approach the entangled visions and interactions of biomedical professionals, technologies, health care systems, social actors, and other institutional contexts to understand coproduction with fertility cryotechnology for cancer patients. This strategy revealed how the technology is attributed value and can situate the female patient as someone "closer to life than to death" (p. 445). This theoretical orientation acutely identifies that technological futures also have social futures, whereby these technologies become essential instruments for ordering social practices and futures.

By focusing on values, visions, and power, researchers reveal the invisible drivers of sociotechnical futures. Through their examination of smart cities, Sadowski and Bendor (2019) found major companies actively sell their visions through their organizational documents, including public-facing documents and more internal technical documents like financial reports. These visions support the status quo of existing sociopolitical arrangements, which benefitted these companies' rise to and maintenance of power. This kind of hidden logic can be dangerous and made worse by perceptions of technology being amoral, rational, and sterile. Taylor conceptualized the social imaginary as means of exploring how people "fit together with others, how things go on between them and their fellows, the expectations that are normally met, and the deeper normative notions and images that underlie these expectations" (Taylor 2004, 23). Imaginaries, sociotechnical or otherwise, once recognized, are a first step in clarifying a whole host of unspoken rules and ordering about how the world works and how people are supposed to engage with each other.

The concept of a sociotechnical imaginary in the testbed is critical to recognizing how visions for the future get created and negotiated within the testbed to achieve broader adoption of both the technology and broader social futures. Karvonen (2020) stated, "Imaginaries involve the strategic construction and promotion of a coherent set of ideals that bring the future into the present and catalyze urban stakeholders to focus their collective energies on a shared agenda of change" (p. 420). The testbed brings both imaginations and visions of the future to the present, mobilizing stakeholders to achieve shared visions and construct the sociotechnical relations necessary to achieve such ends.

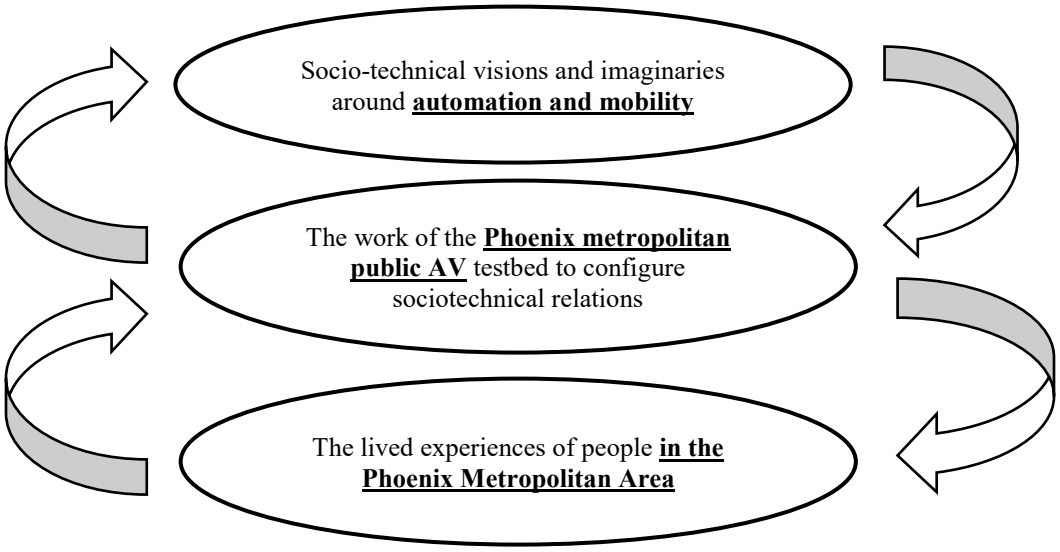
Testbeds as an Intermediaries Between Imaginations and Lived Experiences

The testbed is where co-production of sociotechnical assemblages is made explicit and where sociotechnical imaginaries, designing for user and nonuser experiences, and how to innovate responsibly intersect theoretically. The technology and test environment are in flux, changing and working towards sociotechnical visions of the future. This research is able to understand and leverage the testbed as a place to responsibly innovate to build better futures, in both the short and long term, as it is situated in the space between invention and adoption, where imagined sociotechnical relations are built, socialized, tested, and evaluated. The testbed impacts how users and nonusers are developed in the present and future, impacting their lived experiences in the system. Because the testbed sits at the intersection between sociotechnical imaginations for the future and current lived experiences of people, the testbed becomes a medium for future-building (see Figure 2). Therefore, a testbed is a critical place to engage in thoughtful analysis and assessment for intentional and responsible innovation to manage sociotechnical futures before broader adoption better.

With technological design and integration generating different lived experiences and futures for individuals and collectives, there is an obligation to innovate responsibly for beneficial sociotechnical outcomes within the testbed where the relationships between technologies and people are being sorted out. This research adopts that worldview and leverages the theory of the testbed developed above to investigate the AV testbed in the Arizona Phoenix metropolitan area to explore how the testbed shapes which futures get socialized, tested, evaluated, and solidified related to automated mobility futures (see Figure 2).

Figure 2

The Theory of the Testbed Applied to an Arizona AV Context



Autonomous mobility futures are being actively imagined, built, tested, socialized, and integrated into the Arizona testbed, making it an ideal case study to understand both the lived experiences of people (including users and nonusers) and futures are created in the space between invention and broader adoption of this emerging technology and its associated imaginary. This research bridges the user/nonuser literature with the sociotechnical imaginary literature. How are users negotiated in future-building that is in service of a sociotechnical imaginary? In this case study, they are built through the testbed. The testbed is a place where these future users are tested out presently and imagined in the future. The work of the testbed to configure sociotechnical relations involves stakeholder visions and artifacts, mediators, rules and regulations, and lived experiences. This research provides an opportunity to explore, understand, and then shape the emergence of sociotechnical assemblages through the testbed to lead to better social

outcomes, such as increased access to opportunities that promote mobility, safety, and economic security

The dissertation offers insight into four areas of thinking, including what testbeds look like and how they work, how sociotechnical futures are constructed between invention and adoption, strategies for doing technology assessments to manage the space situated between invention and adoption, and practical insights for building better futures as a result of improved assessment. Chapter 2 introduces the Arizona testbed case study by providing a brief history and then laying out the multimethod approach to exploring the Phoenix metropolitan public AV testbed's work to configure sociotechnical relations. Chapters 3 through 6 each concentrate on a different part of the testbed (experts, institutions, storytelling, and the public) to see how exploring each aspect of the testbed provides insight into how sociotechnical relationships and futures are assembled in the testbed and where there is opportunity to innovate responsibly. Each chapter contains information on how these assemblages get socialized, negotiated, and evaluated alongside visions and imaginaries around automated mobility, as well as the lived experiences of people within the testbed.

To summarize, Chapter 3 focuses on the people in the testbed that shape and perpetuate sociotechnical visions around automated mobility and how these visions get performed. This chapter centers on how the future and users are imagined by people leading, designing, and working in the AV testbed. Chapter 4 is about the work that goes on in a testbed by institutions to form new, or use existing, visions of the future to impact future sociotechnical assemblage ordering. This chapter will explore the various ways that institutions build and organize sociotechnical assemblages by encoding, promoting,

and designing for automated mobility futures around the emergent technology. Chapter 5 explores how storytelling functions in a testbed can create sociotechnical assemblages that shape, alter, and reinforce automated mobility visions, while also recognizing the present lived experiences of those within the testbed. This chapter investigates how newspaper stories mediate the happenings of the Arizona testbed alongside broader automated mobility futures, which results in socialization to the public (testbed inhabitants) about how automated mobility technological relationships, expectations, risks, and benefits are ordered. Although the prior three chapters were heavily centered on the work of the testbed and its relationship to the lived experience of people and visions of the future, Chapter 6 centers its efforts on the lived experiences of people. This chapter investigates the public experience around autonomous vehicles and the testbed, as well as the public's hopes and concerns for both the immediate time and future

Individually, analyzing expert visions, materials, stories, and people is not enough to understand the trajectory of a technology and its sociotechnical relations from invention to adoption, but packaging them in a concerted effort to understand the liminal, physical, and temporal space of the testbed helps to reveal contradictions, struggles, and trajectories that are complicated, messy, and in flux. To conclude, the final chapter brings these four facets of the autonomous vehicle testbed (visions, materials, stories, and people) together to provide insight into the shape and influence of the testbed and the future sociotechnical landscapes they promote. The testbed is a challenging site of analysis filled with dichotomies: its expansive and local, bustling with activity and invisible in its normalcy, and exists both in the present and the future. Ultimately, this chapter will negotiate these dichotomies to provide strategies to innovate around

technologies tested in public spaces responsibly. By looking at how the testbed simultaneously creates autonomous mobility lived experiences in both the present and future, this research provides insight into how to conceptualize, assess, and manage the space between invention and adoption to improve sociotechnical outcomes.

Ultimately, this research finds the components of the testbed (visions, materials, and activities) socialize, provide, and assert social order around autonomous mobility assemblages and related futures. These discourses, artifacts, and performances are sites where imaginations are made real, while simultaneously being key features of the testbed where responsible innovation research can improve social outcomes. The following chapters document a series of tensions that arise from the automated mobility imaginary. This research finds multiple contradictions within the testbed, including being both local and national, in the present and in the future, and safe and unsafe. Tensions also exist between decreased regulations and the need for accountability, technological autonomy and personal autonomy, freedom from driving and freedom to drive, and technological progress with social progress. This research will result in strategies for responsibly innovating, especially when thinking about a technology tested in a public space. Through investigating how users and nonusers get made through building and growing a sociotechnical imaginary, this research finds testbeds are crucial sites for responsible research and innovation that can result in improved sociotechnical outcomes.

CHAPTER 2
THE RESEARCH DESIGN AND CONTEXT OF THE ARIZONA DRIVERLESS VEHICLE TESTBED

"Self-driving cars, and the places and life-styles that are created around them, represent an open-ended social experiment whose participants will potentially include us all."

Jack Stilgoe 2020, 52

In his recent book about self-driving vehicles, Stilgoe emphasized the importance of understanding the process of bringing self-driving cars and their social arrangements into being as not just about making new technologies, but also about making new places, lifestyles, and experiences. The testbed is where this experiment that Stilgoe (2020) referenced takes place. The preceding chapter laid out both the theoretical and practical importance of studying testbeds as places where sociotechnical assemblages and futures are formed, tested, and evaluated. To summarize, a testbed is a liminal space between invention and adoption where technologies and social arrangements are being put together to form sociotechnical assemblages. Accordingly, these testbeds are places where technical ideas and prototypes are simultaneously transformed into the technologies that garner broader societal attention and also integrated into social life in ways that later reshape society as the resulting sociotechnical assemblages are more widely adopted. In this chapter, I detail the case study that I use in the rest of the dissertation to explore how testbeds work, in practice, and to develop my theory of testbeds further.

In pursuing this dissertation, I chose autonomous vehicles as my case study for exploring testbeds because the testbed phase of autonomous vehicle development is

particularly pronounced and visible and is, in fact, labeled as such by practitioners—and also because autonomous vehicles are both currently in this phase and likely to remain in this phase for some time, opening up an extended period of time for observation and interrogation of testbed practices. Theoretical research on autonomous vehicles has also been clear about how the technology exists in a transitional, partly imagined, partly concrete space. In that space, the transformational potential of the technology is articulated in the hype about the technology. However, the precise reconfigurations of life that will accompany the ultimate form and adoption of the technology in social and economic life (if it happens at all) are still being explored and worked out.

As Stilgoe (2018) mused, "The self-driving car is both a technology already with us and a work-in-progress, laden with promise for what it might become" (p. 26). As society figures out how autonomous vehicles and their sociotechnical assemblages are taking shape as works-in-progress, many social issues still need to be understood to create a better future. For example, Bissell et al. (2018) articulated that much of the discussion on autonomous vehicles has narrowly focused on topics like safety, efficiency, and regulation, instead of the "transformations to experiences, inequalities, labour and systems" (p. 116) that are being shaped around the new technology. JafariNaimi (2018) echoed a similar concern, critiquing how much of the conversation on driverless vehicles are about whose life the car should be programmed to save in accidents, instead of intentionally designing the technology to care about all lives. Given that autonomous vehicle technology is already here, has transformational promises associated with it, and yet remains within an obvious phase of testing and

exploring just what kinds of sociotechnical forms it may take in the future, this makes the technology an ideal one to study to learn more about how testbeds shape both present and future sociotechnical configurations.

Arizona provides a unique opportunity to study both the "open-ended social experiment of self-driving cars" (Stilgoe 2020, 52) and how sociotechnical assemblages are created and negotiated in a public testbed filled with various actors engaging in work to build sociotechnical futures. Arizona, and the Phoenix metropolitan area in particular, exists as a place of city life, innovation building, and testing. By having regulations allowing for autonomous vehicle testing, various driverless vehicle stakeholders are now activated and have designed and enabled different activities in the area. Through the design and implementation of both driverless vehicles and the testing of such cars, the Phoenix metropolitan area is a different kind of city than it was before and will continue to evolve as testing continues. The Phoenix metropolitan area is unique because automated mobility futures are demo-ed, socialized, and made real through testing, regulations, and activities via the testbed environment

In Chapter 1, I introduced the theoretical question of the testbed and why it was significant. To reiterate, a testbed exists between invention and adoption where technologies and social arrangements are being assembled and negotiated to form socio-technical configurations. To assemble these configurations, the testbed is a place where different kinds of work, such as *imaginative work, assembly work, evaluative work, and stabilizing work*, are done to create, debate, and establish these social and technical relationships. In Chapter 2, I explain how I am going to research the testbed by introducing the case study research methodology, while using examples of autonomous

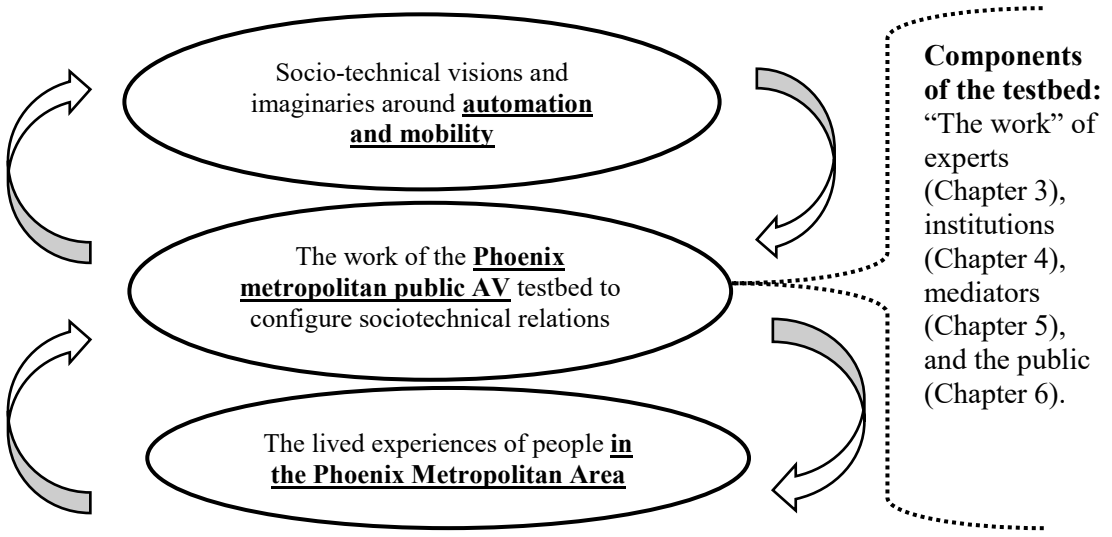
vehicle history to grapple with how different groups conduct work within a testbed, which is critical to the analytical contribution of this dissertation. Then, the chapter will introduce the Arizona testbed, providing a quick timeline and introduction to the key players in the testbed, which will be used as a general backdrop on which to understand the investigation on the work of the Phoenix autonomous vehicle testbed in configuring sociotechnical relations and futures.

Research Design

This section introduces the research design that will segment portions of the testbed and deploy varying methodologies to explore the multitude of ways work done in the Phoenix metropolitan autonomous vehicle testbed configures sociotechnical relationships and how this kind of research can make this visible for intervention. This research leverages a case study approach, intensively studying the Phoenix metropolitan public autonomous vehicle testbed to investigate the theory of a testbed proposed in Chapter 1 as a starting point to understand testbeds broadly and how to structure them for responsible innovation of sociotechnical assemblages. This case study investigates the work that occurs in the testbed by experts, institutions, mediators, and the public as a way of grappling with the immense amount of configuration activity that occurs in this space. By attending to these four areas, this case study provides both depth and breadth on how sociotechnical assemblages get made, while also pointing towards concrete areas of intervention for responsible innovation (see Figure 3).

Figure 3

The Components of the Testbed



For this research, I examine how different testbed stakeholders construct sociotechnical relationships around emerging autonomous vehicle technology. This dissertation's research is structured around the following question: How do aspects of the testbed form, test, and evaluate autonomous vehicle sociotechnical assemblages? Each chapter focuses on one aspect of the testbed: experts, institutions, mediators, or the public. Through this analysis, the testbed as a distinctive kind of emergence will be more fully understood in its role of co-producing system inhabitants alongside technology in service of visions and imaginaries around automation and mobility.

To answer the question of how different aspects of the testbed configure these assemblages, each aspect of the testbed is first interrogated for how users are constructed alongside and in coordination with the technology's development. A methodology is applied to each area to investigate both users/nonusers and the technology to answer the

following questions: Who are the users/nonusers and what lives are they supposed to lead? What is the technology and what is it supposed to do? Then, the testbed framework is applied to this interrogation to explore how assemblages are created and negotiated, before finally evaluating the testbed as a place that manages sociotechnical futures. This approach allows for not only a thorough investigation of the testbed as a theoretical concept, but also as a practical location for improving sociotechnical outcomes (see Table 2).

Table 2

Structure of Autonomous Vehicle Testbed Research

	Results: Understanding the testbed	**Analysis: Applying the testbed framework**	**Discussion: Evaluating the testbed**
Testbed Group	*Who are the users/non-users and what lives are they supposed to lead? What is the technology and what is it supposed to do?*	*What assemblages are proposed and how do they get formed, negotiated, and decided in work being done by the testbed group?*	*Where are opportunities for better testbed management and design and how would they have to be connected to the work of the group?*
Chapter 3. Experts			
Chapter 4. Institutions			
Chapter 5. Mediators			
Chapter 6. The public			

A different methodology is deployed for each area, which will be used to investigate the testbed and as a demonstration of possible methodological tools for testbed management to innovate responsibly. Although each chapter outlines its related

context and specific methodology, this chapter provides orientation and introduction to how methodologies, including interviews, content analyses, and survey research, are deployed in service of the larger research question tied to the work of the testbed in creating assemblages (Table 3).

Table 3

Structure of Autonomous Vehicle Testbed Research

Testbed Actor Group	Methodology	Medium
Chapter 3. Experts	Interviews & observations	9 interviews and 5 event observations
Chapter 4. Institutions	Web content analysis	5 companies, 9 governments, 2 universities
Chapter 5. Mediators	Newspaper content analysis	214 articles
Chapter 6. The public	Survey	429 participants

The following guiding questions are asked of each testbed group in each medium to understand the driverless vehicle testbed, while also understanding how testbed actors imagine users, technologies, and futures. Across the chapters, this research tackles the different groups embedded in the testbed by asking questions that will inform the research about what worlds are being created through the testbed. These questions are as follows:

- How does each group imagine users and non-users of autonomous vehicles and what are their characteristics?
- How does each group imagine the lives that users/non-users are supposed to lead with autonomous vehicles?

- How does each group imagine other stakeholders and their relationship to autonomous vehicles?
- In each group, who is doing the imagining, and what are their perceived roles and power?
- In each group, why are certain users imagined, and others are not?

By leveraging these questions, this research will interrogate how users and nonusers are conceptualized and managed in driverless vehicle sociotechnical system development, narrative-building, regulation, and testing. These lines of inquiry will clarify how users and nonusers are constructed, and by whom, as a way to analyze the work done in the testbed to form and stabilize sociotechnical relationships and what that might mean for the kinds of futures created.

To apply the theory of the testbed to this research, I am influenced by the theory of sociotechnical imaginaries mentioned in Chapter 1 I explaining how visions are created and engrained as an analytic approach. The theory of sociotechnical imaginaries has been previously used to explain how driverless futures are created through the actions of businesses, the creation of the physical world through engineering, and how they get rooted in culture through media (Forlano, 2019). This dissertation, taps into sociotechnical imaginary and responsible innovation concepts, and then deploys a multimethod analysis to examine how various actors and artifacts combine to create users, nonusers, and others in the urban testbed through testbed work. This insight will be used to explore how testbed activities impact inhabitants and future inhabitants of the broader sociotechnical system. By being embedded in the testbed as a researcher, I had access and opportunity to immerse myself in the myriad of ways testbed inhabitants are

constructed. Publicly available documents, observation of public events, a public survey, and stakeholder interviews are the primary data collected to understand the testbed. Information and opportunities were derived from various builders and maintainers of the testbed, including marketers, the media, politicians, technology and knowledge producers, and the public.

After taking the results from the guiding questions about user, non-user, and technology conceptualizations and imaginations, this research will use these results to analyze the work of the testbed done by each group. As a reminder, the work of the testbed includes imagination, assembly, testing, and stabilization type work. For this research, I understand imaginative work as creating and sharing visions of what the technology might be and how it might reshape society, as well as imagining who users and non-users are and their roles, rights, and responsibilities. Assembly work is the compiling and constructing of different prototype socio-technical assemblages. Testing and evaluative work are the trying out of prototype assemblages and assessing how they work in the real world and how people respond to them. Stabilizing work transforms prototype assemblages into stable forms that can be marketed and adopted to society-at-large. The following section will leverage examples of autonomous vehicle testbeds over time to look at how work is done in testbeds to create and negotiate sociotechnical assemblages in service of creating a further explanation of methods.

The Work of Autonomous Vehicle Testbeds

This research is an investigation into how users and technologies are imagined as a way to understand the way different actors engaged in testbed work and offers insight into how the work of the testbed constructs sociotechnical assemblages. In this section, I

use examples of autonomous vehicle testing across the United States, and at various times, to demonstrate how many different kinds of activities and spaces fit into the definition of a testbed, in the sense that these activities contributed to doing the work of imagining, assembling, evaluating, and stabilizing different ideas and concrete materialities of autonomous vehicles sociotechnical configurations. The following sections will provide examples of what is meant by imaginative work, assembly work, testing work, and stabilizing work, recognizing that these categories are blurry, yet helpful ways of understanding testbed work and what that means for the futures that are created.

American has a long history of early imaginative work tied to driverless vehicle futures. At the heart of the visions and imaginations of autonomous vehicles in the US are the American values of both autonomy and mobility. Smith (1994), in his history of American technological determinism, uses John Gast's painting called "Westward-ho," which depicts a woman conceptualized as progress gliding westward with trains following behind her (p. 9), to illustrate the power of technology's ability to enable movement as a motif in American ideals. In this retelling, technology, but in particular technologies of mobility, are culturally celebrated as the engine for American progress. On an individual level, driving as an activity embodies and performs self-determination, agency, and freedom, within a set of driving-based regulations and responsibilities (Seiler 2009). As the focus from the autonomous individual shifts to autonomous technology, new opportunities for imagining a freer and better society abound.

Automated mobility futures, in particular, have been part of the American imagination for decades. These autonomous vehicle futures are not just technological,

and as Kröger (2016) stated in tracing the history social and cultural history of autonomous driving, “Between an automobile controlled by a driver and one that transports passengers, there is evidently not only a technological break, but above all a cultural one” (p. 41). Indeed, early imaginative work shapes and is shaped by the social aspects, resulting in visions of how the technological and social assemble to create futures. Two examples, Futurama and Motorama, demonstrate how the technology of autonomous vehicles and the lives of people have been assembled to creatively show how the technology can reshape society.

The 1939 World’s Fair, with the theme of “Building the World of Tomorrow,” showcased an exhibit by General Motors designed by futurist Norman Bel Geddes titled Futurama, which transported visitors of the fair quite literally into a world of self-driving transport. The experience consisted of a diorama of toy cars, houses, and trees (see Figure 4), while attendees glided over in chairs listening to narration explaining that these cars were the technology of tomorrow where radio waves helped cars keep their distance (Kröger, 2016). This immersive experience impacted about 30,000 people daily at the fair (Fotsch, 2001), which imagined, created, and then reinforced into people’s minds the link between automobility and “progress and the material abundance, freedom, and social harmony that term signified” (Seiler 2009, 100). Given the World’s Fair’s engaging and accessible nature, Futurama is an early example of how autonomous futures are tested and how relationships between technology and social life are imagined, assembled, and performed to socialize and eventually stabilize these configurations.

Figure 4

Norman Bel Geddes Futurama Exhibit Depicting Urban Futures with Autonomous Driving as Spectators Watch from Above

Note: This figure was reproduced in Cicalò, E. (2015) as "Figure 1. General Motors "Futurama", 1939 New York World's Fair."

An extensive amount of imagination work was done in the 1950s by an assortment of businesses, like power companies and electronics manufacturers. For instance, in the mid-1950s, the Americas Independent Electric Light Company advertised in newspapers pictures of a family playing dominoes in a driverless electric car of the future, highlighting both leisure and the value of family (Kröger, 2016). Similarly, the 1956 General Motors Motorama featured a video called "Key to the Future" showing a family driving in a driverless vehicle, where they could transition to a high speed and safety lane for autonomous driving. This ad orchestrated how the vehicle would work and the new possibilities for how families could engage in such

vehicles once “autopilot” was activated. It created a new vision for leisure and family travel that could be realized someday, given the right technology (see Figure 5). Between the ad and the video, these 1950s advertisements imagined, assembled, and then curated a vision for how driverless vehicles would relate to humans, namely that the car-passenger relationship would bolster the nuclear family and enable leisure. Futurama and Motoroma were two places where imaginations of possible futures for autonomous mobility were tested by socializing visions for the future to the public, demonstrating that automobile companies in the US have long portrayed autonomous vehicles as a tool for realizing American ideals of family and progress, as well as an instrument for furthering particular visions of the future of the country.

Futurama and Motorama are just two examples of many that speak to how early imaginative work shapes people’s dreams and inspires people to pursue, invest, and engage with technologies that might realize specific iterations of imagined, formed, and portrayed futures. Imaginative work, and the analysis of it, provide a host of benefits, including improving reflection on desirable outcomes, organizing people, and understanding the roles of actors. Visions and imaginations like these can help collectively organize people towards a common sociotechnical future (Jasanoff & Kim, 2015) and provide an outline of the system, including the role of the government and users (Wetmore, 2020). Such historical imaginative work is helpful context, as it helps articulate how the system has been imagined and allows for better reflection on what the system should be (Wetmore, 2020). Furthermore, outlets for technoscience futures, like science fiction, can be useful mediums to grapple with how people and technology should and should not be organized together (Miller & Bennett, 2008).

However, with all the dreams and imaginations surrounding autonomous vehicles, it is important to think about how these visions translate into the real world.

Figure 5

Images from General Motor's Motorama Film "Key to the Future" Depicting Autonomous Mobility Futures

Source: Archive.org (2018)

As Stilgoe (2020) observed, "When technological dreams meet the real world, the results are often disappointing and occasionally messy" (p. 1). Events like Futurama and Motorama represent one kind of space between invention and adoption, where ideas, prototypes, and imaginaries of new technologies begin to configure sociotechnical relationships, but do so largely in the space of technological dreams. But there are also many other kinds of settings and spaces within which configuration work happens in the real world. Autonomous vehicles are an ideal technology to study how different kinds of testbed settings can imagine, explore, assemble, and evaluate

sociotechnical relationships around new technologies because there are many spaces and ways already in which this technology is tested and where the structure of these tests produces different sociotechnical futures

By articulating examples of autonomous vehicle testing, this section provides concrete examples of work done to assemble and test these relationships. Autonomous vehicles have been tested in a myriad of ways, including challenge competitions (Burns & Shulgan 2018), constructed testbed environments, and open test environments. Although each of these testbed examples is different in structure and nature, these are still conceptualized as a testbed, as the technology and relationship between the social and technical are still being sorted out. Each of these is briefly explored to demonstrate the many ways tests can occur and how the work done in these spaces differ in how it configures and evaluates sociotechnical relationships through assembly, testing, and even stabilization practices.

Between 2004 and 2013, the Defense Advanced Research Projects Agency (DARPA) hosted a series of Grand Challenges focused on driverless vehicles to promote private investment into AVs. These events offered significant financial incentives for constructing an autonomous vehicle that was able to finish testbed courses successfully. The 2004 challenge was a long-distance, self-driving ground vehicle challenge in the Mojave Desert, which posed many challenges for the technology in terms of terrain; a key element of safety was a lack of humans on the course. No vehicles finished the Mojave Desert course in 2004, and no one won the associated $1 million prize. The race was held again in 2005 and was successfully navigated and completed by many entrants. In 2007, the Grand Challenges shifted the

course from an unwieldy desert to a constructed urban environment, filled with city challenges, such as merging, parking, and intersection negotiations with other cars to test how the technology would relate to social practices.

Both of the Grand Challenges create prototype sociotechnical assemblages where the format of the challenge and associated standards described what counted as a working technology. These are two very different Grand Challenges in the way that they were structured. In the first Grand Challenge, this race only imaged what the vehicle might look like and what capabilities they would need to complete the course. It is mostly a technological imagination, which then assembled the vehicle in a primarily non-human environment (e.g., the desert). The second Grand Challenged required competitors to reimagine the technology related to a city, which then assembled the vehicle in combination with human infrastructure for that race. This shifted the approach from prioritizing the technology as a means to an end to get from point a to point b, to being a technology that still has to fulfill its driving role, but has to do it successfully with a city-inspired context.

Neither of the Grand Challenges dealt directly with users or non-users in their design of autonomous vehicles and their associated prototyped sociotechnical assemblages. Burns and Shulgan (2018) tracked the competitors in these Grand Challenges and demonstrated how those participating in these Grand Challenges ultimately pioneered the driverless vehicle space commercially, in major companies, like Google and Uber. In this instance, the technology was tested in narrow course environments, which gave designers the experience and knowledge to take their skills to think about autonomous vehicles not as a research project, but as a business

endeavor which brought autonomous vehicle sociotechnical configurations closer to being assembled, tested, and stabilized in the real world.

As an example, Google tested their autonomous vehicles on Silicon Valley roads in 2009, through the hiring of roboticists charged motivated by the goal of having 101,000 self-driving car miles on streets (Stilgoe 2020). The testing protocol for this is different from the Grand Challenges. Even though there was a technical goal of a certain number of driving miles needed, this Google San Francisco testbed now included testing work that had to navigate a real dense urban environment with other cars and people. In this instance, the people that were being assembled with the technology (as pedestrians and other drivers) were unaware of the technology project.

MCity, the University of Michigan's testbed that opened in 2015, is another example of an autonomous vehicle testbed. It is similar in concept to the urban Grand Challenge, where testing occurs in an environment with human-like factors, but is separated from public streets with real users and non-users. Researchers, university students, and automakers use this course as a proving ground to test the technology in a fabricated urban environment. This is a bounded proving ground that brings together different stakeholders to think about safety, accessibility, and sustainability. Although it may look like the city, it is a controlled environment that simulates complex transportation infrastructures and scenarios. This is an example of a driverless vehicle testbed that exists to understand facets of city life, but keeps the testing to a structured and controlled environment that does not impact the public. The testbed here attempts to assemble and test imagined sociotechnical relationships, but given the lack of public

involvement, these relationships are imitations of what the assemblages could be as influenced by the parameters of the testbed.

Early technologies deployed before technological and social relationships are configured represent another kind of testbed that leverages stabilization work to push the technology towards widespread adoption. For example, in 2015, Tesla Autopilot technology became commercially available, allowing the vehicle to steer, change lanes, and manage speed. This transformed the entire county into a testbed for autonomous vehicles. A blog post by Tesla in October 2015 stated, "We're building Autopilot to give you more confidence behind the wheel, increase your safety on the road, and make highway driving more enjoyable" (para. 2), conveying a vision for how the technology might improve lives. However, there is no guarantee that the emergent autonomous technology would improve lives, even though it was already on the market. Although taking the technology and moving it to mass production is a part of stabilizing work, the actual configurations of technology and people had not been sorted out. Joshua Brown, driving in his Tesla operating on "Autopilot," was killed instantly in Florida from a vehicle crash with a truck (Stilgoe 2018). Although the human driver and the technology were imagined in such a way that would promote safety and enjoyment (and stabilized through their mass deployment with this imagination in mind), the actual sociotechnical configurations between the driver, the technology, and the environment resulted in a very difficult outcome.

These examples of autonomous vehicle testbeds all provide general insight into what kind of work can occur in a testbed, whether it be imaginative, assembly, testing, or stabilization work. These categories are not meant to be all-inclusive and nor are

they meant to have clear boundaries where one ends and the other begins. However, these groupings of testbed work are meant to be instructive for sorting through the many ways work gets done in a testbed to configure sociotechnical relationships.

The Arizona Testbed as the Case Study Site

After introducing the general research design for this dissertation and then using examples of autonomous vehicle testbeds to explain the analytical categories deployed to assess how the testbed configures sociotechnical relationships, I now introduce Arizona as the testbed site for interrogation in this case study. The Arizona testbed is unique because the technology is being deployed in large geographic public spaces in high concentrations by companies to test their product. This testbed is visible, expansive, and in constant development with new technologies, partnerships, and activities.

The testbed sits between visions and lived experiences of people, as a place where work is done to configure the sociotechnical relationships that influence the future. In Arizona, the testbed continuously operates and negotiates what different futures might look like both locally and globally. Businesses, like Waymo and Nuro (or formerly Uber), contribute to the testing and design of the vehicles. Universities, such as Arizona State University, contribute to research and linking stakeholders together. Local governments, like the City of Chandler, create public-private partnerships. Members of the public might see a driverless vehicle on the street and hear about significant developments and events via the media. Across all of these activities, the city is transformed, with different technological, social relations, rules, and artifacts. In this testbed, users, nonusers, and inhabitants are actively being constructed and imagined in

real-time as the technology, and its accompanying sociotechnical assemblages, are developed and tested.

The testbed overlays onto existing sociotechnical relations within the city. The testbed, and the resulting sociotechnical assemblages, will result in the unbuilding and rebuilding of the city (Farias & Blok, 2010; Hommels, 2005). The inhabitants of the Phoenix metropolitan testbed include mothers, students, business owners, and participatory citizens and have identities that are already fully constructed. People travel in different ways (cars, busses, bicycles, walking, and other mobility devices) and have various personal relationships and obligations to such relationships (friendships, romantic relationships, parenting obligations, and professional expectations). People go to school, work, seek health services, shop, and engage in leisure activities. Some people have customs, faith, and traditions from other locations, while others rely on such things that were native to the area. People have projections for what their future lives look like and have long-term strategies on how to get there, while others live day-to-day. The testbed overlays onto all of these existing sociotechnical relationships, and as new assemblages are created and evaluated through testbed work, the future of the city may drastically change. The testbed is not only a testbed for technology, but also the lives of people within the system.

Vehicle testing is not new to Arizona, although many of these testbeds are largely devoid of direct human engagement, focused instead on testing the technological prototype, as was the case with the first Grand Challenge and MCity. Arizona has been the site of many vehicle testbeds, which have taken different forms and leveraged different aspects of Arizona, including its weather, dust, and regulations. Arizona has

connections with the DARPA Grand Challenges for autonomous vehicles. To prepare for the 2005 Grand Challenge, Stanford Racing used the Volkswagen Arizona Proving Grounds to test their driverless vehicle (2005 DARPA Grand Challenge). General Motors located one of their proving grounds in Mesa, Arizona in 1953, and opened another, in conjunction with the US Army, in Yuma, Arizona, shortly after closing the Mesa location in 2009. These testbeds are closed testing environments, with tracks designated specifically for driving these vehicles in development and separating direct assemblage-building from users and non-users. The Yuma site's focus was on "hot weather-related testing, powertrain, ride and handling, and other vehicle development activities" (General Motors, 2009, para. 5), which has a more extended hot-weather season than Mesa and is more isolated from the public. The current testbed iteration in Yuma also uses testing to occur in places outside of the road, including lab and math-based testing, which requires a smaller testbed facility. Nissan built a testing facility, the Arizona Testing Center, in Stanfield, Arizona. Nissan testing also occurs outside of the testing facility. By partnering with Above and Beyond Delivery, Nissan was able to test a fleet of vehicles to evaluate the durability of a commercial vehicle traveling throughout the Sonoran Desert in Arizona. However, the driverless vehicle testbed in Arizona is not facility bound; instead, it is policy bound, based on regulations allowing vehicle testing to occur on public roads. The following paragraphs will describe how this expansive Arizona autonomous vehicle testbed came to be.

The recent timeline of Arizona's events related to driverless vehicle testing is essential to understand how and why the testbed looks the way it does now and give insight into who some of the major stakeholders are in this space. This timeline will

provide context to the rest of the research, helping to elucidate who the main actors are and recognize the events that spurred discourses and decisions. The current phase of driverless vehicles in Arizona, marked by testing on public streets and significant local business investment, arose out of an executive order issued by Governor Doug Ducey in August 2015 (Exec. Order No. 2015-09, 2015). This executive order allowed for the testing of driverless vehicles on public roads, by allowing testing to take place without interference from regulation. Stilgoe (2020) described this police moment in the following way: "In Arizona, policymakers allowed a private experiment to take place in public, with citizens as unwitting participants" (p. 1). At the end of 2016, Uber brought their fleet of self-driving vehicles from California to Arizona, as Governor Dough Ducey criticized California for overregulation (Stilgoe, 2020).

In 2017, both Uber and Waymo began testing AVs on the road in Phoenix. Waymo's Early Rider program allowed Phoenix-area residents to test their self-driving vehicles to influence the technology and customer experience. By the end of 2017, these same vehicles were tested on public roads with no one in the driver's seat as a safety driver. Waymo One was then launched in Phoenix as a ride-hailing service program. By the end of 2017, Uber also began testing self-driving trucks.

March 2018 was a pivotal time in driverless vehicle design and regulatory momentum, as well as public interest. In March 2018, Governor Doug Ducey signed another executive order, this time using the order as a way to commit to public safety around the testing of these driverless vehicles (Exec. Order No. 2018-04, 2018). A few weeks later, on March 18th, 2018, pedestrian Elaine Herzberg was hit and killed by an Uber autonomous car with a safety driver present. Stilgoe (2020), in a retelling of this

fateful day, declared, “Elaine Herzberg did not know that she was part of an experiment” (p.1). Uber suspended their self-driving vehicles promptly after.

This fatality incident did not stop driverless vehicle testing and design, but it invigorated conversations and safety commitments. The focus on partnerships also publicly seemed to increase. Governor Doug Ducey issued another executive order (Exec. Order No. 2018-09, 2018), creating the Institute for Automated Mobility (IAM). The goal of IAM was to facilitate and create a public-private collaboration to advance driverless vehicles. Nuro and Kroger joined into a partnership near the end of 2018 to allow for a driverless vehicle grocery delivery pilot program. Imagry, an Israeli technology startup, tested their mapless driverless vehicle software in 2019 on Tempe and Scottsdale roads.

Although this is a very abbreviated timeline of all of the events attached to the Phoenix metropolitan testbed, it introduces significant events and stakeholders to outline topically what has occurred in the testbed. This context is used as a springboard to explore how the work done within the testbed forms, evaluates, and negotiates sociotechnical relationships both presently and for the future. Given that the testbed is still active, this research also allows for useful insight to responsibly shape the events of the Phoenix metropolitan testbed.

Outline for Investigating the Work of the Arizona Testbed

This dissertation’s research is broken down into four areas of the testbed, and thus four chapters, to chip away at the complex autonomous vehicle sociotechnical testbed continuously being built in Phoenix to reveal how testbeds create, negotiate and evaluate sociotechnical assemblages that create new forms of life for current and future users,

nonusers, and other stakeholders. In the following paragraphs, I briefly describe the research goals and methodologies of the chapter to introduce the specific investigations tied to each testbed group, which will individually and combined provide insight into the testbed and ways to responsibly innovate them. Fuller explanations of the research design, context, and methodology are provided in the chapters. This research will document how the autonomous vehicle system design and testing in this environment unfold within the testbed to create new forms of life, both now and in the future. The strategy provides useful information to improve both the design of testbeds generally and driverless cars testbeds in particular.

Chapter 3 focuses on the visioning of experts in the testbed and how these visions get articulated in testbed public spaces. Inspired by sociotechnical imaginaries as a theoretical framework, this segment looks to understand experts' visions in the autonomous vehicle spaces through interviews and public observation. This chapter articulates the visions that contribute to building the automated mobility sociotechnical imaginary. This builds on such existing research by focusing on an innovation system where these driverless futures are tested out in real-time and by thinking about how these imaginaries impact users' and nonusers' futures. Throughout an expert interview process, nine participants were asked how they have contributed to the testbed building and how they imagine the future of both the technology and people in particular. Public event observation, spanning five events from May 2019-June 2020, is used to supplement the direct interview process, to see how visions are shared in public spaces, unprompted by interview questions.

Chapter 4 analyzes the artifacts produced by institutions that encode and promote the automated mobility sociotechnical imaginary and dissect how these artifacts structure how people are encouraged to imagine themselves in relation to the technology. This will, in particular, look at the way different online materials from industry, academia, and government bring forward visions of the future. These three sectors are selected as members of the triple helix of innovation, where each brings expertise and professionalization to their work and can intertwine to improve the system (Etzkowitz, 2003). Business materials shape sociotechnical relationships, as was the case in the research documented in van Oost (2003). That research demonstrated that the technological design and advertisement of the Ladyshave personal shaver represented women as technophobic, which perpetuated a set of user relationships with shavers. Similarly, autonomous vehicle webpages can create and perpetuate relationships between people and their technology. Universities are the second component of the triple helix that are potential shapers of sociotechnical assemblages in the testbed environment, as they are knowledge and technology producers that can spur economic and social development (Etzkowitz & Leydesdorff, 2000), while also normatively guiding the future of students in their teaching and professionalization training (DiMaggio & Powell, 1983). The third component of the triple helix, government, creates trust (Nelson and Gorichanaz 2019) and engages in regulatory activities (Etzkowitz & Zhou, 2017), which can structure sociotechnical relationships. The analyzed business webpages included Waymo, Nuro, TuSimple, Beep, and Local Motors, while university webpages included those associated with Arizona State University and Maricopa County Community Colleges District. The government webpages that were analyzed included those from the

cities and towns of Phoenix, Gilbert, Chandler, Peoria, Tempe, Mesa, and Scottsdale, as well as state institutions. This chapter analyzes through a content analysis of online materials how these institutions in this testbed create, socialize, evaluate, and encode autonomous vehicle sociotechnical assemblages.

Chapter 5 investigates how newspaper stories mediate the happenings of the testbed alongside the autonomous vehicle futures more broadly to communicate how user and nonuser relations, expectations, risks, and benefits are structured with autonomous mobility technology, both now and in the future. This is an assessment of how the autonomous vehicle testbed is narrated through newspaper stories. The media shape, frame, and prime the public on critical political issues (Scheufele, 2000). *The Arizona Central*, the online branch of *The Arizona Republic*, is one of the leading news sources for the Arizona public. To understand how the local news shapes users and nonuser imaginations related to driverless vehicles, I reviewed every news article from *The Arizona Republic* that uses "driverless vehicle," "autonomous vehicle," or "self-driving car" as a keyword. In this analysis, I code each article for explicit and implicit references to real and imagined users and nonusers. I indicate the relevant stakeholders, decision-makers, and those otherwise in power in the article, alongside relevant topical content. This strategy would ideally result in two different outcomes. First of all, this investigation attempts to see how the current testbed is maintained while also documenting how the media are active participants in constructing future non-users, users, and others. Both questions will result in an analysis of who has a voice via the media. The views that get shared through these stories shape the debate, and because news media can transcend

stakeholder silos and geographic boundaries, a multitude of actors can have their stories impact the design of the testbed and future inhabitants.

Chapter 6 investigates the public experience around autonomous vehicles, as well as the public's hopes and concerns for both the immediate time and future, which will indicate how the public perceives their present and future relationships to both the technology and the testbed. This chapter differentiates itself from other research on the public acceptance of emerging technologies because this focuses on a technology embedded in a testbed environment. In this testbed, the technology is in development, yet it is present, implemented, and not abstract. The testbed experiences are localized, reflecting individual experiences as sociotechnical relations are negotiated, and tensions arise from a lack of informed consent. Understanding the public's experiences in the testbed and their conceptions about future users/nonusers will help answer the question about the testbed's impact on the community. Because the public's perspective is varied and incorporates their current identities, experiences, and impressions, I employed several different strategies to understand the role of the public in shaping both their perceptions and reflections on driverless vehicles and society's broader construction of users and nonusers. To gain perspectives from the public inhabitants of the system, I surveyed Arizona residents to understand their level of engagement and exposure to driverless vehicles, as well as their perceived current and future relationship with them.

Chapter 7 brings these four facets of the autonomous vehicle testbed (visions, materials, stories, and people) together to provide insight into the shape and influence of the testbed on configuring sociotechnical relationships and the future landscapes they promote. It will also provide context on the drivers of these sociotechnical changes,

demonstrating the power behind the automated mobility sociotechnical imaginary and those afforded power in the system. The testbed is a challenging site of analysis filled with dichotomies: its expansive and local, bustling with activity and invisible in its normalcy, and exists both in the present and the future. Ultimately, this chapter will negotiate these dichotomies to provide strategies to innovate around technologies tested in public spaces responsibly.

Across these chapters, there are instances where sociotechnical futures seem at odds with current testbed configurations, where these futures are being nevertheless socialized and encoded. The testbed is big and changing with time, where new assemblages may be promoted by some, but not by others. A lot is at stake with getting the testbed right: how can the testbed do work that configures sociotechnical assemblages well? The technology with the wrong sort of sociotechnical assemblages could cause social harm and make the world less safe, less equal, or less just. The testbed with the wrong sort of configuration process could cause poor outcomes in the future as the technology is adopted on a broader scale and poor outcomes in the testbed in the present. This research will grapple with what that means for the Arizona autonomous vehicle specifically, and testbeds broadly.

This research requires immersion into the ever-evolving work of the testbed, including discourses and activities of numerous, fluctuating, and diverse actors. It is critical to review the visions and materials that different testbed members engage with regularly to comprehend the testbed experience. Whether it be news, policy, marketing, knowledge publications, events, or people, the source of information selected for analysis is investigated for how it constructs users and nonusers of the driverless vehicle

technology to understand how testbed structure sociotechnical assemblages. This information will illuminate what it might look like to be an inhabitant in the testbed and in the new sociotechnical system in the future. This results in a unique understanding of how testbeds form, test, and evaluate sociotechnical configurations and why the testbed as a liminal space between invention and adoptions is a valuable place for responsible innovation.

CHAPTER 3
THE WORK OF EXPERTS

"I think that, you know, there's still a lot of technology that needs to get ironed out or figured out before, these are deployed wide-scale uses."- Interview Participant

"Amazing things happen when you let go." – Video at Public Event

Chapter 3 represents this dissertation's first foray into understanding the work of the testbed within the Phoenix metropolitan autonomous vehicle testbed, and focuses on the kind of work that experts do. Although experts can do many kinds of work, including the day-to-day aspects of their job, this research will look at how they conceptualize sociotechnical futures through an interview process and how these futures get socialized in a public event space. This chapter will demonstrate the kinds of work that experts engage in and use this to articulate that experts manage the scope of the conversation, can engage in uneven assemblage-building that skews towards the technological, generate or slow-down momentum, and attempt to make technological futures seem real and possible to others.

Selinger and Crease (2006) stated, "An expert knows things by virtue of being experienced in the relevant ways of the world" (p. 1). The explanation provided by Selinger and Crease (2006) is appreciated, given that it is broad enough to be inclusive of new technical experts or social leaders attached to any part of the autonomous vehicle sociotechnical assemblage-making process. This research does not tackle issues like trust and deference to experts or contesting expert claims, because the focus of this work is on the testbed work that they do, as evidenced by the methodological media chosen. I focus

on how experts have the ability to generate visions, communicate to others, and mobilize actions.

Experts can engage in a lot of testbed work, such as making decisions, setting agendas, sharing knowledge, and cultivating interest and excitement. Such leaders can take the form of "sociotechnical vanguards" that work to realize specific sociotechnical futures, "riding and also driving a wave of change" (Hilgartner, 2015, p. 34). Understanding how expert visions build, reinforce, steer and inspire future lived realities through their testbed work reveals how these futures are being structured and for whom. These insights illuminate how experts contribute to the testbed in creating and negotiating assemblages, while providing opportunities for improved responsible innovation strategies to facilitate improved autonomous vehicle sociotechnical futures.

How do experts articulate autonomous mobility futures and related sociotechnical assemblages in the Arizona testbed? This research leveraged interviews and public event observation to understand these visions of the future and, in particular, look at what strategies they use from their discursive and performative toolkits to share their visions, perpetuate them, and create buy-in. The first portion of this chapter focuses on the voices of people who demonstrate and enact expertise, through their role as decision-makers, educators, and builders, through perceived privileged knowledge and experience. The interview process investigates how experts describe what occurs in the testbed, how people are thought about, and how the future is imagined and attended to. The second portion of this chapter documents how expertise becomes mobilized in public events. These events represent the intersection between different types of stakeholders and the public. Whether it be through presentations at paneled events or open houses, these

expert voices are elevated and communicate their work and goals within a relatively quick timeframe. Similar to the interview process, this section provides articulates what experts do in the testbed to create and negotiate futures and their related assemblages, including their role in inspiring and mobilizing other stakeholders.

The focus of this chapter is to understand the work that experts do in the testbed to create and negotiate sociotechnical assemblages by looking at how they conceptualize autonomous vehicle users and futures. To accomplish this, I used two methodologies that provide insight into a portion of their testbed work: interviews and public event observations. By taking both of these approaches, I can better understand the visions experts communicate in a curated setting (interviews) and how these visions get performed publicly (event observation). This research is organized into three sections: interview methodology and results, public event observation methodology and results, and a synthesis of both methodologies to understand the ways that experts do work in the testbed.

Expert Interviews

Through interviewing experts, I gained in-depth qualitative knowledge about how experts in the field think about creating users and futures. The interview protocol created a space where experts could discuss how they think about creating and testing autonomous vehicle futures. This section will review the methodology in detail and then will provide results from the interviews, which demonstrated that most experts demonstrated an optimism toward the technology where safety was the primary motivation and testing was an opportunity to make sure the product was safe and viable.

Methodology

I conducted semi-structured interviews with major stakeholders to document how people and companies think about and construct autonomous vehicle futures. I used Meuser and Nagel's (2009) approach to expert interviewing selection, which articulated that experts need to be selected not only for their professional, functional role, but also for their integrated knowledge set and involvement in shaping society. These experts used in this research are not uniformly professionals in autonomous vehicle technology, but for this research, they are identified as experts in the sociotechnical innovation system of autonomous vehicles in Arizona, which may cut across different institutional sectors. Participants were identified through public events, newspaper and government documents, and referrals from others.

Some interview candidates worried they might not be a good fit for the interviewing process or that they did not have enough experience given the newness of the technology. Indeed, not everyone who participated initially self-identified as being someone responsible for building or maintaining the autonomous vehicle testbed or innovation system. Even if a core part of their job was tied to autonomous futures, people felt they were not an expert unless they managed a proving ground type testbed or built autonomous vehicle technology. Several of these people eventually agreed to participate, after explaining that the interview was less about the testing of material technology and more about the entire sociotechnical innovation system.

By the end of the interview process, nine people volunteered and ultimately participated in interviews. Each person answered a series of questions about their role and their visions for the future. The questions were designed to get participants to first think

about their role in the testbed, then share their vision for the Arizona testbed, and then comment on how they think about people in their visions for the future within the scope of their autonomous vehicle role. When people were uncertain about the testbed, it was further defined as the Phoenix metropolitan autonomous vehicle innovation system where driverless futures are tested in open and closed environments. The semi-structure interview included the following questions:

1. What is your role in the Arizona driverless vehicle testbed? What experience do you bring to your role?
2. What do you do to create, build, and maintain the testbed?
3. What does the future of driverless vehicles look like for Arizona?
4. What does the future of driverless vehicles look like for the people of Arizona?
5. How do you think about people while you are building the testbed?

Each participant responded to each question to the best of their ability and was encouraged to stray from these questions if they had something they wanted to share related to the overall topic. On average, interviews lasted about 30-40 minutes, with an additional 15-minute introductory conversation beforehand. Interviews were recorded using online audio recording tools, given that these interviews took place remotely.

Results were summarized in terms of their answers to both the overall research guiding questions and the interview questions. By examining leader and vanguard visions for Arizona tied to the automated mobility sociotechnical imaginary through interviews, this section articulates how visions for futures can impact decision-making and lived experiences. Ultimately, this research illuminates how leaders build technologies and

coalitions, the momentum behind "safety" as a value, and a planning gap between design and outcomes.

Results and Summary of Conversations

Interview participants ranged in terms of their direct relationship to driverless vehicle testing, regulation, and design. Some interviewees worked with autonomous vehicle topics as the core part of their employment, and others have autonomous vehicles as a tertiary concern in their role. For instance, some people think about autonomous vehicles as one of many potential smart city technologies, while another might think about autonomous vehicles as one of many emerging technologies to investigate. For industry-related institutions, marketing roles typically took on the task of participating in the interview.

These voices are representative of perspectives that are entrenched in knowingly building driverless vehicle testbeds and futures. The voices described in this section reflect a diversity of experiences, from autonomous vehicle technology designers and testers to governance leaders to university staff and consultants (see Table 4). Of the roles people took on designing and maintaining the testbed, people mentioned their role as a facilitator, citizen activist, tester, public relations and communications leader, convener of stakeholders, educator, engineer, and smart city builder.

Table 4

Summary of Interview Participant Primary Organization Types

Autonomous vehicle company or service	2
Autonomous vehicle related-technology company	2
Education	3
Cross-sectoral collaboration organization	2
Consultant	1

Participants reflected they had multiple roles in designing the innovation system, often building coalitions and partnerships through knowledge transfer and collaboration. Interviewees found themselves taking on a joint role of an educator, however formally or informally. These educators taught students, the public, engineers, and governmental leaders about autonomous vehicle technology or integration into society. Similarly, several participants identified their roles as facilitators and conveners, bridging disparate groups to have them work together to accomplish a goal. These people brought together people across institutions to try to improve communication, collaboration, and outcomes. Other interviewees also served on boards and groups that have both local and national ties. These groups connect people across geographic and industry boundaries. By taking on multiple roles, educating, and facilitating, these interviewees speak to the power of creating a networked space to achieve outcomes and the need to translate, educate, and convene to make this happen.

There was also a sense that the process of integrating different ideas should continue to improve, even internally within leaders. When people take on these multiple roles, there might be a disconnect in connecting experience. In one instance, an interviewee mentioned there was an opportunity to better connect their perspectives from their own multiple roles in the autonomous vehicle testbed. In that specific instance, the interviewee mentioned their interest in social concerns might not be integrated into their professional work around autonomous vehicles.

Individual and institutional history became a discussion centerpiece on how the autonomous mobility future gets built, both explicitly and implicitly. Interviewees, as leaders with their own experience, referenced their personal backgrounds and orientations

that they bring to their role of building the driverless vehicle testbed. One interviewee mentioned driverless vehicle technology is relatively new, so many people work in this space without direct experience. As an example, one person brought in their experience in political science in dealing with community and stakeholder outreach about autonomous vehicles. Another person had a background in engineering that they then applied to autonomous technology-specific engineering. Someone else worked in government previously, which helped them understand emerging technology governance challenges and ultimately improve their ability to collaborate and convene stakeholders.

Companies and organizations also carried with them a set of experiences and capabilities. The history of the company was identified as a potential barrier to an improved product. One interviewee shared their position as a start-up has allowed their company flexibility to design the technology to its fullest potential and test it accordingly. Another interview participant shared their company's focus on a related technology allowed them to interact with autonomous vehicles alongside other potential mobility solutions. In this way, some interviewees spoke of their company as an institution that enables different outcomes and futures, just by its own structure and focus. This also suggests other companies perhaps are limited by their institutional structure.

Similarly, by working on an emerging technology with transformative potential that shares similarities with existing substitute transportation technologies (driver-based vehicles), there are additional product motivators to increasing adoption. The pressure to be better than existing technology spurs those working on autonomous vehicles to be even more cautious and attentive to improving the technology for the public. One interviewee remarked, "It's not good enough just to be as good," and explained how

autonomous vehicles have to be already more successful than current technology. The very nature of working toward autonomous vehicle technology will necessarily force companies to be superior; otherwise, they will not succeed as a company.

For some, being a successful organization meant that they had to participate in successful collaborations. Coordination and collaboration became a recurring theme, both explicitly stated and implicated conveyed. Interviewees mentioned participation in larger boards and boundary organizations that translated knowledge across localities and sectors. According to one interviewee, coordination is critical, suggesting driverless futures are enabled through city coordination as these technologies cross-geographic boundaries. Such collaboration was identified as a necessary means to an end because cities do not have the expertise or time to become experts on autonomous vehicle solutions. To make decisions outside of the status quo, partnerships with other agencies must break free from business as usual to solve significant problems.

In their bid to enable transformative technological futures, these leaders can propagate visions for the future through their raised voices. Interviewees have differing areas of expertise in their role of building autonomous vehicle futures, so understanding how they are united or not, by their visions for the future, will highlight areas of harmony and discord within the sociotechnical imaginary. These visions of the future can be integrated and designed into the sociotechnical fabric, resulting in different lived realities for people. The interviews demonstrate the future must be carefully planned and that if done so correctly, autonomous vehicles can be the mobility solution. One participant laid out the intentionality that happens during planning, research, and implementation, working with partners, and thinking about society throughout each phase. Many experts

viewed the future of automated mobility as a complex puzzle to solve with immense benefits unlocked if solved quickly and safely.

Although there was an ongoing sense of uncertainty with the future of driverless vehicles, participants articulated visions for the future. Limited regulation was identified as a critical component in terms of allowing flexibility to create a better product to achieve these futures by multiple interviewers. One participant imagined their business would facilitate a more environmentally friendly world, with less congestion. Interviewees had clearly thought out plans for what the future would like in terms of timing, with some imaging incremental autonomous vehicle deployment occurring in the near future and widespread adoption happening in over 20 years. Delivery service autonomous vehicle business models were generally viewed as a more immediate future than passenger autonomous vehicle models, but some appeared to reference ridesharing and ownership models. Although the imaginations of the future might be similar, the visions of how people get to automated mobility differed. One interview participant remarked that the concept of autonomous vehicles is so broad and provocative that, unfortunately, if something happens in one automated space, it makes the public feel poorly about all autonomous vehicles. The vision for the future might be similar, but the way to get there via the technology varies drastically, between ownership, ride-sharing, goods delivery, or public transportation.

Most striking in most of these interviews is the optimism to make the technology achieve the future that stakeholders have promised. At play here is a common feature of the general American sociotechnical imagination about technology, whereby "benefits are seen as unbounded while risks are framed as limited and manageable" (Jasanoff &

Kim, 2013, p. 190). For seven out of nine of these interviews, it seemed as though autonomous vehicles have to and will become a reality, one way or another, given enough safety research and stakeholder coordination.

Sometimes sociotechnical imaginaries experience tension "when powerful competing imaginations struggle to establish themselves on the same social terrain" (Jasanoff & Kim, 2015, p. 323). These interviews characterized this tension when the foundational value of safety was undermined. Autonomous mobility has run into what Jasanoff and Kim (2015) referred to as "moments of resistance" (p. 323) most primarily recollected in the case of the death of Elaine Herzberg, calling into question the primary value-driver in the automated mobility imaginary. One person was a little less confident in this future, describing autonomous vehicles as having "a lot of hype" from 2015-2018. The interview continued where the participant suggested the field had a realization having "10 geniuses in a room working on something" is insufficient for success, and full systematic integration would make these vehicles a positive reality. To solve the complex puzzle of automated mobility, technical and social concerns needed to be attended to, with many actors collaborating for a shared vision.

These visions are created in, and emerge from, the testbed. The testbed was viewed as beneficial in most interviews. Two participants mentioned how autonomous vehicle technology had been levered to help with coronavirus public health strategies. In this example, existing autonomous vehicle technologies and services can stray from their original plan and then be adapted to meet the general public's needs, which is somewhat reminiscent of how users reinterpreted the automobile technology in Kline and Pinch (1996).

Participants recognized the uniqueness of the Arizona testbed, citing opportunities to collect research, build something, and improve outcomes (either economic or safety). Testing the technology ahead of widespread deployment was articulated as a way to improve the outcomes in service of the public and a necessary step to developing a good product for consumers. For one interviewee, testing decisions were made based on partnerships, about the right location and demographics to test the product. For others, testing was mentioned as a beneficial byproduct of relaxed regulations. Another participant hoped to bring safety considerations to testing since the vehicles are already being tested on public streets. Thinking about the Tempe car accident and Elaine Herzberg's death, a participant mused they want to make sure

> such incidents don't occur and that we're able to provide the feedback and . . . help the state understand when it's appropriate to test this technology et cetera so the risk of unintended consequences is as close to zero as possible.

This interviewee found testing was a sensible step for managing new technology, articulating the technology needs to be responsibly managed and introduced.

Testing was viewed as a critical way to make sure the deployment of technology was successful. One interviewee mused, "I think that, you know, there's still a lot of technology that needs to get ironed out or figured out before these are deployed wide-scale uses." In this retelling, this perspective suggests some people are willing to take risks on a small scale, but not in widescale deployment. Some interviewees recognize the risk of testing autonomous vehicles. An interview participant explained the following:

> My personal belief is that it's been far too long, and if we allow this to happen to without the required understanding of the level of risk that we are imposing on the

general public and so my one of my passions and reason why I'm doing this because I'd like to help understand that risk and mitigate that risk.

This participant identified that driverless vehicle testing poses a risk to the public and was inspired to minimize this risk. On the other hand, some viewed the technology as a viable way to bring benefits to people on a small scale.

Through these visions of the future, interviewees brought up social concerns in many ways. Interviewees mentioned the public in different ways, with the public being described as constituents, consumers, and those who would benefit from safer transportation. One interviewee conveyed the public is attended to via local government, where local government leaders, who know their constituent interests, work to improve their publics' outcomes. Through this coordination, cities can find common ground on obstacles they face and then jointly work with stakeholders to design and implement technologies to ease these local municipalities' pressing problems. Another participant shared thinking about the public is mandatory in the autonomous vehicle business because there is no future for the technology without people. Indeed, for some, social concerns were a natural part of the technological design process because social benefits and business-related benefits can be tied together. An interview participant shared, "You know, it's really important for us, economically, as well as socially, to be able to deliver this service to as widely as possible. And so, it was really important for us to work with within the diverse area." This participant spoke to the win-win strategy of working in a diverse area to make the technology accessible to various people, which would yield a better understanding of how to maximize adoption.

Autonomous vehicle technology is also described as a way to push social change. One perspective in the interview process was that driverless vehicles are

> a lot safer, more efficient, more cost-effective, and much more readily available sort of transportation to, you know, to all who lived in Arizona, etc., is our hope, and we do believe that the technology has the potential to certainly push things in that direction.

This statement imparts a sense of techno-optimism that indicates the power of technology to, in some ways, drive history, and sometimes in particular within U.S. culture (Smith, 1994a, Smith 1994b) and carry with it politics (Winner, 1986).

Participants brought up concerns about social issues. These concerns for society were often brought up into what seemed like an overview of their work or when prompted to via the questions asking about people. One person imagined that the autonomous vehicle delivery service strategy would benefit a broader group of people, whereas personal-use autonomous vehicles would see greater technology access inequality. Several people brought up people with disabilities and the elderly, which included brainstorming about how smart technology might impact assisted living care facilities or where to roll out testing operations to "fairly diverse, economically, racially, and age ranges as well." These concerns for society were often brought up into what seemed like an overview of their work or when prompted to via the questions asking about people. It is unclear from these discussions how much business activity is organized around these social goals of helping the elderly or improving mobility access for those who are disabled.

Several interviewees took the approach that if the technology is developed, the benefits will come after people figure out how to deploy the technology safely.

> So, the aim is really that first piece we're trying to help with the understanding of the technology and how to deploy it successfully and safely and the ways that it can then be deployed to advantage to the various communities around the state, etc., will play out after that.

In this way, there are short-term social outcomes and long-term social outcomes where safety needs to be achieved first, and other sorts of social goals (e.g., helping underserved communities) can be achieved second. This might be viewed as if you develop the technology, the benefits will follow.

These social concerns all come together into a larger story about the promises of autonomous technologies. These stories about safety and mobility options permeate nearly all responses about visions for the future, but it is unclear how and how people are intentional in working toward these visions of the future. Most straightforward and intentional in organizing stakeholders and conducting activities is progress toward safety, interpreted in this research as a justification for the technology to increase public acceptance.

Safety benefits were mentioned in several different ways throughout the interviews. Most indicated driverless vehicles could improve road safety. Sometimes, these were more general statements, and other times it was more specific. As an example, improving navigational around construction sites was mentioned by two separate stakeholders as a potential improvement on the current system. Others cited current road

safety challenges and strategies to make autonomous vehicles a safe form of transportation through standards, tools, and collaborations.

Interviews mentioned safety as it if it were the guiding gospel of the technology. Safety was a motivating and driving force for autonomous vehicles, acting in some ways as an origin story to the technology. The story goes that the current technology is unsafe and autonomous vehicles can be made safer if done correctly. To achieve this vision, a whole host of stakeholders are deployed to think about the technology, the infrastructure, and people to improve road safety and prove its safety advantage over the current system. The promise of safety fuels activity, as the justification for the technology and the need to perfect the technology. Autonomous vehicles, in this retelling, have to be the solution.

This is the development of the sociotechnical imaginary in action. Autonomous vehicles are embedded in governmental, industry, and academic institutions and have developed projects and processes to solidify the vision. Interviewees share several different ways in which their visions are encoded into institutions, artifacts, or the social fabric more generally. Interviewees referenced the creation of the Institute of Automated Mobility, Governor Doug Ducey's executive order, law enforcement protocols, careers, and new technology. These artifacts and institutions help make permanent automated mobility imaginations. By physically testing the vehicles on the road, it embeds the concept of automated mobility into communities' psychosocial memory, as one participant mentioned the importance of making driverless vehicles visible. The radical transformation of the transportation system requires a sociotechnical imaginary to shepherd social, political, and technical stakeholders, institutions, and processes to reinvent Americans' mobility.

Event Observation

The Phoenix metropolitan area is an exciting place to be if someone is interested in emerging technology and automated vehicle technology. There is a buzz around innovation and using innovation to improve social outcomes. The energy and confluence of stakeholders in the Phoenix metropolitan area allow for the availability of public events. Public events sit at an important intersection between stakeholders, where public involvement occurs in spaces managed by experts, where the public gets to participate but in a very bounded way. Although there is a barrier to knowing about these events, these events provide the opportunity for the business, research, and technological world to open up to a more collaborative and engaging space.

Events are useful sites of analysis for regional innovation systems. Events can create knowledge spillovers and networks, which can be evidence of and further create a "creative hub embedded in a regional context" (Podestà & Richards, 2018, p.5). Spatially and topically structured interactions allow stakeholders to convene, share knowledge, raise awareness, and coordinate (Anand & Jones, 2008). Similarly, events can be used to transfer information bilaterally. Responsible research and innovation frameworks (e.g., Guston & Sarewitz, 2002; Owen et al., 2012; Von Schomberg, 2013) call for public engagement around a technology to increase the alignment between technology development and social needs. These kinds of events can transfer information from event conveners to the public, and vice versa. As evidenced by the multiple roles that events can play, events can be a rich source of information on understanding how experts imagine, assemble, evaluate and stabilize sociotechnical configurations within the testbed.

Methodology

To use events as a qualitative research strategy, I engaged in a structured observation process, where each event was analyzed for its contribution to user, technology, and future-building activities and how these contributions created or reinforced sociotechnical structures. I selected public events, which allowed for open access to the observational setting. Jorgensen (1989) mused about participant observation methods, stating, "Where the researcher is located with respect to a phenomenon of interest determines what may be observed," (p. 52). Therefore, my studying of events might only provide a sliver of insight related to experts and their testbed work, so the goal will be to understand these observations for what they are in the public setting.

A methodological goal of the public event observation was to situate myself in an outsider observer role of participation, as being an outside observer can prevent ethical questions and improve objectivity (Jorgensen 1989). However, event attendees were interested in my work and incorporated me into their own experiences with the event. True to what Jorgensen (1989) stated, "People have a tendency to involve you," and further states, "Participant involvement… suggests that what you are able to observe increasingly is what people normally say and do even when an outside observer is not present" (p 58). My insider role quickly became someone studying autonomous vehicle futures, which was genuine and facilitated trust and relationship-building. The experience was documented via note-taking, either during or after the event, depending on the event's structures. The events were also documented in photography, or through the collection of handouts when available. Events were selected based on their availability between May 2019 and June 2020, which were identified through online event searches,

university distribution lists, and meet-up groups. Five free public events are the focus of this portion of the research.

Table 5

Summary of Autonomous Vehicle Observation Research Events

Event	Date	Location	Audience	Event Type
Our Driverless Futures: Community Forums on Automated Mobility	18-May-19	Glendale, AZ (ASU Campus)	Interested members of the public selected to be representative of the AZ population	Public engagement and deliberation exercise to think through the governance of the technology.
Imagry Open House	26-Sep-19	Tempe, AZ	Members of the public who found out about the event. Attendees were primarily in, or interested in, the autonomous vehicle industry.	Open house to showcase the business and technology.
Phoenix Mobile and Emerging Tech Festival	26-Oct-19	Tempe, AZ (ASU Campus)	Members of the public interested in science and technology; primarily associated with the Meet Up network	Event with sessions on different technology innovation areas, with a series of sessions dedicated to autonomous vehicles.
Chandler Chamber of Commerce AV Symposium	14-Nov-19	Chandler-Gilbert Community College	Public, primarily invested business, university, or political AV stakeholders	Symposium to hear from governmental, industry, and academia on AVs
The Current State of the Autonomous Vehicle Industry	18-Jun-20	Virtual	Public, people attached to the Meet Up network interested in science and technology	Question and answer with an expert on driverless vehicles

Results

The results section will document who participates in these events and how they approach the topic of driverless vehicles in several testbed events. These events have different goals and structures (see Table 5) and are useful to understand both the multitude of perspectives and the cross-collaboration that goes into creating a driverless vehicle testbed and future. Generally, participants in these events had a pre-existing interest in driverless vehicles or at least an interest in emerging technology and were primarily from Arizona. A summary of each of the five events is provided first, and then these five events are combined to articulate how autonomous mobility futures are translated and framed, technology is performed and demonstrated, and cross-collaboration and networking are facilitated.

Our Driverless Futures: Community Forums on Automated Mobility

The community forum on automated mobility was held on May 18, 2019, at the ASU West Campus in Glendale, Arizona, and was one of a series of public forums that happened across the United States and world. The conference was organized by the Consortium for Science, Policy & Outcomes (CSPO) alongside Missions Publiques, a Paris-based citizen engagement group, and was structured as a citizen's participatory event that would also provide decision-makers information on public perceptions. Roughly 100 citizens, selected to be representative of Arizona, participated in the Phoenix-based event. At the event, they were each broken up into smaller teams organized by tables. Each table had a facilitator who would walk them through a series of activities that would teach them about driverless vehicles, while participants would make decisions about how these vehicles are managed through simulation games.

As a facilitator, I walked my team through different activities, interacting with them casually before and after. The participants at my table spanned a wide range of ages given the selection criteria to participate, and all had unique experiences that affected their opinions, ranging from car accidents, disabilities, and college courses. The activity forced participants to share their individual stories and step into different characters' proverbial shoes, to help participants understand different perspectives.

The first activity asked participants about their transportation routine and their hopes and fears about driverless vehicles. The second activity shared stakeholder viewpoints via a game about concerns about giving up control to automated vehicles. Another exercise asked people to think about different scenarios related to driverless vehicles, included rideshare and ownership, and gave them citizen perspectives on the technology. The different viewpoints included a disability advocate, an elderly individual, an environmentalist, and public transit commuter. The next activity was about "who decides" related to the discussion, engaging the group in an exercise about driverless vehicle regulation. The last activity asked participants to consider how they would like money allocated and testing structured in their local environment.

The participants at the table I facilitated verbally communicated their appreciation for the event, which got them to think of driverless vehicles differently. Furthermore, they indicated they enjoyed the opportunity to meet with people they would have otherwise never engaged in conversation generally, let alone about driverless technological futures. Results and photos were shared back with the participants after the event (see Figure 6) to show the forum in action and to understand how the entire group of people felt about driverless vehicle futures.

Figure 6

Photograph of Participants in the Glendale, AZ Public Forum on Driverless Futures

Source: Consortium for Science Policy & Outcomes (2019)

This process allowed a deliberative and immersive experience for the members of the public. Experts in citizen engagement activities carefully crafted the event. Aside from introductory statements, the experts in citizen engagement were largely invisible in the room, allowing the event's materials to guide participation in the forum carefully. Imaginary stakeholder voices were intentionally embedded into the conversations to allow voices of different groups to be injected into the conversation, even if their voices were not represented in the event. This allowed the event to incorporate an array of public voices and keep the event about the participants and not the experts. In doing so, this event puts inclusion center stage for responsible innovation, by gaining feedback from an engaged public to improve decision making.

The ASU public engagement forum allowed for members of the public to participate and was demonstrative of engaging the public in creating inclusive innovation spaces. Feedback into the design process is best done when incorporated in the early stages of development and governance (Wilsdon & Willis, 2004). This framework's spirit is best upheld in the public forum event, which tried to communicate to regulators early on how the public would like driverless vehicles to be governed. This event provided a baseline level of education on the technology, while also reinforcing the importance of understanding different people's perspectives and needs. Through this approach, participants grappled with different social challenges that make it clear that technological progress is not inherently socially good or bad.

Figure 7

Images from the Imagry Open House, Depicting the Technology and Video Footage of the Technology Working as Props

Imagry Open House

Imagry, an autonomous vehicle mapping business, held an Open House on September 26, 2019. This event was held at their offices, a small unit in an industrial part of Tempe. Over 20 people from different backgrounds attended the first half of the event. One attendee came from the Arizona Department of Education, while another worked in an ASU department focused on getting students jobs and internships. There were also an assortment of Ph.D. and master's engineering students in attendance and several people who worked directly in the automated vehicle industry. The room was set up with two vehicles with the Imagry equipment located on both ends of the room. In the middle of the room was a large television, playing video recordings of the autonomous vehicle test runs in downtown Tempe (see Figure 7).

The event was all about the technology and its viability. A promotional piece in the Phoenix Business Journal described the event as, "Join Imagry for our open house event, where you'll get to see our mapless autonomous vehicles first-hand and network with leaders in Arizona's technology and business community." The structure for the event was all about showing the technology and demonstrating its success. Vehicles with complex technology physically dominated the showroom. The cars were familiar enough to seem normal, but between the technology additions in the back seat and roof, curious enough to spur conversation. These cars flanked the television showing demonstrations of how the technology drives successfully on local streets. The event's format was not focused on the employees or local experts.

The structure was informal to facilitate networking: people went from person to person, getting to know each other and networking. Employees from Imagry were readily

recognizable and would eagerly share in technical terms how their autonomous vehicle product is innovative and potentially transformative. Otherwise, these casual networking conversations were demonstrative of how businesses and new technologies can mobilize people. At least two people joined the event because they wanted to learn more about the technology and industry to help educate others about career opportunities. The ASU engineering students were there to see a version of the technology that they study and try to network for future employment. Others were involved in the automated vehicle industry and wanted to see the technology for themselves. This event was not about expert voices, but was more about letting the technology speak for itself.

Phoenix Mobile and Emerging Technology Festival

The Phoenix Mobile and Emerging Tech Festival was a meet-up on Saturday, October 26, 2019, at Arizona State University, sponsored by Marsh, a risk management and insurance broking group. Other sponsors, partners, and organizers for this event also included a combination of technology-focused organizations (Nerdery, Intra-Edge Technology, Clairvoyant, Lotus Labs), government (City of Chandler), and academia (ASU). The event included opening, closing, and lunchtime speakers, and breakout presentations for the rest of the day. In total, there were over 20 talks with over 25 speakers, discussing a variety of emerging technology topics, including smart cities, automated vehicles, facial recognition, machine learning, and blockchain. Participants in the event ranged from professionals in technological fields to the general public interested in new technologies and engaging in a meet-up space promoted through university networks and meet-up event pages. The event primarily drew technology enthusiasts interested in technology innovation, and would probably be most likely to be

at the early stages of the adoption curve, where some people invest in a technology early before the large masses do at a later point in time (Rogers, 2010).

Doug Lloyd was the first presentation of the day to discuss driverless vehicles in "Self-Driving & Electric Vehicles – Current Landscape." The presenter conveyed how personal this topic is to him, given his daughter in the room and what these technological advancements might mean for her future safety while driving. The rest of the presentation was mostly a question-and-answer format, touching on ethics, data security, autonomous levels, and new advancements, where the speaker primarily conveyed optimism for the latest autonomous vehicle technologies. This presentation had energy throughout it, fueled by the importance of developing the technology to improve the status quo.

The presentations that discussed driverless vehicle futures used different frameworks to understand the technology. Dr. Katina Michael, a faculty member with Arizona State University working in the School for the Future of Innovation in Society, discussed the human factors that need to be explored related to autonomous vehicles through her presentation "Human Factors in Autonomous Vehicles." By using audience engagement through roleplay scenarios, Dr. Michael helped convey that autonomous vehicles are not just a technological problem, but a human one.

The lunchtime keynote speakers included two people from SAE International. Executive VP and Chief Operating Officer Laurie Strom spoke about emerging technologies and how to anticipate their futures broadly, while Director of Innovation John Tintinalli spoke about automated vehicle testbeds more specifically. Their presentations laid out important considerations to think about ways to manage driverless vehicle technology responsibly.

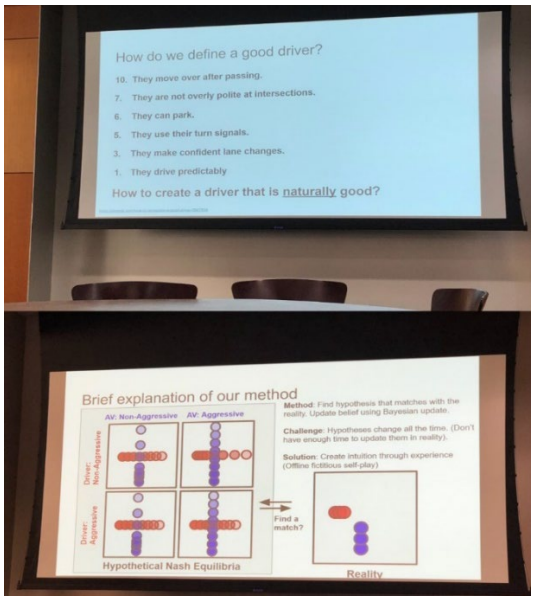
Two afternoon sessions mentioned driverless vehicles, but did not focus on them. In "Driverless Futures- Informing Autonomous Design and Deployment through Public Deliberation," two speakers share the results of a citizen public engagement forums. Forums were constructed to intentionally reach out to members of the public across a variety of cities, engage them in the topic of driverless vehicles, and then allow them to deliberate with each other over issues related to the design, implementation, and governance. Audience members wanted answers about driverless vehicle problems, and the speakers reminded the audience that their expertise is on public engagement and not the specific technology that their public engagement exercise is about. Similarly, in the "Smart Cities" session, State Farm employees shared how they are thinking about smart cities due to the work they necessarily engage in through insurance. Automated and connected vehicles were one part of this vision. The audience was curious about the technological specifics of smart cities, and even questioned why State Farm would engage in such conversations, thinking that an insurance company would only be interested in profit.

The other two sessions covered engineering and computer science research occurring at Arizona State University. In "Safety Control of Automated Vehicles," an ASU professor shares the technical computer science and engineering work ASU is doing to build safety into the design of automated vehicles. In "Scalable and Customizable Intent Inference and Motion Planning for Socially-Adept Autonomous Vehicles," ASU faculty discuss more technological developments related to the computer programming of autonomous vehicles (see Figure 8). In particular, they grapple with how an autonomous

vehicle might make a decision, trying to predict a driver's actions in a nonautonomous car crossing an intersection perpendicular to them.

Figure 8

Presentations by ASU Faculty on Autonomous Vehicle Research Focusing on Technical Improvements to the Technology



These sessions represented only a small portion of the day's overall event, but demonstrated the variety of ways that the community can come together to share their knowledge and expertise. These experts varied in their approaches. Some were optimistic and others were cautious. Some came at the topic from an engineering perspective, others from a social or regulatory perspective. One presentation thought about individual public perceptions, while another wanted to think holistically about the smart city. The day was full of competing, but not incommensurate, approaches to the emerging technology. They all were united by the fact that they viewed safety to be necessary for an autonomous vehicle future.

AV Symposium

The Chandler Chamber of Commerce held a 1-day AV Symposium on November 14, 2019, which brought together people from industry, government, and education sectors to learn "how the Institute for Autonomous Mobility (IAM) is planning to make the State of Arizona a national leader for development and testing of AV technology both on the ground and in the air, and how you can help shape the future of mobility" (Chandler Chamber of Commerce, 2019, AV Symposium). The event was hosted at Chandler-Gilbert Community College and included speakers, panels, and exhibitions. Speakers included employees of Intel, the City of Chandler (including leadership, planners, and public safety personnel), Waymo, Arizona State University, political leaders, automated vehicle technology groups, and members of the Institute of Automated Mobility (IAM). The audience was composed of students, delegates from other countries, and businesses interested in advancing the autonomous vehicle space.

The autonomous vehicle symposium was attended by and featured experts sharing updates about building systems to accommodate and facilitate the technology. The Chandler Chamber of Commerce event was most akin to the relationship-developing conversations presented in Etzkowitz and Leydesdorff (2000). This event became an opportunity for cross-collaboration and to hear perspectives across business, university, and government sectors with the primary interest in advancing innovation in driverless vehicles. The symposium was predominantly a testament to technological optimism, where the autonomous vehicle is viewed as a positive driver for technological change and that innovating toward a driverless future should push forward.

There were exhibition tables filled with different information and takeaways from autonomous vehicle-related businesses which people could frequent. There were also Waymo driverless vehicles stationed at the front of the event. At the Waymo and Intel tables, virtual reality headsets helped explain how driverless cars operate to those relatively new to understanding the technology (see Figure 9). Like the Imagry Open House and the Phoenix Mobile and Emerging Technology Festival, there was a need to show the technology in action. Across many of the tables were stickers and fliers to help educate those who were passing by. A podcaster sat nearby, recording the day's happenings, interviewing leaders, and later moderating a panel.

Figure 9

Images from the Autonomous Vehicle Symposium, including Virtual Reality Headset to Used to Demonstrate How the Technology Works to the Public and Increase Familiarity

The event demonstrated that academia, industry, and government could come together to think about emerging technology in ways that attend to thoughtful, resilient planning and systems thinking. The AV Symposium included examples of how thoughtful planning and collaborations can result in a responsible and innovative future. Some remarks in the keynote mentioned the building of a parking garage in the City of Chandler, which was designed so if the need for parking goes down due to fewer vehicles from driverless vehicles, then the parking garage's first floor could be transformed into business space. Including water and electricity into the parking garage design made the parking garage an adaptable, resilient space allowing future innovation to thrive. Similarly, Chandler employees shared another structural change that would help with the adoption of the technology. The partnership between the City of Chandler and Waymo also includes a rider program for some City of Chandler employees, which works as a proof of concept and has the goals of reducing stress and increase the available time of employees. Through this partnership, Waymo can demonstrate to the public that their technology works as a pilot project, while the City of Chandler can leverage new technology for interested employees.

In the vein of thinking about systems, public safety leaders spoke about the importance of creating and disseminating around first response and emergency management around these emergent technologies. Public safety leaders from the City of Chandler remarked that the partnership between the City of Chandler and Waymo has allowed for the better strategic implementation of autonomous vehicles as a technology situated within a broader social system. The Police Chief noted that they met regularly with Waymo to learn about radar and lidar technologies. Then, in collaboration with the

Arizona Department of Safety, they created a portal for police to share information about the vehicles and know who is responsible. In the Fire Chief case, there was a discussion about how the partnership resulted in the development of an emergency manual. This manual instructed first responders on how to handle an autonomous vehicle when it is involved in a situation. The autonomous vehicles were also redesigned to make sure they could respond to public safety-related sirens, and now, the autonomous vehicles pull over faster than traditional, human-driven vehicles.

Similarly, there was a recognition that if cities are to implement automated vehicle technologies, there is a systems pipeline need to educate students and develop a workforce. With Chandler-Gilbert Community College as the host, students attended the event throughout the day. Additionally, Chandler-Gilbert Community College's partnership program with a local high school was mentioned as a site where ninth-grade students are being exposed to the skills needed to work in cybersecurity, a field that will be impacted by autonomous vehicle expansion.

This intentionality was also apparent in discussions about how technology can be leveraged to improve outcomes before the technology is perfect. For instance, when autonomous vehicles roamed Chandler's streets, some of that information was shared back to improve infrastructure. Participants in the event truly noted an interest in enabling autonomous futures in a way that improves safety, allows for spillover benefits, requires intentional city planning, and cross-collaboration between companies and government. As one attendee remarked, "There's just so much opportunity," speaking to the potential in the automated vehicle industry in Arizona.

However, some parts of the day seemed to be about just accepting technological change and pushing forward with momentum. An Intel video shared during the symposium concludes that "Amazing things happen when you let go," visually reiterating by a driver letting go of a steering wheel. It included a variety of imagery, including an injured person learning how to walk again. This type of language and imagery suggests if people just let go of what is familiar and embrace change instead, positive outcomes will follow.

This trust and need for innovation to bring about social change was apparent throughout the day. Innovating to speed was a central theme at this event, with one speaker noting that "we can't wait another 40 years," referencing the delay to full innovation, standardization, and regulation of various technologies, like the seat belt and airbag. Other panelists received questions about ethics and how to design these technologies responsibly, and there was some resistance by panelists in addressing these questions. Namely, several panel members remarked that it was not reasonable to sit and wait for a perfect technology when there is a much more dangerous technology already operating in the status quo. Safety was invoked by many leaders, suggesting it would be irresponsible not to proceed forward with automated vehicle technology when the status quo is so abysmal. In an afternoon panel, the moderator relentlessly asked about ethics. The panel never really answered the question about ethics or even tried to provide examples of how they are responsibly innovating. Conversations about social concerns were mostly missing from the day and seemed to be perceived as antagonistic to progress.

The Current State of the Autonomous Vehicle Industry

After participating in the Phoenix Mobile and Emerging Technology Festival, I connected to the Meet Up environment, which exposed me to similar events, including a 1-hour-long talk by Doug Lloyd, one of the speakers who presented at the Phoenix Mobile Conference. The event, "The Current State of the Autonomous Vehicle Industry-A Chat with Doug Lloyd" was held virtually on June 18, 2020. The event was structured as a question-and-answer session between Lloyd and the attendees. The virtual event allowed people from different states to join in, bringing together perspectives from not only Arizona, but also California and Illinois. Lloyd started the conversation by disclosing that he is personally interested in the advent of driverless vehicles and can see his children having a safer future with them in the world. Lloyd is a technology enthusiast and has stayed abreast of all of the company and new vehicle updates. For the first half of the event, attendees seemed to be primarily interested in which different driverless vehicle prototypes, the likelihood to market, and how they could interact with a driverless vehicle. Questions related to driverless trucks, companies in Arizona building electric vehicles, and new cars with autonomous technology came up.

A portion of the conversation dealt with the potential shifting business environment for autonomous vehicles, given the coronavirus public health crisis. The answer was that some autonomous vehicle industry employees had been laid off, and testing was stalled. Another participant chimed in and suggested testing had increased in the San Francisco Bay area as it related to product delivery to hospitals, capitalizing on the safety of humanless contact.

The conversation continually stressed driverless vehicles were the future, but given the United States' regulation, the United States might be one of the last for widescale deployment, echoing the theme communicated in the interviews about deregulation increasing innovation. One conversation emphasized the ability to deploy these vehicles in areas not managed by the Department of Transportation, like in agricultural spaces. Another mentioned the reality might be sooner for those communities where there is an elderly population. As an example, a small, aging neighborhood is having success with its pilot program in Florida.

The industry sector was a reoccurring focus, and as a part of that, jobs were occasionally brought up. Not only was the industry impacted by COVID-19, resulting in a loss of employment, but other companies were also bringing new business to Arizona. Additionally, new sectors were popping up thinking about the cleaning of driverless cars. Doug communicated through some of his answers that driverless vehicle engineering jobs were prevalent, as well.

The second half of the conversation included some discussion about how people might influence the future of driverless vehicles. Lloyd offered that people get connected to PAVE, the Partners for Automated Vehicle Education, which tries to bring autonomous vehicle conversations to the public to engage in their technological futures. Additionally, Lloyd shared it could be a good idea to participate in local hearings in cities where driverless vehicles are being tested to have their voice heard and represented.

Events Combined: Framing, Cross-Collaboration, and Performance

Each event provided a different type of insight into how the driverless futures get made in the testbed. Between an open house, a conference, a stakeholder convening, they were all

very different types of events that allowed for various kinds of expertise in attendees and approaches to building and maintain a testbed and autonomous futures. These events are testaments to different ways the testbed gets built, how knowledge is shared, and how futures are established.

Even though these events are all somewhat different, participants at one event were often seen frequenting other events. Networks are set up that allow for the re-engagement of participants and the re-elevation of expert voices. People get to know each other, and, in some ways, there is an opportunity for these events to become an echo chamber. But, networks can also be branching, and as these networks grow, people can become connected to other people, thoughts, and ideas.

Across these events, it was very rare that specific futures were built around people in a way that oriented these visions toward justice, equity, and opportunity issues. By far, the most common and fully developed vision for the technology is safety. This vision is advanced by commenting on the unsatisfactory status quo and suggesting autonomous vehicles were the solution. Although the conversation might be united by safety and some autonomy level, as one interviewee suggested, autonomous vehicle technologies mostly get grouped together. The conversation then turns to autonomous vehicles as a nebulous concept, which brings momentum, but also undifferentiated levels of accountability when something goes wrong or right.

Only a couple of portions of events thought about the future holistically. In the case of the open house, the symposium, the meetup, and part of the festival, the events focused on autonomous vehicles as a general technology that can improve futures given the innovation and further research. With enough research, momentum, and coordination,

autonomous vehicles can be made to solve the road safety problem. City leaders most often brought up and designed for infrastructure and public space management. Although not explicit, these topics are not bereft of social concerns. By building parking garages with multiple trajectories for use, these projects create paths for two possible futures: one with autonomous vehicles and one without.

In most of the events, the topic of people was largely left out of the conversation, aside from generic talking points about reducing road safety accidents. As a stakeholder group, ASU experts most often explicitly brought up social and ethical concerns to consider in the context of the technology, as opposed to other leaders. Indeed, the public forum co-hosted by ASU was the most engaged on the topic socially. The public forum is an attempt at citizen engagement on both a technological and regulatory topical level. These experiences are essential to ensure that the public is involved in the conversation for responsible innovation and empowered to engage in discussions related to how their future is built. These events also co-construct participants who engage with these events. Participants are constructed in these types of participatory events, where they feel as if they have been selected and now are representative of the public's interest (Felt & Fochler, 2010). The nearly 100 participants who attended this event have reimagined their own role and potential power in the Arizona testbed.

The most vocal of voices at many of these events was the technology itself. In public events, showing the driverless vehicle and showing a video of the driverless vehicle in action are key performative activities that event planners or speakers engage in as part of their presentation. This socializes to the attendees what a driverless car looks like, and the video helps the public conceptualize how it works. In the case of the

Chandler Chamber of Commerce event with vendor tables, the Waymo VR experience put the attendee in the space of being a user of a driverless vehicle.

These public events used videos and other artifacts to demonstrate a proof of concept to prove that driverless vehicles do work and educate viewers on how it happens. Simakova (2010) referenced such demonstrations as "theatre of the proof" when researching how one company narrates their RFID technology through the creation of "tellable stories" (p. 568). This theatre of the proof becomes an object and tool to cross organizational boundaries and includes more than just videos. It can consist of launch events, expos featuring the technology, and pictures detailing such events where the audience appears interested and excited.

The use of demonstrations was commonplace in some events, using videos or driving or showcases the technology. The demo-ing of the technology and showcasing of science all speak to educating the public to increase understanding and hopefully build confidence in the technology; however, demos and videos are not value or power-free. Rosental (2013) investigated demonstrations and used this knowledge to engage with the concept of "demo-cracies" (p. 333). In this assessment, demos can be used to gain information from the public and help with better designs or deployment strategies. At the same time, however, demo-cracies contain a power imbalance, where the demonstrators can control the conversation with the advantage of having "prepared their performance in advance" (Rosental, 2013, p. 361) and the demonstrated lack the ability, space, or time to interrogate the highly designed demonstrations.

Expert Work Synthesized

This chapter grappled with how automated vehicle futures and related assemblages are articulated and performed by experts. The interview and observation methodology provided insight into a sliver of the work that experts engage in, but provided fruitful information regardless about values, interests, approaches, and their work in the testbed. The interviews and event observations demonstrated that experts communicate and engage in testbed work that often imagines futures, creates and structures relationships, and tests assemblages. The testbed work of these experts mainly involved the process of making imaginations real, managing the scope of the conversation, and building momentum through networks.

There were several significant differences in the approaches to autonomous vehicle futures put forward in interviews and events. As heard through the interviews, the voices conveyed authenticity, genuine passion, and visions for the future. For many of the voices heard through public forums, their stories felt like a production, which educated participants on advancements with the technology and used gadgets to convey technological prowess. In this way, events were more of a cinematic experience relying on videos and demonstrations, whereas interviews relied on clear articulations of the testbed and future via speech.

In efforts to make imaginations real, experts in the interview process and event observation engaged in or reported engaging in performances, demonstrations, and pilot programs. Performances and demonstrations, including showing the technology in person, using a film of the technology working, or depicting the technology via a model, served two purposes: to socialize the technology for increasing familiarity and to

demonstrate viability to enhance trust. This kind of testbed work leverages a combination of imagination, assembly, and testing work. For example, the video playing at the Imagery Open House showed a rider in a driverless vehicle navigate local streets with AV technology. This video helped viewers imagine the possibilities of the technology, assemble themselves in their mind with the technology given that the video was recorded from a first-person perspective, and test their comfort with the technology as the company could see how attendees responded to the video. This kind of work is also similar to the work of the VR headsets that created an immersive experience for attendees at the Chandler Chamber of Commerce Autonomous Vehicle Symposium.

As evidenced through this analysis of expert spaces, assemblage-building skewed to the technological more than the human in many conversations. Autonomous vehicle conversations either treated the technology as a solution to problems or a technology that can be solved with enough effort. Furthermore, experts often focused explicitly on the technology, instead of taking a broader view of the entire system (e.g., transportation). This can be attributable to several phenomena, including professionalization efforts where presenters studied and taught in their narrow field or where event attendees were more interested in the gadget-ness of the technology in terms of features, than how it might relate to society more broadly.

Additionally, there was a disconnect between private interviews and public events in how the testbed was treated. In interviews, there was a rampant acknowledgment that there is a lot of work needed to make autonomous vehicles safe, whereas in most public events, there was general abstract optimism about autonomous vehicle futures and the improvements that they bring to the status quo. To reiterate differently, public events

tended to keep events situated in the imaginative work space, while private conversations revealed the assembly and testing work that is going on or needs to happen to make the imaginative work real. When mentioned, interviews from autonomous vehicle groups described the testbed as a chance to deploy the technology, gain feedback, and provide a transportation opportunity to some members of the public. The testbed was not often mentioned in the public event space, and if it was, it was more so about building for the future and a business badge of honor versus a lived reality of people presently.

Furthermore, the assemblage imagination and building were more diverse in the interviews than in public spaces, which painted autonomous vehicles and their futures generically. In the interviews, participants articulated the different modalities autonomous vehicles might be used for, including delivery services, personal transportation, or mass transportation option. This kind of nuance was entirely lost in public events. Autonomous vehicle futures were more bounded in public spaces, focusing on the technology as a way to improve transportation-related road safety. Public events did not grapple with what the future might look like more broadly and often focused almost exclusively on transportation versions of automated vehicles, instead of on goods delivery from automated vehicles. Interviews provided insight into how goods delivery, private transportation, or public transportation can drastically be improved via automated mobility technologies, signified by improvements in safety, accessibility, environment, efficiency, and comfort. Although some of the non-safety values were mentioned only briefly, they were at least mentioned in ways that painted a picture of how the technology can improve lives. In three of the five events, the approach was more showing off the technology and engaging in problem-solving to make autonomous technologies

systematically viable, which will necessarily result in a safer future. Only the public forum event explored the diversity of public perspectives and what it might mean to live alongside these technologies. In both of these inquiries, it was only possible to understand futures generally, versus specifically in attending to different groups of people and their individual lived experiences.

Experts, within both interview and event observation spaces, pedestaled autonomous vehicles broadly as the answer to the safety driving problem as they articulated the value of the technology. When discussing social futures, a safer future was the predominant vision for the future across interviews and events. The power of safety as the propelling value for the technology was conveyed consistently throughout public events, but was not consistently the focus of every conversation. At public events, the topics focused on technological advancements and the need to switch to a safer alternative than the status quo quickly. Safety was a major cornerstone of the visions shared in nearly every stakeholder interview, and was done so as a way to discuss safer futures and ensure that the prototype technology was safe. In both interviews and events, there was a technological momentum, where the technology was justified as a technology to improve upon the road safety status quo, and thus resources are dedicated to making sure it is safe. This technological momentum, where the autonomous vehicles are pitched as the only solution to problems within the status quo, demonstrates some areas of concern for stakeholders' ability to anticipate, be reflexive, and avoid undesirable technological path dependencies.

In terms of understanding what experts were engaging in when positioning technology and safety together, I draw upon the commentary of technological fixes that

Stilgoe (2020) used to describe the origin story of autonomous vehicle justification and claimed, “Technologies are often solutions in search of problems” (p. 21). Stilgoe (2020) referenced the technological fix literature to describe how a technology is justified through either solutionism, where problems are re-engineered to fit innovator needs (Morozov 2013), or technochauvinism, where technological solutions become preferable to political solutions (Broussard 2018).

This kind of technological fix work is a demonstration of imagination, assembling and testing activity in the testbed. From an imagination perspective, solutionism positions the technology next to a problem (in this case, traditional driving safety) and generates visions of how the technology can improve their life once that problem is solved. The more salient and pervasive that problem is, the more likely that solution will appeal to the public. Within the autonomous vehicle testbed, this solutionism comes in the form of justifying the technology’s existence in terms of safety, even when there is evidence that it might not be safe yet. By focusing on the new technology by way of criticizing the existing technology, much of the framing suggests that the existing sociotechnical assemblages of driving will largely be the same, just safer.

Experts in the testbed did many things that appear to be good practices for responsible innovation. Open and interdisciplinary events allowed for a multiplicity of opinions and interpretations regarding collective potential futures related to autonomous vehicles. Additionally, experts supported engaging with a multitude of stakeholders for cross-collaboration across industries.

There are also opportunities for responsible innovation work in the testbed- that is, the work that can be done within a testbed to help make sure the sociotechnical

assemblages that are being structured are attached to desirable futures. These strategies are first to increase public engagement over current testing situations and then secondly to shifting the conversations to be outcomes-based instead of technology-based. These two strategies will help raise awareness of the assemblages being built in the testbed presently and make sure that the assemblages align with social outcomes.

Mentioning the testbed and its activities more prominently in public spaces will ensure that the testbed is attended to in private and public spaces. This will improve awareness of activities and considerations that are being worked out in the testbed that are in service of general automated mobility futures. Publicly referencing testbed activities can also add nuance to the conversation by talking about the multitude of autonomous vehicle modalities out there versus the general concept of an autonomous vehicle future.

The technology-first mindset that permeated a lot of the imagination work conducted by experts could be improved by shifting away from solutionism discourse and engaging in outcomes-first work. Without intentional future planning and awareness, stakeholders in the autonomous vehicle space risk engaging in a form of technological somnambulism (Winner, 2014). Eubanks (2017) proclaimed, “Our ethical revolution still lags behind our technological revolutions” (p. 127), and our technological advances take the shape of our current ethics. By focusing on technological advancements or expecting impacts to follow development risks not attending to social challenges that are already neglected. Only Dr. Katina Michaels from the Phoenix Mobile and Emerging Technology Festival and the Our Driverless Futures Public Forum generally paused the technological momentum to intentionally ask what kinds of social futures do participants want,

autonomous or otherwise. Lacking intentional building for an ethical future, not just a technical one, will continue to propagate existing ethical landscapes and power inadvertently.

Not focusing on justifying the technology in terms of a problem, but instead looking at what outcomes the community wants to address can prevent the iterative loop where the technology must become the solution, even when the testbed is suggesting that the technology might not be the solution. This strategy also avoids some of the issues identified in the autonomous vehicle testbed, such as when one expert felt that one the technology was made safe, it would necessarily allow for other outcomes to unfold. In this strategy, people would imagine what outcomes they would like to see generally and then technology and social innovations can be created or deployed accordingly. Autonomous vehicles can then be integrated into a fuller solution set that involves other technologies and social processes to help address a myriad of outcomes instead of one.

By looking into expert work within the Arizona autonomous vehicle testbed, this chapter sought to understand how experts imagine, assemble and negotiate sociotechnical assemblages through both interviews and event observation. Ultimately, this research finds that experts manage the scope of the conversation, attempt to make their visions real to viewers to demonstrate that the technology works, and engage in assembly work in ways that are technologically focused and more generic in public spaces. The next chapter investigates the work of the institutions that many of these experts are associated with to see what others kinds of work might be conveyed through institutional public websites.

CHAPTER 4
INSTITUTIONAL TESTBED WORK

"[A number of corporations] are telling us what automated vehicles will look like, how they will be integrated into society, what problems they will solve, and how our lives will change" – Jameson Wetmore, 2020, p. 3

In Arizona, a multitude of stakeholders contribute to the autonomous vehicle testbed across academia, industry, and government sectors, creating and negotiating sociotechnical assemblages and generating autonomous vehicle futures. These actors contribute through their testbed work a vision for the technology that enables future forms of life for those living alongside the technology. This section will explore university, industry, and government sectors in the Phoenix Metropolitan area to understand how these sectors engage in testbed work, which ranged from imagining and socializing assemblages to creating regulations to enable better human and vehicle relationships.

The preceding chapter examined the kinds of work conducted by experts through interview conversations and public event performances, where experts envisioned autonomous vehicle futures through managing and framing the scope of the conversation, building momentum, making futures real, and uneven assemblage building. The research provided in this chapter is extensive, in the way that it covers the testbed work of three separate sectors, comprised of institutions. To accomplish this research goal, this chapter leveraged a content analysis strategy to demonstrate how the kinds of work these three sectors do in the testbed related to imagining futures, as told through their websites,

varied substantially. These websites report on testbed work, while also engaging in testbed work in and of themselves and serves as a repository that roots and encodes autonomous vehicle visions and assemblages into its institutional memory. This research on institutional sectors found that businesses, government, and educational institutions primarily engage in future-building activities that create path dependencies for the technology and call an assortment of assemblages into being. This chapter will introduce the methodology and then go through a review of each sector's documents, which demonstrates whom they imagine in their testbed work and through what kinds of activities. After a review of the three sectors, I briefly introduce an example of a combined stakeholder group, before providing an assessment on the ways institutions create and negotiate sociotechnical assemblages in their testbed work.

Methodology

The focus of Chapter 4 is institutions, which is an attempt to broadly interrogate how different institutions across sectors engage in testbed work. I deploy a content analysis strategy as a way to systematically understand how intuitional website materials structure autonomous vehicle sociotechnical relationships and futures. To outline this methodology, I provide examples of others kinds of research done to understand the impact of institutions on innovation and then provide a brief overview of the methodological strategy and findings.

This is not the first investigation into how institutions shape emerging technology futures. As an example, Sadowski and Bendor (2018) looked deeply at the industry sector and focused on corporate actors in their ability to shape the "smart city" imaginary. They view "corporate discourses as tools for directing and delimiting what we can imagine as

possible" (Sadowski & Bendor, 2018, p. 544). Applying this to autonomous vehicles, all corporations create their version of automated mobility, and their discourse can provide insight into these visions. Through this work, Sadowski and Bendor demonstrated certain corporations dominate the narrative of what the future should look like in a smart city, and therefore are perpetuating realities that benefit their corporate interests. This raises issues of power and control and calls for counter-narratives and other visions of the future to understand what is at stake for collective futures.

Strand et al. (2018) used the concept of sociotechnical imaginaries as a way to share how stakeholders create new futures. Strand et al. (2018) defined sociotechnical imaginaries as "visions of desired social and technological futures created and sustained by stakeholders in science, industry and politics" (p. 1849). These stakeholders contributed to the creation of visions for the future, which then enables action and collective effort put around the visions. Strand et al. (2018) continued, "The point is not to try to predict the future but to construct it by first imagining it and then instantiate (reify) the idea" (p. 1850). The products of institutional work are evidence of the reification of their creative imaginations as these institutions work towards their envisioned futures.

Similar to Strand et al. (2018), the sectors analyzed in Chapter 4 are academia, industry, and government. These sectors were chosen as they make up the Triple Helix of innovation, which as a concept articulates how sectors engage in innovation work and do so in concert with each other to improve outcomes (Etzkowitz 2003). According to Etzkowitz (2003), innovation takes "on a new meaning as the spirals of the Triple Helix intertwine, cooperating from a position of relative autonomy to enhance each other's

performance of their traditional roles" (p. 308). Each sector brings expertise and professionalization in their institutional roles and landscape, but can collaborate to improve each other and the system through shared knowledge and resources. Although many triple helix analyses (e.g., Farinha et al., 2016; Fogelberg & Thorpenberg, 2012) are used to understand how innovation and competitiveness thrive with different components, relationships, and processes, this analysis will look at materials produced through innovation activity in the testbed and how these sectors construct visions of the future for society to live with and alongside driverless vehicles.

Methodologically, this chapter disassembles the triple helix into the specific sectors of academia, industry, and government, piecing together their sector narratives, interests, and contribution using their electronic footprint via their institutional website. These stakeholders produce content that can describe what they have done or visions for how they imagine their work. This chapter leverages a content analysis strategy because organizational materials are where sociotechnical imaginaries and imaginations are constructed, reified, and communicated (Sadowski & Bendor, 2018). The section analyzes electronic materials published by the critical triple helix of stakeholders in the Phoenix Metropolitan area, including autonomous vehicle groups, governments, and university researchers. Each stakeholder section will include both a summary of the materials found and an assessment about what kinds of users, nonusers, other stakeholders are imagined and how power is distributed, per the guiding questions for this research.

This research will make visible how business, academia, and government sectors create their version of automated vehicle futures and how this work results in the

imagination, assembling, evaluation, and stabilization of sociotechnical assemblages. It will also demonstrate how users are constructed through their testbed work, namely by making the futures abstract, familiar, and better than status quo alternatives or proceeding forward with a technology-centric approach.

To do this, I identified from each sector institutions to provide a sample of the stakeholders in the testbed engaging in work. Then, I explored and documented each institutional website. Two major questions are investigated to understand the role of different sectors in creating the driverless vehicle testbed and its related futures by understanding how their thoughts are encoded in different ways. The first question involves asking of these electronic documents, what does this tell us about the role of the specific actor in creating the testbed alongside driverless futures? The second question attends to the way sociotechnical assemblages can become entrenched into societal and institutional fabrics. What materials and activities are present in the discussion that embed these automated mobility configurations and visions into institutions and culture? While exploring how these visions get encoded and reproduced to become realities, this chapter articulates who is included in automated mobility visions and what lives they are supposed to lead through discourse analysis.

By looking at how testbed work is encoded in materials produced by industry, academia, and government, this chapter reveals that each sector takes different approaches to sociotechnical future-building in service of the automated mobility futures. In industry, automated mobility futures were marketed in ways that were both familiar and understandable, creating imagery and stories so people can understand and envision themselves in this future. These materials provide outlines for people to understand what

their relationship to technology and others should look like with this technology. Governmental materials demonstrated the government creates materials related to infrastructure and business development needs, and engages in planning around both. These documents suggest the government is less concerned about the future that technology enables, but are rather interested in making sure it is planned for correctly from a systems perspective. What does the technology mean for business, taxes, law enforcement, zoning codes, and sustainability? Universities facilitate knowledge to improve the future, whether by engaging in research to enhance the technology, suggest areas for improved governance or social impacts, or learn skills to go into the workforce.

To summarize, businesses promote technological visions for the future, while government builds pathways for it to be successful. Universities find ways to participate in both technological future-building through research and pathway building via workforce education. Analyzing each sector reveals how they build futures, and how users and nonusers are negotiated in these visions. Ultimately, this chapter will find many different kinds of users are imagined for a technology that is still in flux, but that many attempts at future-building capitalize on the technology's portrayal as an improvement to the status quo versus a radical technological upheaval.

Marketing Autonomous Vehicle Futures: Corporate Discourses

Wetmore (2020) summarized, "[A number of corporations] are telling us what automated vehicles will look like, how they will be integrated into society, what problems they will solve, and how our lives will change" (p. 3). Corporate imagery socializes imagined futures and makes them into real futures through their advertisements

and discourse. Industry creates and sells a vision of the world through product and service development. Many industry materials are made to market and share information with potential users or the general public about their technology. A critical eye to such documents is essential because the visions for the future are encoded into these materials and are done so in ways that have implications for how the technology is understood and adopted.

For example, Hildebrand and Sheller (2018) demonstrated current visions of autonomous vehicles have made them gendered with racial dimensions, placing a white male at the center of the advertisement. To break away from the future of the technology being white and masculine, and prescribing these identities back to the users, the authors call upon all relevant stakeholders to think about how they research, design, build, and implement the technology in a way that is thoughtful about what kinds of identities and social hierarchies are reproduced through the technology.

By concentrating on industry in the triple helix, this information will directly share the kinds of worlds that industries are hoping to create to allow for and sustain their product. This section looks at the websites, reports, and videos posted by the major autonomous vehicle groups operating in Arizona, namely, Waymo, Nuro, TuSimple, Beep, and Local Motors (see Table 6). The guiding questions for this larger testbed research were used as a rubric for each website and associated content. Although each business has a slightly different business model, all are linked together by making space for a new kind of technology that disrupts the existing momentum of traditional human driver vehicles.

Table 6

Summary of Autonomous Vehicle Companies Investigated in This Research

Company Name	Type of AV Company	Role in AZ	Core values
Waymo	Personal transportation for the public	Autonomous vehicles, policies, and programs are tested in the southwest Phoenix metropolitan area.	Safety, accessibility
Nuro	Goods delivery for the public	Tested Nuro vehicles in Scottsdale for grocery delivery	Efficiency, safety, accessibility
TuSimple	AV trucks, goods delivery for business	Transports goods via trucks in Southern Arizona	Efficiency
Beep- Robo Ride	Shuttle transportation service	Testing Robo Ride in the Peoria entertainment district	Safety, environmental
Local Motors-Olli	Shuttle transportation	Chandler microfactory is the main Olli build floor	Innovation, environmental

One of the most high-profile organizations working on driverless vehicles in Arizona is Waymo, an Alphabet company, formerly known as the Google Self-Driving Car Project. Their website includes core content tied to their mission and history, alongside safety and career opportunity information. Through their online digital footprint, which includes general website text, images, videos, and reports, Waymo creates a vision for the future, with assurances for safety and responsibility.

Waymo's opening page (Waymo.com) includes the tagline "We're building the World's Most Experienced Driver," an image of three varieties of self-driving vehicles, and a video. Their mission is listed, stating, "Waymo's mission is to make it safe and easy for people and things to get where they're going. The Waymo Driver can improve the world's access to mobility while saving thousands of lives now lost to traffic

crashes." Waymo's vision for the future is to improve access to mobility and improve safety outcomes drastically from the status quo, which will be made possible through their technology, referenced lovingly as "The Waymo Driver."

Waymo also situates itself in the normalcy of everyday tasks when stating, "Whether they're helping people run errands, commute to work, or drop off kids at school, fully self-driving vehicles hold enormous potential to transform people's lives" (Waymo 2020). Additionally, on the FAQs where people asked about becoming a Waymo One test driver, the opportunity is described as facilitating "travel for a fun night out or get a break from driving" (Waymo 2020). Additionally, the Let's Talk Self-Driving section appeared geared toward public consumption, using stories to demonstrate how people could use driverless vehicles. Let's Talk Self-Driving is a Waymo subsidiary website where general members of the public interested in the technology can learn about new developments. In this area, Waymo also listed relationships with the National Safety Council, the Foundation for Senior Living, the Foundation for Blind Children, and Mothers Against Drunk Driving (MADD) near this section. These relationships serve to demonstrate which advocacy groups are represented and which of their constituents are being included in the conversation.

Waymo repeatedly establishes through their website that driverless vehicles will help those who drive, people with mobility access issues, families and children, and the elderly. These groups were documented through images, personal stories, statistics, and narration. This is a broad yet specific approach, demonstrating through their storytelling that autonomous futures are for everyone.

At the bottom of the homepage, the website includes stories about what drives the employees of Waymo. One story comes from a staff member recounting that his sister's husband died from an avoidable road traffic crash. Another staff member shared their excitement about Waymo and how it might provide his autistic nephew with independence as he grows up. A third staff member, who is also a mom, envisions that driverless vehicles will help mothers have stronger relationships with their children as they commute to different places.

Children are consistently depicted throughout Waymo's imagery. Indeed, even an infographic demonstrating the number of lives lost to car crashes included child-like stick figures. Children are also mentioned through a Let's Talk Self-Driving article, where young leaders in a AAA safety patrol program watched, tested, and provided feedback on Waymo's vehicles. The children leaders felt the technology was safe, and their teacher pondered if some of these students might even go on to work at Waymo someday.

Waymo's safety report on their website addresses how Waymo is building a technology that will empower people who have traditionally been excluded from mobility options. The report stated, "We continue to learn about the unique needs of different riders, and what we learn will inform new features that will make the experience accessible to people who have historically had to rely on others to get around" (Waymo 2020). Waymo clearly articulated a vision where people with disabilities can use driverless vehicles throughout their website. In the timeline of notable Waymo historical events, the testing of the driverless vehicle technology by Steven Mahan, a blind man, was included. Additionally, the safety report outlines the different features that Waymo has designed to increase accessibility, including audio and visual cues and tools, a mobile

application, braille labels, and a chat-based rider support option. Let's Talk Self-Driving features a story about Brian, an aging musician losing his vision. Brian, alongside the Federation for Senior Living, in a video and article on the site, describes the benefits of self-driving vehicles in allowing people to continue to be independent, regardless of their age.

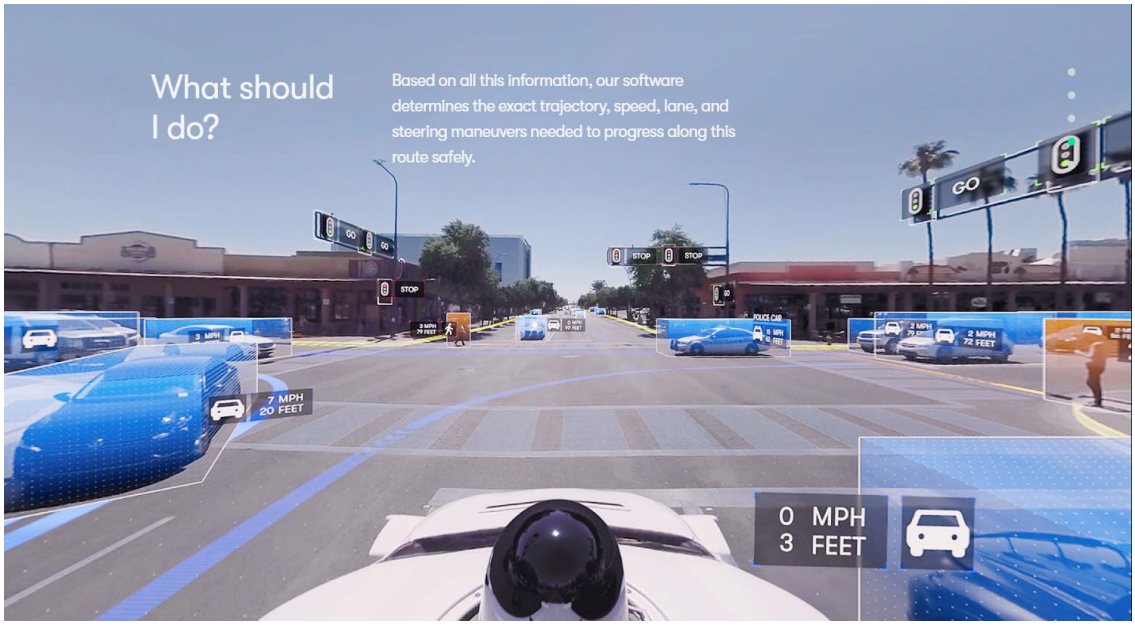
Waymo also included other stakeholders in their vision of the testing and driverless vehicle world. The company, safety/test drivers, and law enforcement/first responders were mentioned occasionally. When the website referred to the company, it was typically about taking information from driving tests and using it to build better and safer technology. Waymo mentioned law enforcement and first responders in both the safety report and a section about first responders. The first responder section includes an online version of the Waymo Emergency Response Guide and Law Enforcement Protocol and first responder's video training. Chandler Fire Department Battalion Chief partially guided the instructional video, and the Chandler Fire Department demonstrates best practices in handling emergencies with autonomous vehicles. The concept of developing safety through coordinated partnerships was also echoed in the safety report by explaining, "We've collaborated with the Chandler Police and Fire departments in Arizona to conduct emergency vehicle testing with our self-driving minivans" (Waymo 2020). Posting the law enforcement and first responder training guide and video online allows the public to learn about driverless vehicles while also demonstrating in detail how educating, partnering, and coordinating with law enforcement enhances safety. Such partnerships, like this one with law enforcement, help legitimize the technology, while

also manifesting the technology's future through increased coordinated commitments and resources.

Waymo anthropomorphizes the car in the way that it has a segment featured on the website called "Waymo 360," where a viewer can see what the vehicle sees as it is driving. Similarly, this personification continues when the website uses language like "ten million miles of experience." This language helps readers understand the technology in comparison to human-driven technology. The imagery and video help build trust by educating the readers and giving them a glimpse inside the black box of autonomous technology (see Figure 10).

Figure 10

Image of an Autonomous Vehicle Making Decisions at a Chandler, AZ Intersection, Socializing Both How the Technology Works and the Embeddedness in the Chandler Community



Source: Waymo.com

Nuro, a company focused on goods delivery, uses text, videos, and images to demonstrate how their product improves efficiency. Nuro notably envisioned people who need goods delivered as key users in driverless vehicle futures. Although testing has ended in Scottsdale, Arizona, the website suggests their testing will continue to include prescription delivery through a partnership with CVS and medical supply delivery in California to help with COVID-19 response. This means users can include medical staff, as well as everyday people who need prescriptions.

Nuro's website demonstrates their product is vaguely for everyone, where they can be connected to "the people and things we love." The website describes the technology as affordable and safe, and a way to accomplish errands from "dinner to dry cleaning " (Nuro 2020). Of course, the site also mentions the technology's ability to increase safety and prevent travel deaths. The website included an image of a child, suggesting this could help families. Nuro capitalized on a narrative and an image that explains how driving to accomplish errands could be better spent having a driverless vehicle delivering goods instead. In this universality, Nuro portrays a broad potential consumer base, where their vision of automated mobility can be for everyone. These sorts of claims are enticing due to their pervasiveness, simplicity, and positivity, which help with building a consumer base, but are hard to interrogate.

To communicate these benefits, the landing page for Nuro included a video of their first customers in the Scottsdale area, which provided an avenue for members of the public to share their experiences with the technology, while images of the Phoenix landscape flashed behind them. It included a family, a couple, and an 81-year-old lady excitedly having their groceries delivered by Nuro's driverless vehicle. The vehicle

included testimonials that suggested the delivery service would help busy families, the elderly, and people who just do not like shopping for groceries. The participants remarked on the convenience, ease, affordability, innovativeness, and friendliness of the technology and its service.

Indeed, aside from the beginning video, Nuro articulated the lengths they went to design the technology in a particular way that will increase adoption and comfort. Like Waymo, Nuro also featured a safety report that emphasized transparency by outlining the technical measures taken to ensure the safety of people accessing the goods being delivered and the safety of others on the road. In their Delivering Safety report, Nuro describes that it uses a people-centric approach and that "the vehicle itself is designed to be friendly and approachable: through its colors, form, and even the sounds it makes" (Nuro 2020). This humanizes the technology.

In addition to making the car appear friendly, the report also outlines the kinds of bodies considered in the design of the product through design considerations to help ease use and comfort. According to the safety report, they "designed the compartment's size and position with ergonomics in mind, so customers do not have to bend over to lift groceries" (Nuro, 2020, p. 10). It also provided consideration for those with disabilities. The report described how Nuro (2020) stated they are "building in a sound generator to help make pedestrians, including the visually impaired, aware of [their] presence" (p. 24). This statement demonstrates Nuro is envisioning pedestrians' safety and the visually impaired while they are building their technology for the future.

Other stakeholders were also included on their website. Nuro's staff were more prominent in their website than other companies, using the site to establish the Nuro team

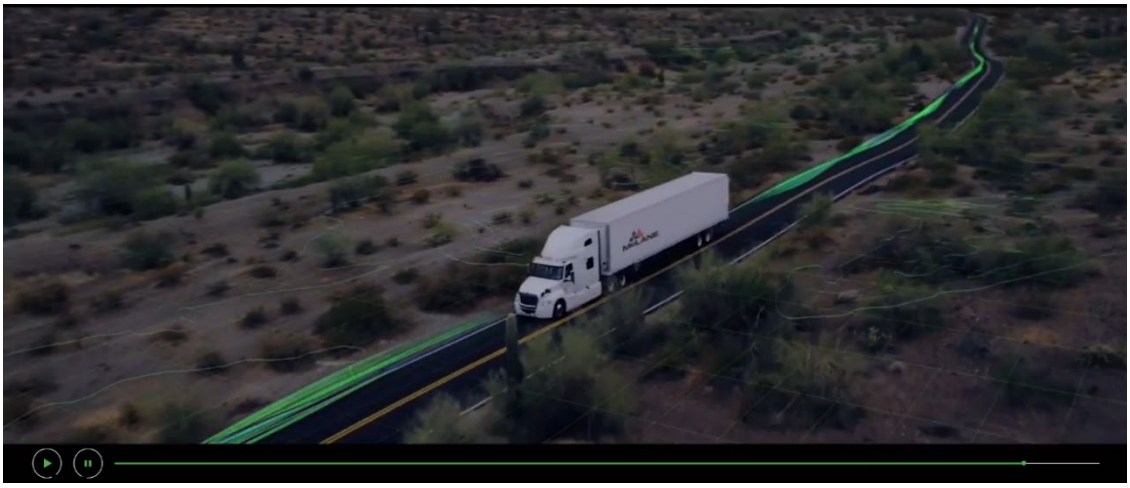
as a credible and experienced workforce, citing achievements and university educational accolades. The website also listed partnerships formed around the technology. Nuro's partnerships are highlighted through blog posts, updating website visitors on new connections, such as the CVS partnership to deliver prescriptions and Walmart's partnership for grocery delivery.

TuSimple, a self-driving truck company, took the approach of designing their website to be sleek and high tech, with a dark color scheme and video of a truck driving with superimposed lights and rings to demonstrate its sensing capabilities, as shown in Figure 11. Superimposed onto the video is a statement that TuSimple is a "better way forward" and that its autonomous network is the "safest and most efficient way" for a self-driving truck to come to the market. After clicking on the next portion of the homepage, TuSimple claims their "ecosystem approach," comprised of features like digital maps and the TuSimple operating system, allows for autonomous trucks to operate at any time and in any condition "safely and efficiently."

A portion of the website is dedicated to autonomous vehicle technology. A video describes the unique challenges trucks face in terms of autonomous designs. The following subsection, titled "Not Afraid of the Dark," describes how a combination of LiDAR, radar, and HD cameras creates a 360-degree view to enable awareness and planning up to 30 seconds ahead, creating efficiency and preventing danger. The language of seeing in the dark is reiterated at the end of this page in a section called "Harness the power of AI" that claims the TuSimple artificial intelligence improves safety and reliability.

Figure 11

Image from TuSimple's Website, demonstrating a Driverless Truck on a Long Stretch of Desert with Cyber Imagery Overlaid



Source: tusimple.com

Aside from demonstrating the sophisticated nature of the product, this website is about building partnerships with businesses. TuSimple mentioned UPS, NVIDIA, and SINA Corp as investors and used video testimony from foodservice shipper McLane, service provider Penske, and carrier U.S. Xpress. These video testimonies describe TuSimple as a chance to be ahead of the technological curve and innovative to maximize efficiencies, industry value, and safety. Additional partners listed included USPS, Navistar, AWS, and Sony, in a section that mentioned how partnerships help strengthen the product's safety and reliability. Prominently highlighted on the website is a button saying "Ship with Us," which takes website viewers to a form they can fill out with their contact information after identifying whether or not they are a shipper or a fleet operator.

Local Motors has developed a different kind of driverless vehicle named Ollie. Olli is described as "your friendly neighborhood mobility solution and the world's first co-created, self-driving, electric and cognitive shuttle" (Local Motors 2020). The central

values human-enter values communicated were reducing accidents and improving safety, gaining time back from driving, improving access to transportation for those with mobility issues (e.g., the disabled), and improved environmental outcomes. In particular, safety was attuned to through the main page and safety guide, similar to Waymo and Nuro. The website's video also suggests the technology could be used for families. In one image, Olli picks up a mother and son for transportation. Local Motors' Olli shuttle is characterized as an approachable shuttle that improves safety, access to transportation, and the environment.

Despite this messaging, the website is heavily focused on the innovativeness of the technology and its specifications. The Local Motors website includes a video that describes how different their vehicle is from traditional vehicles, including a 9-hour structure printing time, 100% recyclable material, 80% 3D-printed, and 90% fewer parts than a traditional vehicle. "Of Moonshots and Shuttles" describes the landing page for this video, further tapping into innovation-oriented language. Furthermore, at the end of the "Meet Olli" page is a section called "The Disruption is in the Details," which provides the technology's technical specifications. As a combined result, the electronic materials put forward by Local Motors, as it relates to Olli, demonstrate a future that is technologically savvy first to achieve mobility and environmental outcomes second.

Beep, and its pilot program, Robo Ride, are very similarly orientated to Local Motors in terms of the technological futures it creates. The goal for Robo Ride is to transport people via an autonomous shuttle, which should be presumably anchored in a city center, campus, or business or retail park. The company describes itself as an automated service mobility provider, as an institution that delivers a mobility solution for

communities that is autonomous, electric, and multi-passenger, which leverages technology-based partnerships for autonomous shuttles. For their Arizona project, their webpage includes a video of the RoboRide. The City of Peoria is listed as a partner, and the website includes a link to Peoria's public works cite on the pilot project. It also includes a quote from the Public Works director. Beep's overall website includes visions of automated mobility applying to "cities, townships, campuses, business districts, retail centers, and private communities," which would lead to a world with less congestion, better parking, increased safety, and improved environmental outcomes. The website mentions the impacts of improved safety, lessened congestion, improved sustainability, and improved mobility for all, including the disabled and elderly.

By examining the electronic materials of several key autonomous vehicle industry groups involved within the Arizona driverless vehicle testbed and corresponding innovation system, this research reveals the numerous ways testbed work occurs to create and negotiate sociotechnical assemblages and futures. In terms of materials used, there was some symmetry across most companies. Primarily, websites leveraged images and videos to demonstrate the technology in action and included statistics to support the technology's rationale. Waymo, Nuro, and Local Motors also communicated ideas through a safety report. All websites also included job postings. Despite the commonalities in materials, both the technological solution and visions for the future, including potential users and society more broadly, varied across each automated vehicle-related company.

The purpose of these automated vehicle companies differed, deploying autonomous vehicles differently to achieve their automated mobility vision. Nuro and

TuSimple focused on goods delivery, Local Motors, and Beep focused on automated vehicle shuttle service, and Waymo focused on a ridesharing, personal vehicle strategy. That means, in three of the instances, autonomous vehicles transported people, and in two of the instances, the technology transported goods. For the shuttle service providers, those companies focused on city centers, townships, and campuses as their core audience to offer automated mobility solutions in a dense locale. For Waymo and Nuro, the key user audience primarily appeared to be the public, as they would request that their goods would be delivered to them, or they would request to travel from point A to point B. TuSimple was the only company oriented to appealing to industry and business leaders as partners and technology users. These differences are important because there is no singular vision for who will use the technology, let alone how the technology will be leveraged.

When comparing the websites, there are some differences and similarities which demonstrate some of the tension occurring in the testbed and building of the sociotechnical imaginary. In terms of website design, Waymo and TuSimple took opposite approaches. TuSimple's website is sleek and is focused on demonstrating the technology in action and promoting critical stakeholder feedback that reflects the value of partnering with TuSimple for testing. On the other side of the spectrum, Waymo's site is about making the technology appear accessible and safe and immersing the audience (public) into their driverless futures. Nuro exists in between Waymo and TuSimple. Like TuSimple, Nuro's technology involves the shipping of goods, but the difference in presentation comes from how the technology will deliver products to both individuals and

businesses. This results in a broader approach of socializing the technology, which involves creating visions of the future for the public, like Waymo.

The primary similarity across websites was the use of visual images to demonstrate the technology in action, making it both real and accessible to viewers. Every website included videos of the technology operating, a barrage of driverless vehicle images, and glimpses into the vehicle's technical aspects. Such images and videos were proof of the concept that the technology worked and did so in familiar ways. Every website had some sort of image that briefly described the technical components that make the vehicle autonomous.

Several sociotechnical imaginaries were deployed to help make viewers more comfortable with the technology. As an example, both Nuro and Local Motors took an additional step of making the technology seem more accessible to the general public by designing and describing their driverless vehicle technology as friendly. Safety reports were listed on three websites, which demonstrated awareness and thoughtfulness on safety to website viewers. The narrative not only described that the technology works, but that it also works in places that people and companies see themselves in. Waymo, Nuro, and TuSimple also leveraged video testimonials to demonstrate other people liked the technologies. In the case of these companies, imaging was often Arizona-specific. All websites had images of the Arizona testbed scattered throughout, including testing locations, local participants involved in pilot programs, or local leaders, making the technology familiar.

Figure 12

Excerpt of Nuro Video Demonstrating the Technology Works While Socializing the Technology Through Familiar Arizona Landscape Imagery

Source: nuro.ai

In addition to demonstrating the theme of "the technology works," these companies also shared a mix of themes around central values. Every website focused on safety as an outcome of the technology. Waymo was the most comprehensive in their vision for safety, as they created a narrative about poor road safety in the status quo, with opportunity through high safety technology from their autonomous technology, and coordinated safety through their partnership with law enforcement and first responders. Nuro, Waymo, Local Motors, and Beep all discussed accessibility. TuSimple also heavily valued efficiency and reliability.

To elaborate, different stakeholders were articulated in both the driverless vehicle testbed and driverless vehicle futures. TuSimple was almost singularly focused on getting

businesses to partner to use their autonomous technology and related services. The users for TuSimple were a combination of shippers and carriers. For the other companies, their users were a lot less specific and therefore required imagination about who could use these technologies. These websites suggested their technology was for the general public.

Websites had to justify to visitors why their technology should be considered part of their technological futures to demonstrate the technology could be universal. Building trust is the biggest obstacle companies have in advancing their visions of autonomous futures. Waymo heavily describes the current problem of road safety primarily through statistics and then uses images and stories to demonstrate its added social benefits. Waymo, in particular, undertakes a massive endeavor of constructing potential new futures for the general public, given their potential ridesharing business model. To have their product be successful, they have to build the technology and the future surrounding the technology. That is, it could be that Waymo built autonomous vehicle technology to improve road safety and mobility, but then to make this technology and vision possible, Waymo has to create images of families using the technology to run errands safely or demonstrate accessibility via testimonials around disabled experiences with the product.

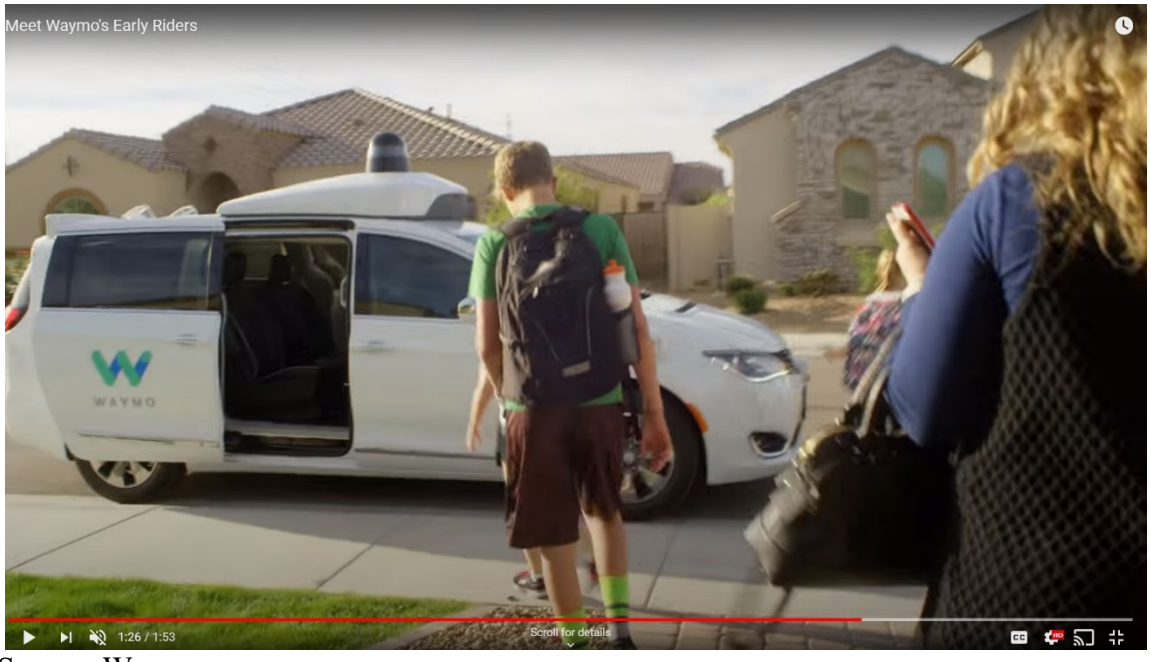
Other companies also enroll participants in their visions for the future. Nuro leverages the narrative of technology, helping to ease the current stresses of daily life with goods provisions and uses a customer testimony video to advance this. TuSimple and Local Motors both engage in the narratives that improved technology means progress, and every company promotes the idea that the technical is superior to the human when it at least comes to driving. Depending on the approach of showing the

problem with the status quo and the technology's value for the future, users were attended to differently.

The depictions of the technology straddle the line of being innovative and groundbreaking while being similar enough to existing transportation to be familiar to establish comfort. Waymo does this exceptionally well, as their videos with the Chrysler Pacificas in a suburban residential are used to show how these technologies can benefit families (see Figure 13). In this imagery, everything is perfectly ordinary and mundane, except that somehow the vehicle is driving. Portions of the website are designed to give insight into the black box of the car, but do so in such a way that is detailed enough to establish trust without overwhelming viewers with the details.

Figure 13

Screenshot from a Waymo Video, depicting a Suburban Family Entering an Autonomous Vehicle



Source: Waymo.com

Some potential user groups were frequently imagined in these visions for the future. In most of the companies' renderings of the future, children and families were present as potential imagined users in every website. In addition to children and families, four of the five companies mentioned those with mobility issues. Waymo, Local Motors, Beep, and Nuro articulated visions for how these technologies could impact people with mobility issues, mentioning both the elderly and disabled. Waymo took the most extensive approach in demonstrating how the technology can and already has impacted those with mobility issues through their news stories, videos, and partnerships.

Current iterations of the driverless vehicle testbed seem possible through partnerships and stakeholder investment. Each website had sections that listed some partnerships supporting their company to advance their visions for the future and gain credibility. Some of these stakeholders are used to demonstrate technical strength (NVIDIA). In contrast, others represent what kinds of values and advocacy groups are being thought about (Mothers Against Drunk Driving) and what potential user types are imagined (Foundation for Blind Children, City of Peoria, and McLane shipping). Enlisting other organizations on their websites creates coalitions that demonstrate mutual support for each other's visions.

Labor opportunities were socialized fervently across materials in support of autonomous vehicle technology. Every website had a section for careers, although not every company had a career available in Arizona. A majority of jobs for both Nuro and Waymo were located in Mountain View, California. In Arizona, TuSimple had primarily engineer career openings in Tucson and Waymo had a few opportunities in Chandler related to fleet and operations. Local Motors had only one position open in Orlando,

Florida. By providing career opportunities, this functionally supports the company and enrolls future members of the workforce that continue the company and its technology's momentum. With the companies often having a majority of the careers in a state outside of Arizona, this also demonstrates although testing and a customer base are being built locally, significant career opportunities and decision-making occur elsewhere.

Business websites provide a small glimpse into the autonomous mobility triple helix in Arizona. These websites are meant to socialize and eventually sell a service or product. To do this, these websites promote certain values and engage in narrative building. What these websites do not do, nor would people expect them to do, is provide alternatives to their products or resultant constructed visions for the future. To summarize, for four of the companies, autonomous vehicle technologies will help the public more broadly. Two out of the five groups create visions about transporting goods, while the other two industries create visions of transporting people. Nuro also has to create these visions for the future, given that people need to choose to have their goods delivered in at least half of their business model. Some companies are technology-focused, whereas others are people-focused. Across all organizations, the future is described as a place that is safer and filled with more options and time for users, as autonomous vehicles take unwanted work away from people or organizations. Automated mobility futures appear to be consistent in general appeals toward improved safety and accessibility, but the path there is contested.

Teaching and Researching Automated Futures

Universities are important engines of research and training. As an organization, they can engage in disciplinary or multidisciplinary knowledge endeavors and work with

other entities to transform knowledge into application. Etzkowitz and Leydesdorff (2000) articulated the university is the core institution within the knowledge sector due to its educational and teaching focus, and its ability to put knowledge into use. In addition to research endeavors, universities develop students, who are all human capital, to invent and innovate from their training. This section will examine these functions through ASU research productions, syllabi, and student research to understand how higher education institutions engage in work that configures sociotechnical relationships.

A quick search on ASU's website for "Autonomous vehicles" provides approximately 2,450 results, which includes a smattering of news articles, syllabi, student organizations, and reports. The top 100 results were tagged in terms of their type of activity and any visions for the future. The activities of a university are disparate and encompass a lot of commitment and activity by a variety of stakeholders within the institution. From this information, student research held in a digital repository, syllabi and course descriptions stored in course catalogs, and faculty research stored in a published research database were further explored to describe how knowledge is created, taught, and distributed through an academic institution. Furthermore, this will shed specific light on the kinds of knowledge creation and dissemination occurring within the Phoenix-metropolitan area.

The search engine query returned results about both faculty and students, and included topics that spanned research, engagement, and education. Of the 100 articles, about 5% were about student course opportunities, which included documents like course syllabi and press releases about new course offerings. Over 15% of results were demonstrations of students' research projects, often as culminating experiences to their

degree program. Additionally, student opportunities outside of the classroom were also depicted in the results, such as the Mechanical-Autonomous Vehicles (MAV) club. Many articles focused heavily on faculty research, including research on liability, technological history, technological development, safety, and governance. About 12% of search results were about engagement via events meant for education and discussion, including events on autonomous vehicles. One event promoted included a student-built driverless vehicle competition, while others featured faculty members discussing the future.

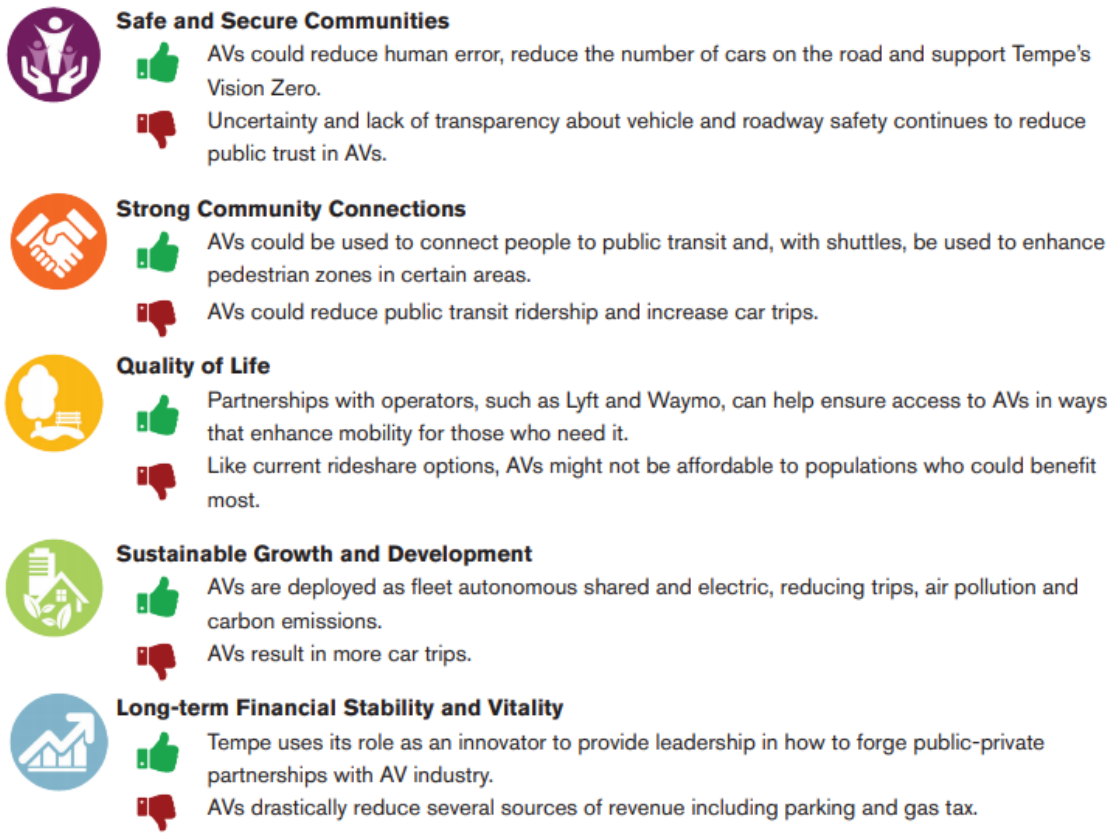
Other search results document how university members work collaboratively with other institutions. A report produced by ASU Center for Smart Cities and Regions called "Autonomous Vehicles in Tempe" Opportunities and Risks" provides policy considerations for the City of Tempe to help them think through how to safely and adequately implement these vehicles in the city. This document imagined different potential futures that can be made around safe and secure communities, strong community connections, quality of life, sustainable development, and financial stability. Under the quality of life category, the report discussed accessibility related to age, disability, and financial access, while also mentioning issues of climate and congestion. Bu providing risks and benefits on these topics, this document helps to increase awareness to help with decision making (see Figure 14).

One result linked to a resource site produced by ASU's Media Relations and Strategic Communications compiled autonomous vehicle experts, while ten other associated links returned in the search went to profile pages of such experts. ASU's expert search revealed to faculty members that specialize in autonomous vehicles. One

person is located in the Schools of Engineering, while the other is listed in the Thunderbird School of Global Management.

Figure 14

Snapshot of ASU Center for Smart Cities and Regions Report for Tempe, AZ That Demonstrates Opportunities and Barriers of Autonomous Vehicle Technology Alongside Tempe Goals



Source: ASU & City of Tempe, 2019, https://ifis.asu.edu/sites/default/files/tempe_av_report_-_final.pdf

Leveraging these findings through the search engine, I leveraged course syllabi, student research projects, and faculty research to gain a greater depth of understanding about what university members think, do, and share. To start on this deep dive, these

finds are supplemented with a Web of Science search to see what other faculty research types might be out there from ASU experts. Relevant research articles published by Arizona scholars were used to investigate how the Arizona academic knowledge producers envision users and nonusers. To do this, I used Web of Science to narrow the journal articles by the organization (Arizona State University) and subject (driverless/autonomous vehicles). These journal articles provide insight into where academic research is happening, how technical knowledge might be employed, and how researchers might be imagining users and nonusers in the system.

The Web of Science search returned three articles that met the criteria of having author keywords referencing driverless vehicles or autonomous cars from Arizona State University in the last 5 years. Two articles were published in transportation-related journals, while another journal was focused on cyber-physical systems.

A team of researchers at ASU contributed to a journal article about vehicle communication in Khayatian et al. (2020). This journal article was technically focused on communication between connected and automated vehicles with either intersection infrastructure or other cars at the intersection. By improving the technology to have better communication at intersections, the research suggests the technology will be safer, more efficient, and less energy consumptive. The research received funding from the National Institute of Standards and Technology and the National Science Foundation.

Nair et al. (2018) collaborated with other universities in addition to ASU, including the University of Texas-Austin, Univ Conception (Chile), and Hong Kong Polytechnic University (China). This research was support by the Center for Teaching Old Models New Tricks through the U.S. Department of Transportation, as well as Data-

Supported Transportation Operations and Planning Center, also through the Department of Transportation. This research investigated rank-ordered preferences through a 2015 Puget Sound Regional Travel Study to understand interest levels of autonomous vehicles.

Wei et al. (2017) also collaborated across institutions, including with authors from Beijing Jiaotong University, Yalova University (Turkey), Yildiz Tech University (Turkey), and Mississippi State University. This research was funded not only by the U.S. National Science Foundation but also by the Scientific and Technological Research Council of Turkey. This research was conducted to increase safety by optimizing vehicle to vehicle and vehicle to infrastructure communication for optimal platooning.

These three articles demonstrate clearly how interconnected university research can be. All three articles are funded by the federal government and were done so through different departments, foundations, and centers. Articles also included cross-collaboration with academics from other institutions outside of both the state and country. These three articles also speak to the breadth of research faculty do at ASU, which includes understanding public interests socially, as well as investigating safety improvements technically.

In addition to research, educating students is a central component of the university's mission and function. A quick review of course material and culminating projects suggests students learn about driverless vehicles and also take that knowledge to continue research on the topic. Both the courses and research projects speak to the various approaches to understanding driverless vehicles through academia.

Although driverless vehicles may be mentioned or brought up in many different course conversations across campus, several courses focused explicitly on driverless

vehicles. The university has offered at least four separate courses focused on autonomous vehicles (excluding aerospace) in the last five years, as identified through a search of the ASU Course Catalog and ASU website. These courses included "Ethics of Technology Entrepreneurship: Autonomous Vehicles," a graduate-level engineering topics course called "Connected and Automated Vehicles," an electrical engineering graduate course called "Introduction to Electric and Autonomous Vehicles," a driverless vehicle innovation 1-hour group discussion held through the School for Future of Innovation in Society.

Students can also learn about autonomous vehicles through nonautonomous vehicle-specific courses or other means, and have this learning be cumulative over time. Thus, it is essential to look at the products of student learning versus discrete course activity. Although student research might not be as heavily funded or cross-institutional as faculty research, student research projects similarly demonstrate the breadth of research and learning at the university. The ASU Digital Repository houses several student research projects, which were works demonstrating the culmination of these students' learning experiences at the university. By searching for "autonomous vehicles" and their derivatives in the repository, this investigation revealed 11 research projects at the undergraduate and graduate levels were filed between 2015 and 2020. This information is critical because it shows what a student learned through their educational experience at an academic institution and is a testament to the knowledge they will bring as human capital into the workforce. Whether or not projects were technical or social, their abstracts all alluded to improving autonomous vehicle and social outcomes.

Many of the projects were technical or scientific. The following three examples demonstrate the different niches students have learned about related to driverless vehicle technological design. One master's thesis on robotics discussed research on a simulation testbed, while a doctoral dissertation investigated the benefits of a time-of-flight lidar versus a Doppler lidar. An honors undergraduate thesis investigated how RFID could be used in traffic sign recognition for autonomous vehicles to be better integrated into the current infrastructure. Another honors thesis thought about the creation of preventative maintenance systems within autonomous vehicles. In their master's thesis, Ulhas (2019) posited, "Testing autonomous vehicles in real-world scenarios would pose a threat to people and property alike. A safe alternative is to simulate these scenarios and test to ensure that the resulting programs can work in real-world scenarios" (p. i). Ulhas (2019) used this premise to investigate how vehicles can visually identify objects and examine cross-platform training of neural networks as a strategy to do this.

Several projects veered toward the social sciences. One honors thesis discussed the relationship between automated driving systems and carbon emissions at the intersection of engineering and sustainability. On honors thesis looked at the history of autonomous technology and its legal and policy frameworks to understand opportunities for autonomous vehicle outcome improvements. Another honors thesis explored the relationship between driverless cars, smart city strategies, and transparency. Another honors thesis took the approach of understanding how autonomous vehicle data could be monetized successfully.

Both faculty and students were engaged in researching and learning about autonomous vehicles. Broadly, topics included thinking about the history of the

technology, building the technology, and integrating these vehicles into society. Faculty added to the body of literature related to their research, and some faculty worked to try to share knowledge outside of the university. Higher education involves the education and professionalization of students to prepare them for career and post-college success. Students learned about both the technical and social aspects of autonomous vehicles, although it is unclear whether students received both sets of knowledge or one or the other. These students will eventually have careers, either in the autonomous vehicle industry or in other industries, but bring their knowledge with them regardless.

All of these documents found in the academic sector within the testbed speak to the multitude of roles that higher education institutes take on during testbed work. These institutions engage in imagination work through their research on the topic, while some engineers also conduct testing work. Through their mission as a university in preparing the future workforce, academic institutions also engage in stabilizing work, sharing knowledge, and teaching skills to enable a workforce around autonomous vehicle futures.

Governing Automated Futures

Policies and laws can impact how people understand justice and morality, and place rules on how people live their lives. Norton (2011) investigated how the personal car-based transportation system came into being by looking at the entire transportation sociotechnical system. Norton pointed to law and law enforcement as essential locations where the world gets made and how relationships to technology are negotiated. In the case of the automobile, a jaywalking legal battle over who is at fault (the pedestrian, the vehicle, or the driver) ended up changing the social norm of having streets for pedestrians

to having roads for cars. This made the formerly common activity of jaywalking illegal. Additionally, conversations around city planning became essential to improve efficiency. As a result, the city manager's role took prominence, with 48% of them being engineers by 1919. In the first half of the 20th century, the advent of the automobile led to the creation and redefinition of city features, such as parking lots, crosswalks, and crossing guards.

Government websites document information from new initiatives and partnerships, while also documenting key political conversations. Similar kinds of research have been done to understand the government's role in local contexts for managing emerging technologies, which inspire this assessment on the governmental materials. Nelson and Gorichanaz (2019) engaged in a thematic analysis of city council meetings to discover the ethical themes around drone regulation and establish that trust is key to emerging technology acceptance. Foley and Wiek (2013) investigated nanotechnology innovation in a local Phoenix context, looking to understand who is participating and what are some opportunity areas for governance approaches. They found cities support technology innovation as an alternative to land development and to solve the city's problems. In their role, they might manage land development, permitting, and city technology incubators, while potentially having an adversarial and competitive approach to other cities. These examples demonstrate how city roles and documents can become a key feature of the innovation system.

This research documents the driverless vehicle-related website information from major cities and towns in the Phoenix metropolitan area, as well as any other towns that had made the news in the area. The following section provides an overview of documents

founds on the Phoenix, Gilbert, Chandler, Peoria, Tempe, Mesa, and Scottsdale websites, as well as information tied to the Governor's Office and the Arizona Department of Transportation. Each website was searched for references to autonomous vehicles. Each page from the website results was combed through to understand two questions, in addition to the larger research questions about users and futures. This section will begin with larger state government groups and end with local cities. Results across cities varied, with some local governments having many documents and others barely having any. Transportation commission-type meeting minutes were the most commonly available document on city websites, followed by news releases about city happenings.

Governor Doug Ducey released several executive orders to further driverless vehicle technology. One executive order allows for the testing and driving of these vehicles on public roads (Exec. Order No. 2015-09, 2015), while an updated one in 2018 commits to protecting public safety (Exec. Order No. 2018-04, 2018). Another executive order created the Institute for Automates mobility (IAM), creating a public-private collaboration to continue to advance driverless vehicles (Exec. Order No. 2018-09, 2018). These pieces of legislation are analyzed to understand the historical landscape, the critical stakeholders envisioned by the policy, and the users and nonusers suggested through the orders.

The Arizona Department of Transportation also has a section of their website dedicated to autonomous vehicles (ADOT, n.d.), which includes links to the executive orders and a link to a law enforcement protocol. This website provides information about testing and operating these vehicles in Arizona and includes links on how to notify the state about testing such vehicles and request forms needed for operating these vehicles

without a driver. To operate without a driver, an Autonomous Vehicle Testing Statement and Certification that includes information on how federal laws or safety standards, as well as state laws and regulation, are met (or are otherwise exempted/waived), how failure in the automated driving system will achieve only a minimal risk condition, and that the vehicle meets certificate, licensing, insurance, and title requirements. Additionally, a law enforcement protocol must be submitted.

The website also listed information on an Arizona Self-Driving Vehicle Oversight Committee. This section suggests the committee is aligned with the "governor's mission to boost economic growth, create new jobs, and promote 21st-century innovation that improves the way Arizonans live." A quote from Governor Doug Ducey is included that further mentions improved economic competitiveness, jobs, university research, and transportation options that will have "social and public safety benefits that will improve the way we live and get around." Listed members of the board include those from the state departments of insurance, transportation, and public safety, as well as the University of Arizona. The last meeting minutes posted are from August 2016.

Websites from major cities were also analyzed to understand how cities discuss driverless vehicles and their future, if at all. Although city websites might be more stagnant than newspapers, they give insight into the priorities of city leaders, which paint a roadmap for what the future of living in the city might look like. The kinds of documents found on city websites typically included meeting minutes, newsletters, annual reports, and planning documents. In two instances, a specific section of the city's page was dedicated to driverless vehicles, whereas for the rest, they were embedded throughout the entire website structure or archived. Websites like this help explain the

status quo and describe the future of the city, and archived data might demonstrate the history of these discussions. Some cities and towns discussed driverless vehicles more prominently than others, while others mention the technology in passing.

The City of Mesa had five results referencing autonomous vehicles, include two website pages, one news article, and two documents (strategic plan and education brochure). One website and one document were no longer appropriately linked. The remaining website page that referenced autonomous vehicles was about smart transportation and mobility, one of the Smart Mesa Today focal areas, and references autonomous vehicles as part of the future that is coming. The news article mentioned the suite of technologies that are being implemented, like time to green indicators, to help prepare for driverless vehicles. The education brochure mentioned a research lab at the ASU Polytechnic campus focused on autonomous vehicles.

The City of Scottsdale's website featured eight references to autonomous vehicles, three of which were meeting minutes. An opinion column by a councilwoman referenced autonomous vehicles as a potential technological advancement that might help with transportation demands, citing a potential pilot program partnership with an autonomous vehicle company. Another partnership was referenced in one set of meeting minutes included in the approval of meeting minutes. This document referenced an autonomous vehicle delivery partnership with Fry's and a conversation about sales tax projections, acknowledging that autonomous vehicles were not accounted for in the tax projections model.

Interestingly, one document was a closed caption transcript of a City of Scottsdale 2019 Regular Meeting. Although this meeting was not about autonomous vehicles, one

comment was made by Government Relations Director Brad Lundahl during a conversation about the 2020 State Legislative Agenda. He states, “A lot of states are losing their testing facilities and those companies are coming to Arizona because of our favorable regulatory climate. We’re just saying we would like to continue that as long as these vehicles are safe.” Similar language was used by Lundahl in 2018 when discussing the 2019 Legislative Agenda. This kind of language documents the support for Arizona’s loosened regulatory environment, which favors innovation and economic opportunity through business development. However, it also creates tension as decreased regulation might result in decreased safety for the public.

The City of Phoenix website included a variety of documents that mentioned driverless vehicles. These documents ranged from event flyers, meeting minutes, newsletters, and research studies. The February 28, 2018 edition of PHX Connect, a weekly newsletter for City of Phoenix employees, featured an advertisement for a self-driving vehicle event, which featured a presentation by the Maricopa Association of Government’s transportation director. The presentation was promised to cover research and planned for autonomous vehicles, and the potential impacts of that technology socially and across the larger transportation system. Another document included a presentation about the future of Phoenix and its economic development. In this, autonomous vehicles were included on a list for technology attraction and expansion goals in an economic development presentation on living in Phoenix. Another file was from February 2014 and included public feedback captured during a public open house as part of the Phoenix Comprehensive Downtown Transportation Study. One comment was listed that asked for the city to prepare for shared ten-person autonomous vehicles,

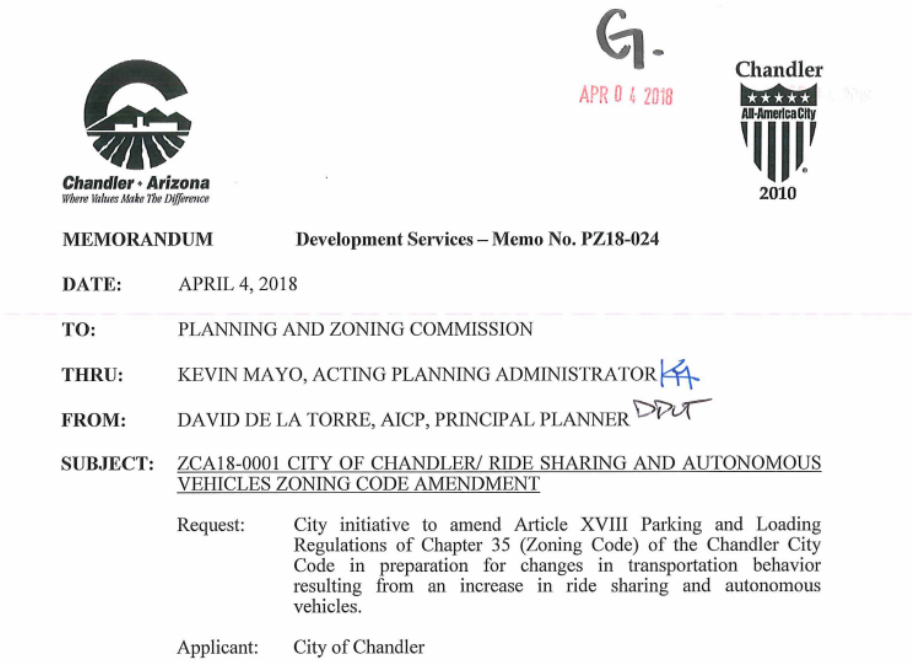
claiming they will be “cheaper, faster, and more convenient than bus systems. These sets of documents demonstrate the multifaceted ways that the City of Phoenix thinks about and engages in driverless vehicles, which ranges from educating employees, gaining public feedback, and including it on future roadmaps for development.

The City of Chandler website has the most targeted information related to driverless vehicles, including clear visions about what the future of Chandler might look like for its residents. Twenty-two pages mentioned autonomous vehicles, which ranged from annual reports to news articles, and a page dedicated to autonomous vehicle technology businesses. These documents demonstrate how autonomous vehicles are deeply engrained into the City of Chandler’s current conception of themselves and future plans for themselves. It is a part of the city’s identity, making its way into their annual reports and news, as well as protocols and policy.

The most significant page on the City of Chandler’s website was about autonomous vehicle research and development efforts, which self describes the city as a “hotbed for the autonomous vehicle industry,” due to its development efforts and proving grounds. This page listed Waymo, Intel, NXP Semiconductors, General Motors, Maxim Integrated, Microchip Technology, Rogers Corporation, and Garmin as leading companies in autonomous vehicle technology that operates in Chandler. These businesses include companies that develop and test vehicles, semiconductor technology, power and battery technology, specialty materials, and navigation systems. The page also includes a downloadable automotive tech sheet, which lists the role of different sorts of Chandler businesses in this space, meant to demonstrate the expansive economic development in Chandler around this industry.

Figure 15

City of Chandler Memo Depicting Zoning Regulation Initiative for Autonomous Vehicle Planning to Anticipate Infrastructure Changes Needed for Future Technologies



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2010

MEMORANDUM **Development Services – Memo No. PZ18-024**

DATE: APRIL 4, 2018

TO: PLANNING AND ZONING COMMISSION

THRU: KEVIN MAYO, ACTING PLANNING ADMINISTRATOR

FROM: DAVID DE LA TORRE, AICP, PRINCIPAL PLANNER

SUBJECT: ZCA18-0001 CITY OF CHANDLER/ RIDE SHARING AND AUTONOMOUS VEHICLES ZONING CODE AMENDMENT

Request: City initiative to amend Article XVIII Parking and Loading Regulations of Chapter 35 (Zoning Code) of the Chandler City Code in preparation for changes in transportation behavior resulting from an increase in ride sharing and autonomous vehicles.

Applicant: City of Chandler

Source: City of Chandler, 2021, https://www.chandleraz.gov/sites/default/files/documents/imported/ZCA180001.pdf

Another page listed on the website is tied to the 2019-2024 Strategic Framework. The mobility section listed autonomous vehicles as a way to expand its transportation network. Another section of the strategic framework focused on innovation and technology, which featured a picture of a Waymo driverless vehicle testing near Chandler City Hall. Another report, the 2019 annual report on public safety, briefly mentioned Chandler Fire partnered with Waymo engineers to prepare for emergency response incidents and develop an emergency response guidebook as a result. Another portion of the annual report mentions that Chandler was named the Autonomous Vehicle Capital of

the World. Another portion of the annual report focused on "being the most connected city." This section mentioned the partnership between Waymo and the City of Chandler for establishing a ride-hailing program for city programs, which is mentioned as an opportunity for "cost savings" and "employee productivity." Several portions of the website mentioned zoning code changes that allow for decreased parking and increased loading zones for ridesharing, which will allow for ridesharing autonomous vehicle technology to be better leveraged in the future (see Figure 13).

These documents demonstrate the city has intentionally planned for this future. In terms of artifacts encoding futures, this is most clear in the way that safety guidebooks and zoning codes have been updated to allow for an autonomous mobility future. Additionally, creating an employee ride-hailing partnership increases the exposure to the technology and can enroll more people in support of autonomous technology. Finally, though the earning, celebration, and sharing of being the Autonomous Vehicle Capital of the World, this motivates an entire community, including the public, business, and political leaders, to rally around the title and continue their work toward the vision.

The Town of Gilbert's website had evidence of strategic planning for the future of driverless vehicles. There were a couple of instances in which strategic planning around autonomous vehicles was done and included in larger institutional priorities. For instance, the Heritage District Redevelopment Plan included design strategies to ensure that parking lots could be turned into alternative spaces if the need for car parking goes does in the future. Another way in which strategic planning was reified included a specific budgetary request for collaborations. In the 2019 annual budget, the engineering services group wanted to collaborate with other divisions to develop a plan for autonomous

vehicle operations. These two examples demonstrate how institutional resources are being considered or deployed to future development and strategies around autonomous vehicles.

Notably, citizens were the focus of several Town of Gilbert artifacts that allowed for insight into the public's needs and incorporated their engagement into the process. There were three instances of autonomous vehicles being referenced in Citizen Task Force meeting minutes. These meeting minutes emphasized an interest in keeping up with autonomous vehicle technology. Additionally, another search result yielded an article post from January 2019 that included a transportation poll, asking Gilbert's citizens to share their feedback on transportation solutions, which included driverless vehicles. Between the Citizen Task Force meeting minutes and the citizen poll, the Town of Gilbert has set up strategies to gain feedback and involvement from the public, and in at least these two instances, autonomous vehicles have been considered, demonstrating that the government does work to assemble the public with the technology, while the public gets an opportunity to imagine relationships by way of the government.

The City of Tempe is a potentially interesting city of analysis. It is home to Arizona State University, was the site of Uber's testing of autonomous vehicles, and was the city where Elaine Herzberg was struck and killed by an autonomous vehicle. Unsurprisingly, driverless vehicles showed up in many documents hosted on the City of Tempe website. Several transportation commission meeting packets included references to driverless vehicles. For instance, on October 10th, 2017, Brent Cain of the Arizona Department (ADOT) presented information on autonomous vehicles. In the presentation, the first slide sets the stage by saying, "The Human Driver… is the most unreliable

component of an automobile," before proceeding to share facts on safety and crash data. The presentation shared how the open regulatory environment encourages that Arizona to "embrace tomorrow's technologies today" and that Uber, Waymo, Ford, and GM have all contributed to Arizona's research and development efforts. Notably, the presentation showed Uber's on Tempe streets, Waymo picking up children in a suburban neighborhood, Ford on the Whitman proving grounds, and GM Chevrolet Bolt EV test vehicle on a Scottsdale road. The presentation seemed to conclude by setting out an agenda of considerations for the next steps, including changing transportation and infrastructure planning, policy barriers to adoption, safety, and mobility impacts, and evolving driver acceptance and behaviors.

On May 8th, 2018, Thad Miller from ASU and Rosa Inchausti from the City of Tempe presented on autonomous vehicles opportunity and anticipation while Bob Hazlett from the Maricopa Association of Governments followed with a presentation on driverless vehicle planning. The first presentation asks the City of Tempe to think about how to use its position as an innovative city to capitalize on opportunities from driverless vehicles, while also anticipating how to manage these technologies appropriately. The presentation educated the audiences on the different kinds of potential uses of driverless vehicles (commercial, rideshare, single occupancy, public transit, and electric). The presentation ended with policy considerations, such as community engagement, public-private partnerships, and ASU-Tempe partnerships.

The presentation on planning began with an image of a Waymo picture in front of Chandler City Hall. The presentation includes a diagram indicating a convergence between battery technology, ride-sharing, and autonomous vehicles. It then shapes the

conversation by sharing the safety, economic, and mobility/quality of life facts about current travel, using an image from a Waymo Safety Report. The presentation educates the audience by explaining the different levels of autonomation and diagramming the key technology in a driverless vehicle. It also provided an overview of opportunities (ridesharing, safety, more space, and efficiency) and concerns (road congestion, inequity, and privacy). The remainder of the presentation illustrates how driverless vehicles will influence planning processes and does so in a very detailed way that demonstrates thoughtfulness around new users, lifestyles, and needed stakeholder engagement.

Much of the City of Tempe's documents were about being planful, whether it be Miller and Inchausti's presentation on anticipation or references to thoughtful planning around road congestion. That planfullness extended into sustainable concerns. Driverless vehicles were discussed in sustainability commission meetings and were mentioned as part of a smart mobility plan in the City of Tempe 2019 Climate Action Plan, demonstrating autonomous futures can also be sustainable futures.

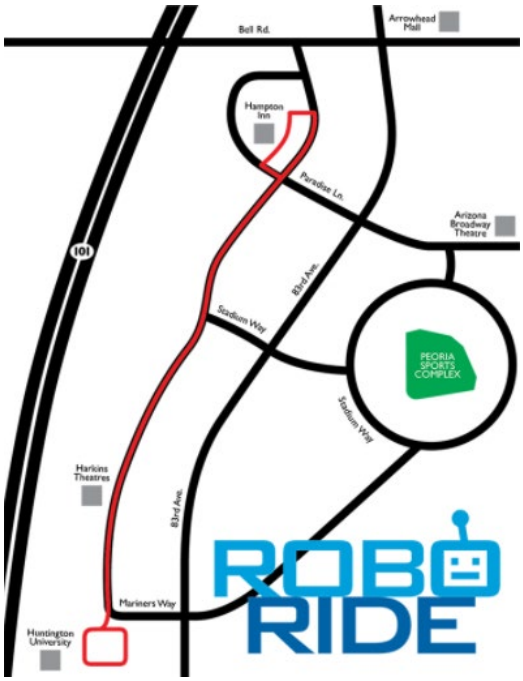
The City of Peoria had four unique website pages that referenced autonomous vehicles. One link was to a Peoria planning report called Plan Peoria AZ: General Plan 2040, which referenced the need to continue to follow emerging technology like automated vehicles and adjust transportation and parking planning accordingly. The Public Works Department had a page dedicated to sharing information about RoboRide, an automated vehicle mobility test service in the Phoenix Metropolitan area. This page shared information about the technology, including its ADA accessibility, zero-emission technology, the route through the entertainment district, free cost, and lack of booster seat options. It also included a promotional video showing people riding in the autonomous

vehicle in Peoria and a public feedback survey to gain insight from community members about their experience. The other two web pages include two news articles. The first news article was about how funding was approved for the automated vehicle service Robo Ride pilot. This article included a quote from the Mayor, stating, "This transportation pilot is a unique experiment for our community" and the CEO of Beep, calling the service a "safe, green and intelligent mobility solution." The other article was about an ASU and Peoria partnership bent on expanding innovative solutions, in which automated vehicles were listed as an example of a desirable innovation.

Through these documents, the City of Peoria portrays itself as planful, dedicated to innovation, and up for testing to improve transportation outcomes. The planning document references the role of city leaders as important planners in infrastructure that is needed to work alongside transportation solutions. The Robo Ride webpage and its related news article both mention that the service is available to all users and is a pilot program for the entertainment district (see Figure 16). However, the webpage also hints that the technology might not actually be available to everyone, specifically noting that there are no booster seat options available and therefore is not appropriate for small children. The language in both articles also explicitly mentioned people with disabilities as potential users, as it was referenced as an ADA compliant technology. The future put forward through these documents demonstrate a future that is innovative and climate-friendly, made at least partially possible through Robo Ride's zero emissions. The kind of testbed work imagines and assembles the technology differently than personalized transportation groups like Waymo and then implements the technology within a city context.

Figure 16

Map of Peoria's Robo Ride Route Articulating How Autonomous Vehicles Can Change Transportation Opportunities in a Bounded Area



Source: City of Peoria, (2020) https://www.peoriaaz.gov/government/departments/public-works/transportation/autonomous-shuttle

Government documentation on autonomous vehicles is multifaceted. These websites can include topic-specific initiatives, news and newsletter coverage, event advertisements, public presentations through committee notes, and policy. This review of different city documents helps reveal the substance of government activities (transportation committee hearings, public engagement exercises, and infrastructure planning) and materially demonstrate how social and material coalitions are built for autonomous mobility futures. Governments take in information about the technology and

how to manage it from industry and academia and then try to build business and infrastructure to build pathways for the technology to succeed.

The role of cities and their relationship to autonomous vehicles consistently appears to take on two foci. Firstly, cities cultivate partnerships to attract business for economic development. In the economic development context, cities celebrate and promote the companies that partner and reside within the locality. Secondly, transportation policy needs to be attended to to allow for successful autonomous vehicle implementation. This involves changing zoning codes, thinking long-term about infrastructure development, and listening to constituents' feedback. Cities attempt to find a way to promote themselves as a popular business place for the technology, while simultaneously learning how to manage it in their community.

Most city websites did not have a particular section of their website dedicated to driverless vehicle initiatives. Many cities, including Tempe and Chandler, had autonomous vehicle-specific presentations through committee hearings, such as transportation planning committees. These hearings sometimes leveraged voices outside of the government and included stakeholders from the university and other government leaders. These presentations were educational, either teaching about the technology or responsible planning, and involved imagery that typically showed the technology integrated into city landscapes. Furthermore, many of these presentations often included imagery and slides from industry, which carries industry vision over into the government space. When university voices were incorporated into the governmental space, as evidenced through the available electronic documents, it was often to slow the conversation down and remind the audience that people should be planful and think about

how to manage these technologies responsibly. In addition to other sorts of activities (e.g., strategic planning and community conversations), these hearings engage in planful thinking, where autonomous vehicle technology is discussed in a way that is then integrated into a broader discussion about how this technology can be responsibly managed.

Many of these documents and conversations were future-oriented. In some spaces, autonomous vehicle technology is a foregone conclusion, where planning should happen around how to responsibly manage these technologies. In other spaces, as in the City of Chandler's case, the technology might not be guaranteed either way, but the infrastructure can be created in flexible and resilient ways that allow for either future to be fully leveraged. The changing of zoning codes to allow for autonomous mobility rideshare possibilities, and then the promotion of such changes, creates a path for the future to be more readily realized.

Industry and university leaders are not the only voices heard within the public spaces of government; indeed, this research demonstrated specific avenues were set up to gain public feedback. Some cities also seek feedback from their citizens by way of polls or open-house events. The Town of Gilbert, the City of Phoenix, and the City of Peoria all created spaces, either electronically or in person, to gain insight from the public about their mobility thoughts. Citizens can leverage government processes and resources to learn more or influence autonomous vehicle implementation.

Sectors Combined

In practice, it is worthwhile to provide an additional summary of an example of how the three sectors of industry, academia, and government can come together to

understand their work outside of a siloed lens as identified through their jointly created artifacts. Although there were examples of cross-sector collaboration (e.g., Dr. Thad Miller presenting at a government meeting), there are also highly formalized groups created to allow for cross-sector collaboration. Most notably, the Institute of Automated Mobility (IAM) is one attempt to combine the triple helix of actors with working to improve the outcomes of automated mobility. Created through an executive order by Governor Doug Ducey in 2018 and organized under the Arizona Commerce Authority, this institute is a hub for testing, research, and development. The IAM website listed three different kinds of risks to not improving the status quo, including road crash deaths, road crash costs, and hours spent in traffic. Their website includes a timeline of events from 2015 through 2018 in Arizona tied to automated vehicle technology, focused on regulatory and business operations.

Collaboration and partnership are clear values demonstrated through their website, even including a model that speaks to the kinds of stakeholders coming together to solve autonomous mobility problems. Potential users and nonusers are not mentioned explicitly through this website, although it is hinted at through road safety and efficiency statistics. This website's primary stakeholders appear to be those in academia, industry, and government, largely promoting the collaboration as a knowledge advancement strategy. Regardless of whether or not it is the IAM example or the numerous cross-referencing of cities on industry documents, cities in university documents, or industry and academic information in government documents, these autonomous mobility futures are tied together across sectors.

The Work of Institutions

There is no shortage of activity or documents related to autonomous vehicles, as demonstrated by industry, government, and university documents. The review of institutions from different sectors provided a broad landscape of the work done in the testbed, including activities and interests of those in the Arizona driverless vehicle testbed that create and negotiate sociotechnical configurations. Depending on the sector, institutions envision the future of driverless vehicles and then coordinate their activities to bring that vision to life. This research revealed three key findings: different sectors engage in separate kinds of testbed work, this work can create path-dependencies, and the testbed work expands assemblage-building to other sorts of configurations besides people-car relationships.

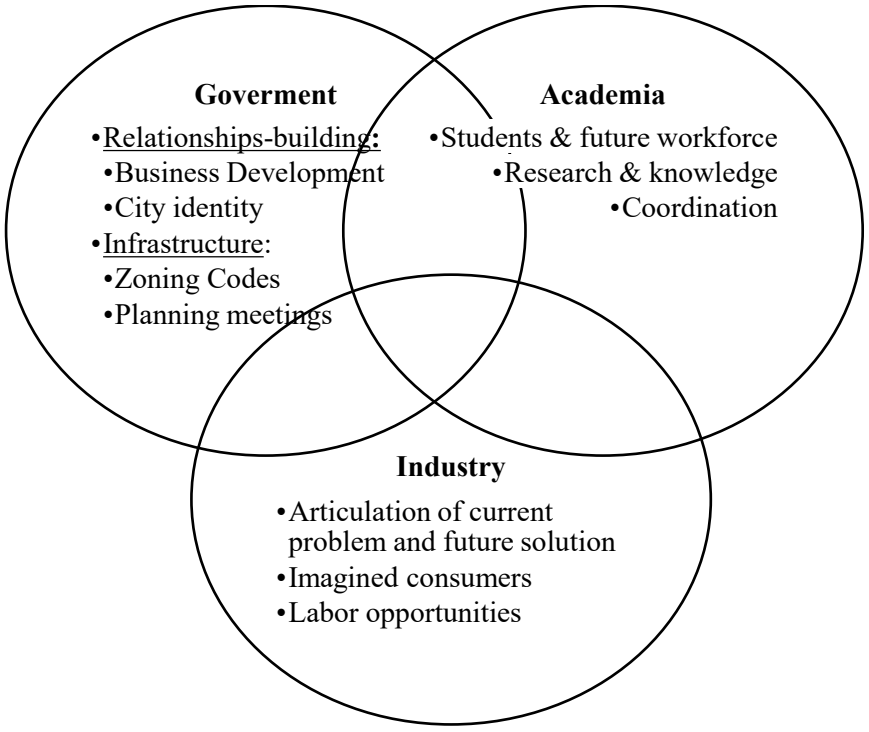
As evidenced in the document review, these three sectors build technologies and futures in different ways (see Figure 17). Industry institutions primarily leverage their electronic artifacts to market and build a consumer base around their technology. In doing so, they take on the role of an educator as they teach viewers about the safety of the technology and how this technology differs from the status quo. In their educator role, the industry stakeholders uniformly used video imagery to demonstrate the technology in action to build trust in the technology. This sector deploys statistics, narratives, and imagery to build futures for potential future users through their marketing, education, and confidence-building.

Primarily, companies engaged in the most amount of work around driverless vehicles and heavily contributed to the imagination space, articulating orchestrated visions of how people and the technology would relate to each other. The videos

demonstrating the technology in action straddle the line between imagination and assembly, as their goal is to help others imagine life with their product, while also demonstrating how the social and technological have been assembled. By leveraging videos documenting the success of pilot programs and using them for marketing content, they are assembling prototype configurations and sharing them with the public. Additionally, the companies engaged in assembly work by articulating who the related stakeholders are, including groups like the Foundation for Blind Children and Foundation for Senior Living. The industry sector also engaged in a form of stabilization work by creating labor opportunities for the public.

Figure 17

Products of Industry, Academia, and Government That Encode Autonomous Mobility Futures



The documents ascertained through government websites represented mostly archived documents posted to the website and included things like press releases, events, or meeting minutes. Very rarely, there would be a web page dedicated to autonomous vehicles as a topic. Regardless, these documents demonstrated that governmental materials typically documented or facilitated education, integration, and identity-building around autonomous vehicle technologies and futures. Government documents became ways to facilitate education. For instance, presentations at committee meetings included informative conversations about what the technology is and how to plan for it, and the posted meeting packets of these hearings further disseminate this knowledge. Additionally, in the City of Phoenix, an informational autonomous vehicle event was held, and they encourage their staff to attend. In addition to educating leaders and employees, government documents revealed the ways driverless technology is integrating into larger city planning around economic development (e.g., business lists, jobs, economic development expansion plans) and transportation (e.g., zoning codes, tax planning, emergency response planning). Finally, as was evidenced in the City of Chandler's website, cities can also leverage materials to engage in identity-building as a city, where technology gets wrapped up into a city's identity, and documents are shared celebrating this event. Through these roles, autonomous vehicle futures were socialized in the governmental space through the presentations and employee participation programs and encoded via manuals, policy changes, and strategic plans.

Governments engaged heavily in stabilization work by supporting infrastructure demands to create paths for the sociotechnical assemblages to exist, such as changes in curb regulation in Chandler. Through zoning codes and planning meetings, autonomous

vehicles were integrating into the infrastructure fabric of the city, acting on imaginations of an autonomous vehicle future and then assembling the technical (infrastructure materials) and policy objects (regulations) needed to enable this future. Furthermore, governments also engaged in assembly work by creating relationships across businesses for business development and leveraging existing imaginations of autonomous vehicles to support a city identity.

University documents reveal how a university is a place for knowledge development through each and research, as well as knowledge dissemination via partnerships with external groups. Primarily, university documents demonstrated how new research added to the existing knowledge through formalized faculty research or student projects. In this, they find ways to improve the technology or share information on how to plan for the technology's integration into society responsibly. In addition to research and education, the university also took on a facilitator and knowledge transfer role. Whether the university was holding events or attending governmental events, producing reports, or teaching, the university often took the role of facilitating cross-sector, collaborative conversations about potential planning or knowledge problems.

Universities engaged in a combination of imagination, assembly, testing, and stabilization work. Imaginative work comes from research by both students and faculty as they contemplate how driverless vehicles might interact with the work. Testing work also occurs in the space of research, as these vehicles are tested in both simulations and courses, with various levels of human engagement. Assembly work occurred through coordination efforts conducted through the university, as was when ASU partnered with the local government to help them think through potential opportunities and challenges

with autonomous vehicles. As indicated by this summary, universities are engaged in testbed work that spans early imaginative work in their knowledge creation, assembly and testing in their research and coordination efforts, and stabilization efforts in future workforce training.

Each sector wrestled with the past in its own way and either leveraged, built upon, or dismantled existing relationships in the process. For industry, they communicated a future that is familiar, yet different. For government, they grappled with existing infrastructure decisions, and for academics, they approached problems as a way to add knowledge to both people and the broader literature. The discourses of the different industry websites demonstrated a finely straddled line of technological momentum. On the one hand, the industry decries existing technological momentum around human-driven cars, given their safety and efficiency issues. On the other hand, they clamor to keep pushing forward on autonomous technologies given the advancements of technology and proof of concept testing. The language of the number of historical miles driven and referencing the autonomous technology as the Waymo Driver pushes the user to think of the new technology in familiar evidentiary and linguistic terms. The history of transportation is embedded in each sector's approach to reinventing the future.

Depending on their roles and activities, the sectors all further autonomous mobility futures in different ways. Specific-user imaginations were mostly employed by industry materials, specifically suggesting autonomous vehicles could create better futures for families, the disabled, and the elderly. Industry did this through videos, testimonies, news articles, stakeholder partnerships, and safety considerations. University

research also touched on this, but typically had more facilitative and passive approaches when suggesting social concerns are worth considering.

General social future considerations, however, were elevated by all three groups. Although the government did not focus on user design, they generally created autonomous futures by making sure infrastructure and emergency response were coordinated. Autonomous vehicles were also incorporated into larger future conversations about improved sustainability, economic development, and safety. The university advanced improved technological futures, alongside safety, sustainability, and legal futures. The industry sector advanced futures that were not only safe, but efficient, comfortable, and often environmentally friendly. Although industry had different technological strategies for how automated mobility futures would be realized, either through public shuttles, rideshare, or goods delivery, government and much of the university documents did not attend to these differences.

Combined, this analysis demonstrates how each sector engages in different kinds of activities and ultimately contributes to work in the testbed that spans imagination, assembly, testing, and stabilization work. Each area called an assortment of new assemblages into being. In this broadening, the sectors not only attended to passenger-car relationships, but also demonstrated the other social and technical structures that must be enabled to bring the sociotechnical future into existence. This can be most clearly seen in the government space when the physical infrastructure needed to be changed to support these vehicles and in the business space where Waymo articulated the necessity to work with and train first responders.

Each sector contributed to path dependence-type work by establishing things within the testbed that would enable autonomous vehicles to become a reality. For instance, training future professionals, hiring personnel, and changing infrastructure all helps to create momentum where people and technological artifacts have been organized in such a way to help make autonomous vehicles likely to be the future. The infrastructure and workforce were reconfigured in the testbed to help ensure the technology becomes a reality.

This investigation into institution work demonstrates that institutions, as conveyed through websites, configure relationships in the testbed that are not only about person-car relationships, but are also about other car relationships that are attached to autonomous vehicle sociotechnical. Table 7 demonstrates some examples of the kinds of relationship building and configurations that come together through institutional work. In the testbed, car and emergency personnel are assembled together in renewed ways to respond to crises given the introduction of a different kind of vehicle with entirely new technical configurations. Another kind of configuration noted here is the kinds of relationships needed between material options. The City of Chandler anticipated that autonomous vehicles would require different kinds of curbs to allow for more drop-off/pick-up locations, so new zoning regulations were created to install curbs that improve autonomous vehicle use.

Table 7

Assemblages Formed Through Institutional Websites

System Car Relationships	Examples
Car – Emergency Personnel	"We've collaborated with the Chandler Police and Fire departments in Arizona to conduct emergency vehicle testing with our self-driving minivans." – Waymo Safety Report Waymo provides law enforcement and first responder interaction protocols
Car-Person-Errands	Nuro's website demonstrates their product is vaguely for everyone, where they can be connected to "the people and things we love." and a way to accomplish errands from "dinner to dry cleaning."
Car-Policy-Infrastructure	Zoning codes, curbs, taxes
Car-City	"The most connected city" – Identity of the City of Chandler
Car-Institutional Partners-Attached Supporters	Autonomous vehicle partners like Federation for Senior Living, Mothers Against Drunk Driving, & Kroger
Car-Environment	"the world's first co-created, self-driving, electric and cognitive shuttle." Tempe goals of Sustainable Growth & Development
Car-Business-Employees	Universities train people to work in the field AV businesses post jobs

Although all three sectors of the triple helix might promote futures, by either directly envisioning them or by setting up the infrastructure as pathways to accommodate them, accountability for the technology in action seems missing from this analysis. This might be attributable to how the three sectors work together to achieve autonomous mobility futures, which is a form of networked governance. Karvonen (2020) shared networked governance can "obscure responsibility and accountability through diffused forms of political agency and convoluted decision-making processes" (p. 419). From this

research, although it is clear who is responsible for envisioning autonomous mobility futures, it is not clear who is responsible for the byproducts of the enacted autonomous mobility futures.

Although archived information can be easy to find with the advent of the internet, this research falls short of having a comprehensive view of every artifact an institution has created that might encode additional visions. Industry websites are marketing-oriented, government websites appear to be repositories for meeting minutes and reports, and academic websites tend to store new stories, event advertisements, and formalized research publications. Additional research would leverage information that is less in the public view, such as schematics, professional agreements, and internal strategic documents, to gain a fuller picture of the work done in the testbed by institutions.

CHAPTER 5

NEWSPAPERS AS MEDIATORS OF THE TESTBED

"Waymo… already has been shuttling one Chandler family with four children to myriad sporting events, dinner dates, and other appointments, the company said Tuesday." - Ryan Randazzo, 2017a, News Article from the Arizona Republic

As indicated in the previous chapters, driverless futures are built through a lot of activity in the Phoenix metropolitan area testbed by many stakeholders and institutions; however, it may not always be readily apparent to general audiences how, when, and by whom these futures get built. The translation of such testbed work and the mediation of such activities to help the public understand the happenings of the testbed can occur through news articles. New sources are vital to look at because they document, frame, and assess events and topics within the testbed. News media also engages in storytelling, which depicts the main actors in the story and the outcomes of their actions. Through these stories, newspaper articles share knowledge and interpretations that contribute to testbed sociotechnical assembly and negotiation work, both passively through their reporting on events and actively through their decision-making on how stories get told.

This chapter will investigate the role of local newspapers in how they create and negotiate sociotechnical assembles in the testbed. By engaging in a content analysis of news articles referencing autonomous vehicles spanning five years, this research is able to articulate how the testbed is portrayed, who is included in the testbed, and what this means for the kinds of sociotechnical assemblage-making work attached to newspaper

article design and dissemination. This chapter will first review the literature on the multiple ways that newspapers engage in work in their reporting of emerging technology and then share the research design and methodology. Then, I provide a summary of the happenings of the testbed as conveyed through the articles and indicate who the relevant users and stakeholders are that are depicted alongside these happenings. Afterward, I use these findings as an opportunity to extrapolate what this means for the kinds of testbed work that newspaper articles engage in. This chapter argues that newspaper articles and their associated writers articulate the playing field of the autonomous vehicle testbed. In doing so, newspaper writers determine who is relevant and has authority, normalizes/destabilizes existing testbed sociotechnical configurations, and promotes resilient and heuristic themes and values for easy consumption. Journalists and newspapers do not sit outside of the testbed as observers to the testbed; instead, they are a part of the testbed and contribute to it.

Literature Review & Chapter Methodology

Newspaper stories are typically broadly disseminated depictions of events geared toward public consumption. The information the editorial staff determines to include and distribute is incredibly important for how people learn about events and make decisions about them. Lee and Scheufele (2006), in their investigation of media effects on public attitudes related to nanotechnology, found those relying on newspapers for their information reported higher levels of knowledge. In contrast, those who watched scientific television had more reverence for scientific authority. The way information gets portrayed can impact the public's understanding and deference to different actors.

News articles can also impact the choices people make. An analysis of news media cannot just include a depiction of events; indeed, a robust analysis should attune to specific editorial decisions that might impact public knowledge and opinions. For instance, improving information sharing can result in different consumer behaviors around technology. Palm and Lantz (2020) found information dissemination resulted in increases in solar photovoltaics adoption in Sweden.

News media can play a role in sharing benefits and risks tied to emerging technology. Nisbet and Lewenstein (2002) found biotechnology was positively discussed in American newspapers from 1970 through 1999 by capitalizing on scientific and economic frames. This topic started to become more controversial as newspapers shifted to discussing cloning through ethical frames. Media coverage has the potential to influence how people make decisions. Similarly, Scheufele and Lewenstein (2005) discovered media frames impact public opinion of nanotechnology. Anania et al. (2018) found people were less likely to ride in a driverless vehicle after being exposed to negative information, with an increase in willingness to ride with positive information.

How a story is narrated through such frames can also increase the amount of media attention the story will receive. Nisbet et al. (2003), in their analysis of stem cell media coverage, argued the amount of media attention that stem cell research received was related to how much of the issue could be framed in dramatic terms and told in familiar terms by journalists. This analysis suggests issues journalists can frame dramatically or familiarly might receive more attention, and therefore have compounding effects of continued exposure to the same types of stories.

It is essential to pay attention to whose voices the media includes in their stories, as different perspectives might bring differing tones, frames, and opinions. Sun et al. (2020) also used newspapers are a source of understanding beliefs around emerging technologies. This research suggested stakeholders framed artificial intelligence as sophisticated and powerful, but that the voices of the public were missing in their representation in newspapers.

Representation of voices and content coverage are essential facets to analyze to understand where there might be a disconnect between newspaper coverage and reflection of public needs. Wolbring (2016), grappling with representation and engagement issues, found no newspaper articles or academic articles discussed how robots could negatively impact disabled people, which is at odds with the disabled community's concerns. If newspapers increase knowledge and influence action, then not having certain kinds of information impacts how the public receives knowledge and then acts, perpetuating equity disparities from journalistic decision-making.

These missing voices can be a product of the editorial process. Bowers et al. (2004) explored the embedded power relationships within journalism and what editorial decisions might mean for ethics. Journalists select interviewees, and then interviewees share information from their perspective. A journalist takes some part of the collected data to tell the story, and editors determine if the article will be published. When a subject is unable to speak, in the case of technology or a deceased individual, someone will either talk on their behalf or be voiceless.

All of the examples cited in this section discuss the kids of work that newspapers engage in, whether it be the framing of a technology, the exclusion of perspectives, or the

education or hyping of readers. This research engages in a content analysis of newspaper articles as a way to understand how newspapers in the Arizona testbed assemble and negotiate sociotechnical relationships both passively and actively in the testbed. The content analysis is comprised of newspaper articles published in the Arizona Republic, Phoenix New Times, and ASU Now news sources from Jan 1, 2015, to Jan 1, 2020. Analyzing local news stories should capture information that is immediately relevant to and potentially consumed by the public from the Phoenix metropolitan area. Indeed, such local media can cover regular events, like new jobs, car accidents, and local voices that would otherwise not be interesting enough for national news, but very much represent the reality of the area. News articles had to reference "driverless vehicles," "autonomous cars," "self-driving cars," or any related derivative of these to meet criteria for inclusion into the pool. Articles were removed that were either duplicates or were misidentified as having to do with driverless vehicles from the keyword search.

Each article was coded for user/non-user design, key stakeholders, and values. Furthermore, at the article level, I wrote memos to capture the core meaning and function of the article, to then create themes around the work being done in or by the article. This research finds that those constructing newspaper articles promote and socialize other testbed work, while also engaging in testbed work by articulating the playing field of the testbed and determining what matters.

I demonstrate these findings by first providing a summary of the content of the articles and an overview of which stakeholders are imagined as potential users. Then, I explore how newspapers engage in testbed assembly work that identifies who is relevant and who has authority, imagination work that promotes resilient heuristic themes and

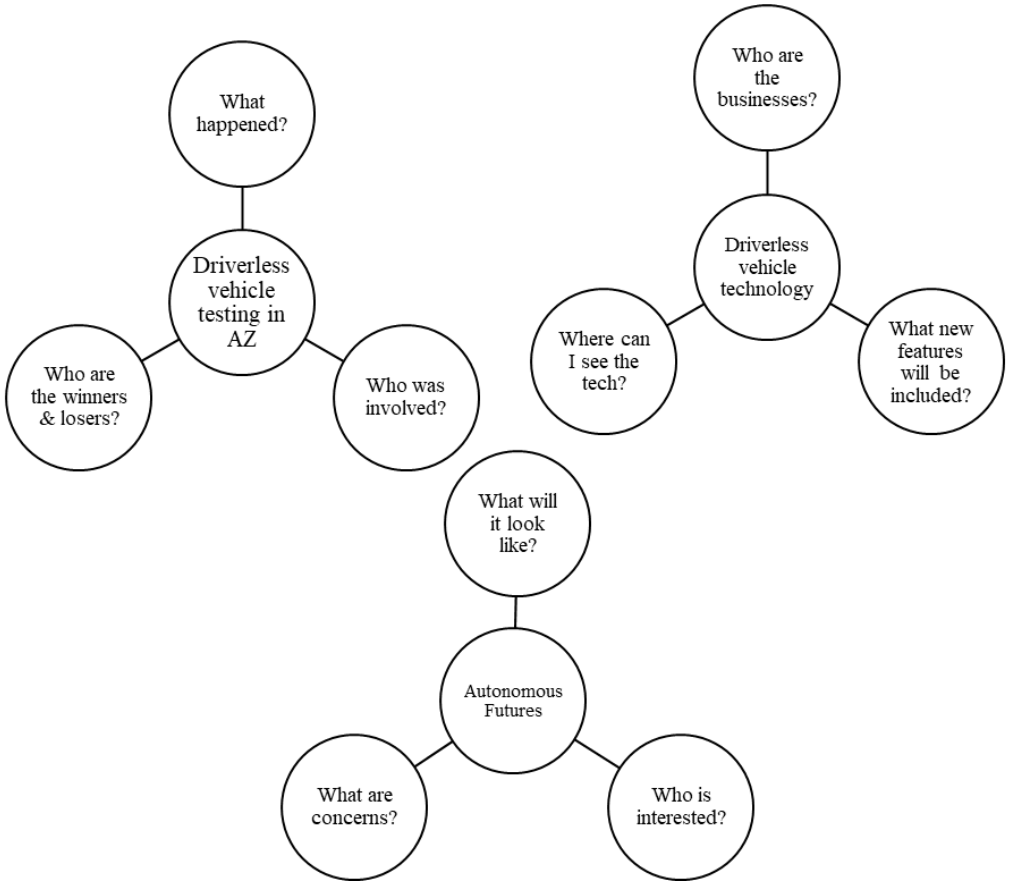
values, and stabilization work that normalizes the activities of the testbed. As newspapers report on events, describe causalities, imagine opportunities, and attribute blame, these articles all conduct work that assembles people and technology together, either passively or actively, in ways that also structure expectations about right and wrong, fault, and normalcy. This chapter is a testament to how news reporting does not sit outside of the testbed work that journalists report on, but instead is intricately enmeshed in its own testbed work that structures autonomous vehicle futures and sociotechnical relationships.

The Story of the Testbed: Key Characters, Setting, Plot, and Conflict

The news articles examined in this research can be divided into three separate categories as it relates to autonomous vehicle storytelling: stories about the activities of the testbed, stories about autonomous vehicle technology, and stories about autonomous future (see Figure 18). The articles analyzed were typically about driverless vehicle development or the driverless vehicle testbed and were primarily about activities occurring within Arizona. New stories from other parts of the country made local news as well, although these were typically about driverless vehicle testing or partnerships in other states. The articles that were about the technology were often connected to major automotive manufacturers and their mergers or new technological gadgets and their future. A small portion of articles also references autonomous vehicles with other technology, like the Arizona light rail system as an alternative transportation option. These differences in content end up creating varying approaches related to technology storytelling: is the technology just a gadget, a feature of everyday life, or something that exists in the future?

Figure 18.

Three Approaches to Autonomous Vehicle Content Coverage



In terms of content and event coverage, the news stories frequently commented on two significant events: loose regulation in Arizona by way of Governor Doug Ducey's executive order and the death of Elaine Herzberg by a self-driving Uber with a safety driver in the vehicle. The minimal regulation conversation was related to discussions about attracting businesses and increasing jobs in Arizona. As a result, road safety and innovation are the central values communicated through newspaper articles. The articles expressed the need for safety for all sorts of people: pedestrians, drivers, passengers, autonomous vehicle operators, children, and police. Although less prevalent than road safety and innovation, infrastructure design was also a reoccurring theme in the

discussion of driverless vehicles in Arizona. This theme was present in conversation about transportation planning, light rail expansion, the last-mile problem, curb availability for drop-offs, and parking lots. When combined, however, the news articles help link these events and themes, painting a broad picture of how the testbed operates and how futures are constructed through events and editorial decisions.

For articles about the testbed, the information included some description of the technology, but mainly focused on social aspects of how the technology integrates with society. Many of these news articles talked about specific testing programs, although the notion of "testing" was not always clearly labeled in articles. Sometimes, the testing of vehicles was presented as a pilot program, an opportunity, or simply a new fact of life.

Testing occurs in different ways in this testbed. Ten articles outlined pilot programs for a partnership between Nuro and Kroger, where people in 85287 zip code could order Fry's groceries for a driverless vehicle to deliver them. Another grocery pilot program involved a Waymo and Walmart partnership, where a Walmart in Chandler would pack the groceries and Waymo would provide a free ride to pick them up. Other testing included Waymo's early rider testing in Chandler and Uber, which was primarily tested in the Tempe area. Pilot programs featuring a partnership between USPS and TuSimple and freight trucks also made the news, focusing on using autonomous vehicles in the trucking industry to get packages to customers without overtaxing truck drivers on commutes. Most of the conversations on how driverless vehicles would be implemented were focused on the rideshare modality, where a fleet of cars would be managed to taxi people around. This conversation was furthered through Waymo and Uber's rideshare-inspired pilot programs.

These testing programs, and the subsequent coverage of them in the news, create glimpses into what a driverless vehicle future might look like for technology users. From the testing examples listed previously, it is already clear that the future might seem like a place where people can use these technologies for grocery delivery, ridesharing, and expedient mail delivery. Each pilot program tests portions of these potential futures, and then the news paints a part of this picture about what the future might look like for others to envision. Some articles, however, cited a lack of transparency relating to the driverless vehicle testing occurring in Arizona, so there is a question in the news media about whether or not the testbed and proposed driverless vehicle futures are even clearly understood to be able to make sense of what is happening.

As described through the news articles, the Arizona driverless vehicle testbed is a place made possible by deregulation in the name of innovation. As an overview, this testbed is a place where future safety is discussed more than current safety, with some memories of testing accidents that did not kill anyone cropping up until one accident fatality finally happened. The testbed has jobs for people very explicitly tied to driverless vehicles. These jobs include working on driverless vehicle research and development, testing driverless cars, educating about autonomous systems, and regulating them. These jobs have waned with the banning of Uber testing and increased at the expansion of Waymo's facilities. People can also apply to volunteer to be test riders. Events are held discussing driverless vehicles and advertised through the newspapers. In this testbed, liability and fault still seem up for debate, while some community members bemoan the lack of transparency in testing. Other events and public statements work toward showcasing proof that driverless vehicles work, with leaders sharing stories about how

they have ridden in one themselves. Other stories, however, treat driverless cars as anything but comfortable, describing the technology in ways that at worst seem alien and, at best, overly futuristic.

The stakeholders imagined in the news articles are those tied to significant events deemed as newsworthy. Aside from Governor Doug Ducey and pedestrian Elaine Herzberg, there are few other named people consistently at the heart of the driverless vehicle stories. This makes the reality of the testbed abstract, and therefore, makes the technology feel abstract and yet omnipresent. The following section will detail the varieties of actors in the stories, focusing on users, nonusers, and the assortment of other stakeholders in the driverless vehicle testbed.

In the testbed, users and nonusers are only roughly defined as the technology is not widely implemented or adopted, and that people's relationship to transportation technology can shift based on their circumstance. Since the technology is not widespread, people might be nonusers due to awareness, circumstance, interest, or ability. Several groups of users and nonusers are either consistently mentioned, imagined for the future, or already exist in the testbed. Test riders who participated in Uber or are participating in Waymo are the most current examples of users in the testbed. These users are mostly geographically bound to the East Valley, and, in the case of Waymo, these users had to apply and be selected to participate. Driverless vehicle safety riders, employees tied to the driverless vehicle testing, were also brought to the forefront of the discussion.

Driverless vehicle safety riders sprang into the forefront of the discussion from the same Tempe car accident, where the role of a safety driver was heavily debated. In the testbed, a safety driver can be a user, but also might be regarded as a stakeholder and

employee. Depending on whether the car was in autonomous mode or not, these safety drivers oscillate between being a user of a traditional car and a driverless car.

Everyone else besides these test riders or safety drivers are nonusers of the technology in the testbed since widespread adoption has not occurred and use of the technology is contingent on need. Of these nonusers, some are more fervent in their viewpoint. An article from December 2018 detailed the ways people have revolted against driverless vehicles. These steadfast nonusers were represented in the local news media after several incidents occurred between members of the public and Waymo safety drivers. In this article, these nonusers threw rocks, blocked traffic, and even brandish a weapon in an attempt to make the environment difficult for the driverless vehicle.

For future users and nonusers, there was a higher level of depth imagined into who these people might be. The imagined users included families, the elderly and disabled, transit riders, drunk drivers, and those who might otherwise be killed in a road accident. One of the main nameless groups of people articulated through the new stories is those that would otherwise die from accidents. In a December 2016 article documenting a news conference about welcoming Uber's driverless vehicles, Governor Doug Ducey is quoted as saying, "We lose tens of thousands of Americans every year in avoidable accidents caused by human error" (Smouse 2016). As another example, Mothers Against Drunk Driving (MADD) are quoted in an article from September 2016, saying that driverless vehicle technology could "stop drunk driving and save lives" (Randazzo 2016). In these examples, future users could be any Arizonan who could potentially die in a driving-related accident, especially a drunk-driving accident.

Families and children were also referenced as potential users. An April 2017 article describes that Waymo is looking for more volunteers to use the driverless vehicles and states, "Waymo… already has been shuttling one Chandler family with four children to myriad sporting events, dinner dates, and other appointments, the company said Tuesday." Another November 2017 article describes that Waymo can help families accomplish their errands.

Accessibility and mobility are briefly mentioned in some articles to discuss the advantages to groups of people like the elderly or disabled. Five news articles mentioned how autonomous technologies could help the disabled. One article from February 2017 shared how a legally blind man from Texas tested a Google driverless car alone. In another news story, Waymo's goal was described as achieving "autonomy that would require no human input, giving people with impaired vision or other physical challenges that prevent them from driving the freedom of mobility (Randazzo 2017b)"

Young people are imagined as potential users through the use of public opinion research sharing their lack of car ownership. A AAA survey cited in a January 2018 article found millennials have faith in driverless vehicles. A study by the University of Michigan Transportation Research Institute mentioned in a January 2016 news article shared that millennials are less interested in car ownership, making driverless vehicle ridesharing an excellent opportunity for technological development. By making this claim and framing the research around autonomous vehicles, this article is able to focus on driverless technology as the alternative to car ownership, when in reality, there are many other alternatives, like public transit and bicycling.

Transit riders were also imagined as potential users, as several news articles referenced driverless vehicles in relation to light rail transit discussion. One argument conveyed was that investment in light rail transit should not continue because people will use driverless vehicles in the future. Another argument conveyed through another news article shared light rail users could use driverless cars to solve the last mile problem.

There were a few clear nonuser perspectives that demonstrated how the technology is not desirable. For instance, one news article showcased an interview with the IndyCar CEO at the Desert Diamond West Valley Casino Phoenix Grand Prix at ISM Raceway (now Phoenix Raceway) in Avondale. CEO Mark Miles shared sports car racing would not envision a future where autonomous vehicles were allowed to compete professionally. One racecar driver, Graham Rahal, spoke for rural America when saying, "Most people think of things like that from a big-city perspective. They don't think about the fact that there's tens of millions of people who don't live in big cities. There are millions of people who need to drive because they live on rural backroads… The heart of America still wants to drive" (Knight 2018). This statement conveys an informative perspective the news article captured because it suggests the people designing and advocating for the system are not representative of most of America. Whatever momentum driverless vehicles gained over the years, this quote suggests big city interests are contrary to those in the heart of America without a voice.

Some articles had no reference to users or nonusers and focused on revealing a new technology or business merger. A subset of news articles focused on driverless vehicles as a technology gadget, business opportunity, or investment opportunity. For these articles, at best, users were mentioned briefly as consumers. For instance, articles

talked about mergers and new partnerships formed between large automotive manufacturers, while others would talk about the Consumer Electronics Show and the latest technology showcased there. In the case of two articles on the merger between Ford and VW, social impacts like mobility and job loss were mentioned as asides, where most of the focus was on the businesses combining for innovation (see Table 8).

Table 8

Examples of Technology – Focused Articles

Title	Date
"At CES this year, they are really reinventing the wheel"	Jan-16
"BMW promises to deliver self-driving car by 2021"	Jul-16
"All Tesla cars will be equipped to be fully self driving"	Oct-16
"Upgrade your old car with new-car tech	Mar-17
"Daimler, Bosch teaming up for self-driving car service"	Jul-18

In spite of all of the nonusers and users explored here of both the driverless vehicle testbed and the driverless vehicle future, both users and nonusers were not the focus of news articles. Instead, news mainly gave attention to those who were building driverless vehicles and regulating them. The primary actors in the news stories were autonomous vehicle testing groups like Waymo, Uber, and Nuro, the state government (most notably Doug Ducey), the police, East Valley city officials, and university leaders. In the case of Waymo, Uber, And Nuro, their stories were about the ways they expanded efforts in Arizona, although Waymo and Uber would occasionally be brought into discussions referencing the technology's safety.

The police are a major actor in both the driverless vehicle testbed and imagined driverless vehicle futures. In the testbed through the news stories, they became the narrator of events and how they unfold. Aside from a storyteller and expect, the police

can also be a member of the public. The police are also residents of the testbed and potential driverless futures. An article from March 31st, 2017, shared a Tesla on autopilot hit a Phoenix police motorcycle. This article commented on safety concerns for all motorcyclists and drivers generally and gained traction in the news because it was a police officer hit by a vehicle.

Aside from articles about law enforcement responding to accidents and conducting investigations, the police are also depicted as having a procedural relationship with driverless vehicles. In the case of Nuro's testing, the police are to pull over the safety chase vehicle that follows behind the Nuro autonomous vehicle instead. Sometimes, however, companies do not use law enforcement in conventional ways. When people harass driverless cars, Waymo has been encouraged to call law enforcement. A police report cited in a news article from December 2018 stated the "company doesn't always report threats or harassment after an initial encounter, but might do so later if one person continues to cause problems" (Randazzo 2018). In this way, some relationships between driverless vehicles and law enforcement are portrayed as a little less actualized.

There were numerous other people in the system that were imagined as impacted in a driverless future, and the reporting on these people and institutions helps to assemble them with autonomous vehicles. Some of the people listed were defined by their professional roles, including students, job seekers, Motor Vehicle Division workers, and truckers. Workers will have different lives. Those in the Motor Vehicle Division might lose a good portion of their work if licensing roles change, while truckers might have fewer job opportunities. Engineers, conversely, might have additional opportunities. An

ASU article detailed how ASU is preparing students for a more innovative future with a new degree program focused on autonomous system design to build the future workforce. Indeed, students and the university actively contribute to building the driverless vehicle testbed and expanding the workforce. Other ASU Now news stories highlight how students, faculty, and ASU partnerships are already researching and designing systems to work with driverless vehicles within the testbed. One ASU Now article highlighted ASU program Venture Devils for helping people develop ventures. The article featured Sensagrate for receiving $10 million in funding for winning the 2018 Smart Infrastructure Challenge. Other groups were featured as a way to advocate for core social developments. Mothers Against Drunk Driving (MADD) occasionally were referenced in the article, bringing to light that drunk drivers should ideally be a user of this technology. Because Elaine Herzberg was homeless, homeless people navigating city streets alongside autonomous vehicles were also imagined and assembled as a byproduct of the incident.

The concept of forming and maintaining strategic partnerships was a recurring motif in the news articles for how the world gets made when constructing a driverless future. Many strategic relationships were leveraged to create the existing sociotechnical arrangements in the testbed. Strategic alliances appear to be necessities to make both the testbed and driverless future a reality. Existing institutional structures are not prepared to handle driverless vehicle futures in a silo, and standard operating procedures must change. For a testbed environment to operate, the news articles powerfully demonstrate partnerships must be clearly defined. Furthermore, many of these strategic relationships recognize that a driverless vehicle technology cannot just exist in the technological space,

but also need integration into broader social structures. This is consistent with the findings from Chapter 4, as groups within and across academia, industry, and government work together to promote autonomous mobility futures, even when clarity on what exactly that future might look like differs.

Partnerships were needed to set up the testbed. To use driverless vehicles in grocery acquisition for consumers, Nuro partnered with Kroger, and Waymo partnered with Walmart. As articulated in the newspaper stories, Waymo developed many other partnerships as well. In a June 2017 article, Waymo and Avis Budget Group teamed up to have Avis initially maintain and house Waymo's fleet of cars, and then in a July 2018 article, it was identified that they partnered to allow driverless vehicle rides to and from car rental pick-ups with Avis Budget. Other partnerships articulated in that same July 2018 article include a collaboration with The Element Hotel in Chandler, the Ahwatukee Foothills Towne Center for retail shopping, and AutoNation for customer transportation. Other sorts of partnerships included a relationship between Waymo and Metro Transit to help solve the final mile problem and a partnership with Lyft for rideshare. For technological development partnerships, major automakers merging was cited in x articles.

Inclusion and Exclusions of Stakeholder Perspectives

Through the journalistic testbed work of crafting a story, writers solicit interviews for their research into the topic or include different kinds of people into their reporting. When journalists select what to include in their news articles, they establish a power dynamic elevating some perspectives and ignoring or suppressing other viewpoints. However, journalists are not necessarily bent on incorporating some voices at the expense

of others as a matter of principle; indeed, there are systematic reasons why some views are included while others are not. The following section will explore the dynamics of voice inclusion in these newspaper articles about driverless vehicles and the testbed, focusing on the inclusion of political and law, company, public, and technological voices.

As noted earlier, Governor Doug Ducey is a reoccurring media reference. His power and influence as Governor helped to make driverless vehicle testing reality in Arizona. By being a partial enabler of driverless cars in Arizona and by nature of his leadership roles, his quotes about decreasing regulation for improved innovation and safety are a cornerstone of most media articles. For instance, a quote from his executive order was used in two articles, stating self-driving technology "will promote economic growth, bring new jobs, provide research opportunities for the state's academic institutions and their students and faculty, and allow the state to host the emergence of new technologies" (e.g. Zappala 2017). This statement articulates how innovation can grow the state and its public opportunities across a variety of sectors. The Governor has also framed the conversation in terms of safety by saying, "We lose tens of thousands of Americans every year in avoidable accidents caused by human error" (Smouse 2016) Such statements result in a call-to-action that invokes technological deterministic logic that suggests without autonomous vehicles, American lives will be lost. Through a combination of innovation and safety statements, these comments were reoccurring frames of reference in news coverage. Indeed, 20 articles reference the executive orders in some way to frame the conversation on driverless vehicles.

Another challenge as it relates to power is the authority that comes from stories given by police officers in the investigation. Law enforcement, broadly throughout the

articles, often assumed the role of storyteller and fact sharer. In their role of reviewing evidence and determining fault, police spokesman shared who the primary parties were in an incident, what happened, and who was responsible. One article grappled with the power issues at play in determining fault. The Maricopa County Attorney's Office (MCAO) switched ownership of the Elaine Herzberg case to the Yavapai County Attorney Office. MCAO had a previous ad campaign relationship with Uber about increasing road safety by preventing drunk driving. This article helped raise awareness about how relationships can influence how information is conveyed and interpreted.

This research revealed a slight dichotomy in how traditional auto manufacturers and autonomous vehicle groups communicated their stories through the news. News stories about traditional auto manufacturers were not engaged in the same level of narrative creation as did autonomous vehicle groups like Waymo. Whereas traditional companies could rely on name brand and existing technology, autonomous vehicle groups are trying to create a future in which the public could envision themselves.

Autonomous vehicle companies were at the forefront of many discussions. Journalists included Uber in 99 articles, Waymo in 69 articles, Nuro in 10 articles, and TuSimple in four articles. Waymo was a dominant voice in describing what the future should look like with driverless vehicles, justifying the work occurring in the testbed. Waymo's language communicates a steadfast commitment to improving road safety. One article recounts the public event mentioned at the start of this research, where Waymo's Chief Operating Officer called the testing of driverless vehicles a "risk worth taking." Additionally, autonomous vehicle group Nuro also shared their vision for how driverless vehicle delivery services would operate in a city. In an article describing Nuro's

commitment to safety, an employee states, “We’re going to prioritize the safety of a bicyclist or the safety of a pedestrian over the safety of your milk” (Randazzo 2019). Through news coverage describing testing and the events of testing, company voices are prominent.

Journalism also can provide a space for members of the public to share their feedback and experiences. In news articles, the general public gains a voice through three different avenues: direct quotes, letters to the editor/opinion pieces, and public opinion research. Some quotes are integrated into news stories that demonstrate the opinions of the public. For instance, in an article discussing the Nuro delivery partnership with Kroger, one parent shared, “When my sons were infants it would have been so nice to have something like this when they were sick and I couldn’t get out… If I’m sick or I’m not feeling well, this is a good option” (Randazzo 2019). An article about the future of the West Valley helped imagine the future of West Valley residents through the voice of a West Valley resident, who also had experience in urban planning. The author suggests some age-restricted communities might be a good place to test these technologies and questions whether or not communities should help pay for these kinds of technologies instead of investing in other forms of public transportation.

Including public voices is an integral part of journalism to help narrate the opinions and needs of the community. In the case of the driverless vehicle articles analyzed, the way public voices are incorporated appears to be in reaction to the technology, where the writer tells the story with the technology as the main character. Not only are these voices in response to technology, but they also are often ancillary voices, not at the center of the article.

In an article documenting members of the public revolting against driverless vehicles through rock-throwing and taking a literal stand against driverless cars, these members of the public were central to the story. This story serves as a moment of tension, where members of the public felt they were threatened by the technology, and therefore threatened the technology in return. These unsatisfied people were treated with contempt in the article, as their actions were described as harassment, and the conversation changed to Waymo driver safety. A statement from Waymo includes commentary that they are committed to local engagement. The article quotes Waymo, stating, "Over the past two years, we've found Arizonans to be welcoming and excited by the potential of this technology to make our roads safer" (Randazzo 2018). Based on their local engagement efforts, Waymo speaks on behalf of the public, making the rock-throwers look like a minority. Similarly, law enforcement spoke on behalf of an arrested member of the public when documenting the following: "He stated he was sick and tired of the Waymo vehicles driving in his neighborhood, and apparently thought the best idea to resolve this was to stand in front of one of these vehicles" (Randazzo 2018). These kinds of summaries that law enforcement provides can be helpful and informative, but recognizing the role of speaking for someone else is a useful analytical step.

Law enforcement and companies were not the only actors that spoke on behalf of the public; indeed, public opinion research was used as a proxy for the perspectives of people. For instance, one article shared the results from a JD Powers survey about preferred car technology, noting that drivers want safety features in new car technology. Another article cited a 2015 MIT Age Lab study that found only 31% of baby boomers would purchase a driverless vehicle. Public opinion research gives glimpses into what the

public wants, but findings should be contextualized to understand how the survey was administered, who participated, and how the questions were framed.

Conclusion

Mediators in the testbed, like newspaper journalists, engage in the work of assembly, imagination, and stabilization, while also reporting on testing activities. In the case of newspaper stories, these articles mediate the happenings of the testbed, while also engaging in their own testbed work. Local news stories provided analytical insight into how driverless vehicles are created in the testing of these vehicles by reporting on the technology and the significant events that have characterized the testbed. Between less regulation, increased testing programs, new jobs, and safety concerns, these articles capture glimpses into what the future might look like with driverless vehicles. This research finds that the work of newspapers in the tested accomplishes three key varieties of testbed work: assembling which actors are relevant and have authority, stabilizing/destabilizing relationships through reporting, and promoting resilient heuristic themes and values. Combined, this Chapter demonstrates that newspapers as mediators of sociotechnical assemblages play a critical role in articulating the playing field of the testbed and then determining and socializes what matters.

The newspaper articles share images of what future sociotechnical relationships may look like around autonomous vehicles. There were three different approaches to reporting on driverless vehicles that helped to convey the diversity of what is important in autonomous vehicle sociotechnical assemblages. These approaches include reporting on the technology as a gadget or business venture, reporting on the testbed as a place of

sociotechnical interactions, and reporting on autonomous vehicle futures more broadly. Across these different reporting structures, various potential users and non-users, as well as related stakeholders, were identified and reported on in the previous section, which is a helpful context for how people and their relationships to the technology are being defined and sorted out.

Newspapers draw attention to events and crystallize in the minds of the public what is important and what is not. What is newsworthy? Nisbet et al. (2003) found that an emerging technology's newspaper coverage was tied to the dramatization of the story. One way that drama works in autonomous vehicle storytelling is about the nature of autonomous vehicle development and research. Most new stories were about relevant and familiar topics to the public, related to new jobs, safety, or testing opportunities. New research advancements of the technology or testing outcomes are left out of the discussion. Secondly, autonomous vehicle car accidents get a lot of media attention because it is unique and interesting, unlike regular car accidents. For instance, the death of Elaine Herzberg is newsworthy and essential, but the event was made even more critical by the fact that it was the first pedestrian death caused by an autonomous vehicle. Because deaths by human-driven cars are the norm, these accidents might not get as much coverage as the autonomous vehicle accident. Thirdly, car accidents are counter to the narrative of improved road safety, a core part of the autonomous mobility discourse in Arizona. This kind of narrative conflict is especially appealing, as public safety as a core value impacts all readers.

To bring this back to the work of the testbed, it is important to reveal the ways in which these sociotechnical assemblages get formed, negotiated, and stabilized, as to raise

awareness of the hidden and nonhidden work that ends up structuring sociotechnical futures after technological design and before widespread adoption. News articles share and conduct imaginative work through their reporting through the documentation and dissemination of existing prototype assemblages or envisioned assemblages. For instance, in the story about Nuro's grocery delivery autonomous vehicle, a local resident commented about how the vehicle would help her get groceries when she is not feeling well, while another story used a quote from Waymo to talk about how the technology would help those with physical impairments gain more mobility. Another news story documented how Arizona test users of autonomous vehicles are using it to participate in activities like events and appointments differently. All three of these examples communicate to the public, by way of inclusion in the newspaper articles, about how sociotechnical relationships between people and technology can be structured.

The key social groups assembled with the technology typically involved a constellation of stakeholders, including government, law enforcement, pedestrians, and businesses. Businesses were consistent voices in the autonomous vehicle stories, where leaders provided their perspective on the technology or the company shared new opportunities for testing, sharing their own imaginations for how people and technology can work together. Governor Doug Ducey was also a major player in the news stories, as his quotes were used to engage in imaginative work about the innovative potential of driverless vehicles. Given his role as governor and his issue of executive orders, articles either centered on him and/or repeated quotes from his orders. Law enforcement and Waymo were often consulted as experts, while Elaine Herzberg's death brought the issue

of safety into the forefront, raising awareness about how the sociotechnical relationships established in the testbed may not be beneficial.

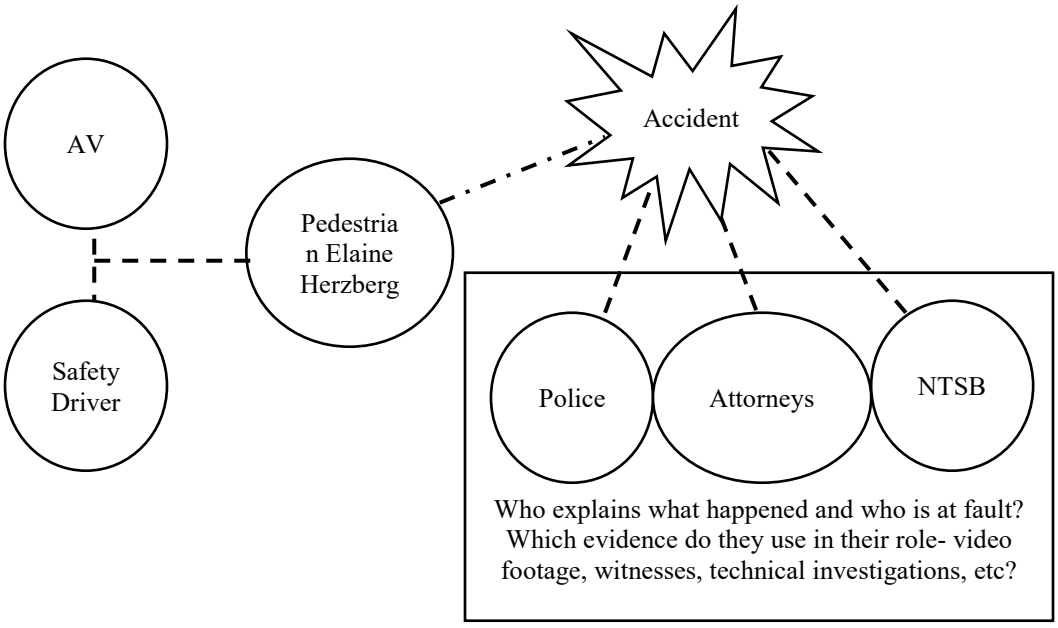
The testbed's narration occasionally articulated who future users and nonusers of the technology are or would be somewhere throughout the article, although this was often not the focus of the story. Within infrastructure conversations, light rail riders were identified as both users and nonusers of autonomous technologies. The young, elderly, and disabled were also mentioned as potential users. Through general statements about safety and roadway accidents, current drivers were imagined to be future users to transition from the current technology to a safer technology. This visioning for potential users often came from autonomous vehicle company employees or was captured through the reporting on survey research. Sometimes in the search for newsworthiness, unique and exciting voices get elevated. Most noteworthy was the elevation of a racecar driver's position, who spoke on behalf of middle America against autonomous vehicles.

The articles also do the work of assembly by organizing the relevant stakeholders and values through storytelling decision-making that determines who is relevant and who has power. How newspapers determine who has a voice and how they can use their voice matters deeply in the testbed, because how people and technology are supposed to interact and the implications of these interactions are still being sorted out. As an example, the results demonstrated that law enforcement was regularly connected to the technology by being portrayed as an accident responder and a determiner of fault in their reporting and investigations around the technology. The ways in which the role of law enforcement in the testbed is conveyed matters because fault in terms of the accident is still being figured out. I reconstructed the assemblages referenced in the Elaine Herzberg

stories mentioned earlier to demonstrate the relationships between technology and people, as well as people and people, are flexible, are still being sorted out (Figure 19). Initial news reporting relied on police representations of what happened, which leveraged video footage, and placed the blame squarely on safety driver Rafaela Vasquez. Then, weeks later an article shared that the National Transportation Safety Board investigation, instead, found that Uber also had disabled part of the braking technology. By then, the police accounts and released video footage of Vasquez had already circulated and imparted the narrative that the human-av relationship would have worked if only the driver had been paying attention. This stands at odds with the NTSB finding that suggest that the human-AV relationship could have worked if the technology had been properly configured.

Figure 19

Assembling Authority and Fault Through News Reporting



As such, there are potential power imbalances in these news articles. In the reporting of events, law enforcement, politicians, and companies have their voices elevated through newspapers. To a much smaller extent, public views are represented. Both the public and driverless vehicle technology are often spoken on behalf of other groups. Public voices gained traction through public opinion surveys or other stakeholders summarizing their interests. The technology gets inspected and reviewed in different ways, and as a result, someone shares their interpretation of the technology. This dynamic admittedly feels odd, as most people are used to a "driver" having a voice to be able to share their perspective on what happened. In this case, the "driver" technology has to be interrogated, read, and interpreted to be able to explain what happened.

News articles also promote resilient themes that leverage heuristics to make the argument salient. The news articles battled between two overarching themes: less regulation and more safety. The news articles convey the message that decreases in regulation increase innovation and jobs, as a byproduct of Governor Doug Ducey's political involvement and company testing in Arizona as a result. These articles also focused heavily on safety as a concern within the testbed and the future of driverless vehicles. Driverless vehicle crashes, and in particular, the Herzberg accident, became major talking points about the testbed. Both the loosening of regulations and the Tempe pedestrian's death became clarifying events in the development of autonomous vehicles, as they were anchoring points for most stories while also serving as a heuristic carrying the values of innovation and safety. Similar to Nisbet and Lewenstein (2002), which found biotechnology positively discussed in economic frames, autonomous vehicles were positively discussed when similar frames of job creation and innovation were applied.

However, the key statements related to innovation and economic opportunity were integrating into articles with competing narratives about unsafe technology

The newspaper articles also conduct inadvertently stabilizing or destabilizing work by normalizing or criticizing the happenings of the testbed through reporting. Newspaper stories have a performative aspect to them, as they socialize and frame conversations. With over 200 articles returned matching the search criteria, the activities of autonomous vehicle research, development, and testing institutions are socialized to the public. Although newspapers might not engage in out-right testing work, they are facilitative in the process of evaluation, in the way that news reporting serves as a medium to connect the public to information on formal testing activities. In the way that the newspapers tell the stories, these articles can guide the reader on what they should think about sociotechnical configurations. These stories share new insight and report on events tied to the technology, increasing awareness of both the technology and how it has been integrated into society thus far. Similar to Palm and Lnantz (2020), it is possible information dissemination on autonomous vehicles leads to increased adoption of the technology.

The news stories on autonomous vehicles straddle an interesting temporal line. They report on the past and status quo events while referencing a technology built for the future. In this way, the reporting on autonomous vehicle technology in Arizona becomes standard, as it is already a part of the local area's culture. The newspaper articles reviewed here were typically about events and advancements and were designed to be informative. In this space, there is less rumination on what this might mean for the future and more about perceived facts of life and immediate futures. In this way, the newspaper

articles suggest automated mobility futures are already here, or at least nearby. There are already power dynamics at play, the technology is already integrated into society, and real-world examples of technology gone both well and awry.

This investigation into newspaper articles and how they mediate and engage in testbed work demonstrates that journalistic enterprises must view themselves as being active participants in the construction of sociotechnical assemblages, not just passive reporters recalling events, especially when situated in a testbed environment. By not meaningfully attending to their role in shaping sociotechnical relationship building, journalists risk haphazardly establishing new assemblages that can assign relevancy, values, authority, and normalcy to the events, people, and technology within the testbed. Newspapers should take this role seriously as the mediator between sociotechnical activities/the testbed and the public, given that the sociotechnical structures set up by writers will translate to consumers of the articles.

CHAPTER 6
THE WORK OF THE PUBLIC

"I have never ridden in a driverless car. I don't feel I am [able] to say anything bad or good about this driver-less car." -Survey Participant

In this chapter, I engage with feedback from the public through survey research to understand the work that residents of the testbed do to imagine and assemble their own relationships with autonomous vehicles. By asking residents of the Phoenix metropolitan area about their familiarity, impressions, imaginations, and feedback about both the testbed and the technology, this research demonstrates how residents would like the design and implementation of autonomous vehicles to occur, while also demonstrating in what ways the public engages in their own internal testbed work. The chapter begins with a personal story to demonstrate how residents can continuously reassemble their sociotechnical relationships with the vehicle before diving into how survey research can be useful in both responsible innovation work and understanding perceptions related to technology in particular. I then review the results of the survey, including the public's feedback for designers and regulators, and their impressions about driverless futures and testbeds. I use this knowledge as a springboard to discuss the kinds of work that the public participates in. As evidenced in the survey results, the public conduct hidden internal work where they imagine how assemblages can be reconfigured with the technology, while some are unable to take this vision and understand their own potential futures with the technology. Additionally, this research finds the public has clear ideas

about the kind of testing and stabilization work that should be done to enable beneficial autonomous vehicle futures.

My Own Life in the Testbed

Before diving into the methodology and research of this chapter, I will share my experience as a member of the Phoenix metropolitan testbed to convey the numerous experiences that testbed inhabitants can have that shape their own relationship to the technology and interest in the technology's sociotechnical future. When I lived in Tempe, I felt bombarded with Uber's driverless vehicles on the road. It felt exciting to be a part of something that seemed like it was out of a science fiction novel and so consistent with the language of 'innovation' that my employer and current educational institution promoted and instilled within me. The testing felt excessive at times as I frequently witnessed a string of autonomous cars drive on the road with only their safety drivers in them. I even had the opportunity to ride in one as I ordered an Uber to take me to school when I was sick, watching the technology's imagery whirl as a computer screen showed me the technology's view of the world around it. The driving felt ordinary, which I later would reminisce was a good thing, given the numerous ways the technology could have failed. A driverless vehicle did fail within a year, as Elaine Herzberg became the first driverless vehicle pedestrian fatality less than a mile from where I lived.

Until that accident, I never had an instinctual fear of being a pedestrian while companies tested these vehicles near me. A little over a year later, I saw Imagry cars driving on the street with the driver not touching the steering wheel. By then, I learned to police myself as I walked to work, avoiding the occasional jaywalking and making sure I

stayed on clear, visible paths. I am an example of someone torn between firstly, excitement from building an innovative future with mobility options, and secondly, fear of failure within the driverless vehicle sociotechnical system. My localized experiences shaped my perception of the technology and how I planned to interact with these testing situations going forward.

Existing Public Opinion Research on Emerging Technologies

Understanding local public perceptions is an essential step in comprehending the current realities and futures of the people who live in the testbed. Other members of the public might have similar experiences as listed previously, while others might have no experiences. Across those who have interacted with the technology and those who have not, there is a range of opinions existing for people related to the driverless vehicle testbed and their own personal driverless futures. Capturing this multiplicity of views will help complete the cross-sectional profile of opinions and visions for the future of those inhabiting the testbed.

The literature on responsible innovation suggests public opinion research is useful and necessary in ensuring socially responsible technological development and implementation. Engaging the public earlier in technological developments, referred to as "upstream engagement," can improve the ultimate research and development of a technology to be more in line with societal needs, benefiting both the technological and social (Wilsdon & Willis, 2004). Public opinion research can also be a part of a communication and early warning strategy, as outlined in the "mid-level methodology" of "real-time technology assessment" (Guston & Sarewitz, 2002, p. 100). Assessing public attitudes about technological developments and media portrayals of it can help

analysts understand the public knowledge, opinions, attitudes, and risk judgments of members in the lay public. This kind of research can improve the trajectory of a technology and "encourage the development of more open process of technological co-production" (Guston & Sarewitz, 2002, p. 103). This endeavor helps identify any current gaps between technological development and societal needs by analyzing public opinion alongside stakeholder perspectives and newspaper portrayals. This research will demonstrate harmonious and discordant views on both the current iteration of the testbed and the future the testbed promotes. Using this knowledge, this chapter will provide practical information about the public's needs and interests to improve responsible innovation in both the testbed and technology, while simultaneously providing insight into the kinds of work that the public does and does not do in the testbed, which can influence their present lived experiences and futures.

Existing research, both internally to this work and externally, demonstrates some trends around driverless vehicle opinions and how people envision associated sociotechnical relationships. For example, the survey of American perception of connected and autonomous cars from Bansal and Kockelman (2017) asked participants how much they would want to pay for features related to the different levels of autonomation of vehicles and how interested they were in that technology. More general framing questions from this survey found that 54.4% of respondents felt driverless cars would be a useful improvement in transportation technology and that 58.4% were scared of driverless vehicles. Internationally, Cunningham et al. (2019) surveyed Australian and New Zealand members of the public about driverless cars, using a similarly structured willingness-to-pay approach. Two perceived benefits of driverless vehicles (safety and

increased mobility for people with impairments) were predictive of their willingness to pay for driverless cars. This approach oriented people to think about their relationship to the technology as a product versus a technology that can enable different kinds of lived experiences.

The public opinion of a driverless vehicle testbed is something entirely different from the public opinion of an emerging technology because the testbed is a place where the technical and social are formed and negotiated to created lived experiences and futures. Penmetsa et al. (2019) started to unpack what it means to live in a testbed by linking autonomous vehicle perception with exposure to the technology in their analysis of survey data collected by a Pittsburgh organization that supports safe mobility. Their research suggests those who have had interactions with driverless vehicles had higher safety expectations for the technology. Other results from the survey demonstrate a majority of the respondents (70%) views that a regulatory body should develop regulations around driverless vehicle testing and that on a 1 (*very unsafe*) - 5 (*very safe*) scale of safety, 57% say they feel a 4 or 5 using Pittsburgh's streets with autonomous vehicles. This demonstrates the public not only has expectations about the emerging technology, but also expectations around how its testbed should be regulated and how that might impact their safety.

The newspaper analysis from Chapter 5 revealed public opinion polls found people are a mix between fearful and excited about the technology, and subsequently translated this information to the public. One survey conducted by AAA cited in a 2016 news article shared 75% of drivers had fears about using driverless vehicles. Another article, "Goodbye to the Great American Road Trip," cited a poll by Consumer

Technology Associated, which reported 75% of U.S. drivers are excited about driverless vehicles and that 79% feel like these vehicles will be a safer alternative to human drivers. Citing a 2015 MIT Age Lab study, a news story about the adoption of driverless vehicles revealed that 70% of baby boomers would test a driverless vehicle, but only 31% would own one. Similarly, the newspaper analysis revealed Waymo spoke on behalf of the public based on their public engagement experience, stating, "Over the past two years, we've found Arizonans to be welcoming and excited by the potential of this technology to make our roads safer" (Randazzo 2019). Assembled, all of this existing research begins to paint a very discordant picture of public acceptance and use.

This chapter is a departure from thinking about experts, institutions, and journalists who are all actively engaged in the autonomous vehicle testbed work as a fact of their purpose or career. Instead, this chapter focuses on the lived experiences and expectations of participants living in the testbed, who end up engaging in their own hidden testbed work as they are confronted with images, stories, conversations, and visible representations of the technology. Public opinions are a valuable source of information related to understanding the Arizona driverless vehicle testbed, as it will inform the research about their testbed work and how testbed work can be better structured to meet their needs.

Members of the public will eventually become users or nonusers while also maintaining their other identities related to their job, familial roles, and interests. As residents of the testbed, they may or may not know about driverless vehicles or driverless vehicle testing. They may have lived experiences tied to driverless vehicles, heard or read about this technology, and even dreamed about what their future might look like living

with them. Documenting and analyzing these perspectives will illuminate how people experience the testbed and envision the future in ways that will further the conversation on how the testbed develops people and their futures.

Surveying the Testbed Inhabitants

I use a survey methodology to understand public opinion, imaginations, needs, and feedback to gather the information that is helpful to better create autonomous vehicle sociotechnical assemblages and informative to how the public does work in the testbed to construct such assemblages. In particular, for this research, I survey Phoenix metropolitan area residents to document their exposure to driverless vehicles, recognize their imaginations for the future, and solicit important policy and technical factors they would like considered in the design and implementation of the technology. The survey also asked about their emotions and perceived impacts tied to living in a driverless vehicle testbed.

I designed the survey to gain a variety of insights into how people interact and perceive autonomous vehicle futures and the Arizona autonomous vehicle testbed. Over the course of twenty-four questions, the instrument's structure guided participants to first think about their exposure to driverless vehicles and then share their thoughts about driverless cars before providing feedback on the testbed. This survey provided participants ample opportunities to share their ideas in a free-response format to prevent the study from overly framing relevant considerations for participants. Indeed, the final question was the only part of the survey that included a select all question format where participants could select perceived risks, benefits, and impacts tied to driverless vehicle testing on public streets.

The survey was administered through SurveyMonkey Audience to people in the Phoenix-Mesa-Scottsdale metropolitan area from May 27 through June 4, 2020. Survey Monkey Audience recruits participants for the survey from a pool of people who are have volunteered to take surveys online. The average completion rate of the survey was 76%, resulting in a total of 431 responses, with 429 answers suitable for inclusion in the data set.

Table 9

Survey Demographics

		Frequency	Percentage	Valid Percentage
Gender	Female	268	62.5	62.5
	Male	161	37.5	37.5
	Total	429	100.0	100.0
Age	18-29	18	4.2	4.2
	30-44	39	9.1	9.1
	45-60	83	19.3	19.3
	> 60	289	67.4	67.4
	Total	429	100.0	100.0
Highest Education Level	Less than high school degree	1	0.2	0.2
	High school degree or equivalent (e.g., GED)	34	7.9	7.9
	Some college but no degree	80	18.7	18.6
	Associate degree	56	13.1	13.1
	Bachelor's degree	123	28.7	28.7
	Graduate degree	134	31.3	31.2
	(Missing)	1	0.2	
	Total	429	100.0	100.0

Survey respondents were generally older, with 67.4% being over the age of 60 and another 19.4% being age 45 to 60 (see Table 9). Similarly, when asked about their primary employment status, 46.5% indicated they were retired, while 34.6% were

employed full time. Participants were college-educated, with approximately 60% of respondents having either a bachelor's degree or a graduate degree. Women were the largest gender demographic, making up 62.5% of participants. Although women, those college-educated, and those over 60 years old were overrepresented in the survey, their feedback provides useful insight into their experiences. Indeed, with the elderly identified as a potential user group by autonomous vehicle groups, these survey results provide a key opportunity to read feedback on a technology for whom they are imagined as potential users. The information collected provides insight into the local public's general knowledge and experience with driverless vehicles, their expectations and hopes around these technologies, and their perceptions of impacts related to driverless vehicle testing on public streets.

Table 10

Did You Know Driverless Vehicles Are Being Tested on Phoenix Metropolitan Public Streets?

		Frequency	Percentage	Valid Percentage
Valid	Yes	359	83.7	83.7
	No	55	12.8	12.8
	Uncertain	15	3.5	3.5
	Total	429	100.0	100.0

Survey respondents were generally aware of driverless vehicles and their testing, although less than half had ever seen the technology, and fewer had tested a driverless car themselves. Nearly 84% of participants indicated they knew driverless vehicle testing was occurring on Phoenix metropolitan streets (see Table 10). Although this is a high percentage, it also suggests about 1 out of 6 respondents did not know definitively that

these technologies were being tested on public streets. About 47% of participants have seen a driverless vehicle on the streets of the Phoenix metropolitan area, while another 7.2% have seen a driverless vehicle, but not in the metro area (see Table 11). The survey asked participants to share the locations of where they had seen a driverless vehicle. The Arizona locations included Chandler, Ahwatukee, Peoria, Phoenix, Scottsdale, Tempe, Gilbert, Surprise, and Mesa. California locations include San Jose, Santa Clara, San Mateo, Menlo Park, and the general area of northern California. Participants also named Chicago and Copenhagen as two other cities where they had seen a driverless vehicle. Only 2.6% of participants have ridden in a driverless vehicle (see Table 12).

Table 11

Have You Seen a Driverless Vehicle on the Streets of the Phoenix Metropolitan Area?

		Frequency	Percentage	Valid Percentage
Valid	Yes, I have seen a driverless vehicle on the streets of the Phoenix metropolitan area.	203	47.3	47.3
	No, but I have seen a driverless vehicle somewhere else besides on the streets of the Phoenix metropolitan area.	31	7.2	7.2
	No, I have never seen a driverless vehicle.	148	34.5	34.5
	I am uncertain if I have ever seen a driverless vehicle.	47	11.0	11.0
	Total	429	100.0	100.0

The survey revealed driverless car technology did not take up a large amount of their mental energy or social conversations. When asked how often they think about driverless vehicles, 41.8% of survey respondents indicated they never think about the

technology (see Table 13). Similarly, 47.2% have never talked about driverless vehicles with their family, friends, or coworkers.

Table 12

Have You Ridden in a Driverless Vehicle?

		Frequency	Percentage	Valid Percentage
Valid	Yes	11	2.6	2.6
	No	415	96.7	96.7
	Uncertain	3	0.7	0.7
	Total	429	100.0	100.0

Table 13

How Often Do You Think About Driverless Vehicles?

		Frequency	Percentage	Valid Percentage
Valid	Daily	10	2.3	2.3
	Weekly	39	9.1	9.1
	Monthly	77	17.9	18.0
	Quarterly	87	20.3	20.3
	Yearly	36	8.4	8.4
	Never	179	41.7	41.8
	Total	428	99.8	100.0
Missing	(Missing)	1	0.2	
Total		429	100.0	

Understanding where people get their information can be helpful in comprehending who is sharping the discourse on a topic and what kinds of values they might convey through their work. As explored in Chapter 5, media frames and frequency can impact the attention paid to emerging technology and their personal perception of it. Over 45% of survey respondents primarily learned the most about driverless vehicles from local news stories, while another 21% learned about driverless vehicles through

national news stories. Consistent with hearing about news stories, Figure 20 demonstrates through a word cloud how much respondents are attuned to the accident where Elaine Herzberg was killed. A smaller subset of people (9.3%) learned the most about driverless cars from seeing them on the road. For 2.8% of people, this survey was their first exposure to driverless vehicles (see Table 14).

Figure 20

Word Cloud of Responses from the Question "What have you heard, seen, or read about driverless vehicles in Arizona?"

Table 14

Where Have You Learned the Most About Driverless Vehicles?

		Frequency	Percentage	Valid Percentage
Valid	By riding in a driverless vehicle	5	1.2	1.2
	By seeing driverless vehicles on the roads	40	9.3	9.3
	I never knew about driverless vehicles before taking this survey.	12	2.8	2.8
	Other (please specify)	22	5.1	5.1
	Through conversations with others	17	4.0	4.0
	Through driverless vehicle company advertising	9	2.1	2.1
	Through local news stories	194	45.2	45.2
	Through local or community events	3	0.7	0.7
	Through my education and schooling	3	0.7	0.7
	Through national news stories	90	21.0	21.0
	Through nonfiction or fiction books	1	0.2	0.2
	Through social media	19	4.4	4.4
	Through state or local government materials or communications	5	1.2	1.2
	Through television shows or movies	9	2.1	2.1
	Total	429	100.0	100.0

Feedback for Designers

The next section of the survey asked participants to consider what kinds of issues driverless vehicle designers and regulators should consider. To start, participants gave feedback about what they would like the designers of driverless vehicles to consider while building the technology. The most common responses included demands for safety improvements, options for the technology to pass back to a human driver, comfort, climate, and usage for people with different mobility challenges, which are a part of larger conversations about risk perception, comprehension, and accountability with black box technologies, and user-centered design.

To be clear, a minority of respondents made it very apparent they would like driverless vehicle development stopped. The most significant negative responses included a recommendation to developers "Not to build them at all they are unsafe vehicles to have on our streets and highways period." Another survey respondent mused they would like developers to think about, "How they will be BRAINWASHING US to thinking we like giving our freedom up!" and then mused about the driverless vehicle itself by saying, they "hope it is humane, and impervious to gunshot!" These two responses are examples of the public's concern about safety and personal liberty, but they have two notably different approaches. One views their development as inevitable, and the other is calling for an end to driverless vehicle development.

Overall, most respondents wanted safety considered in the design process. Although many responses were calls for safety more broadly, other respondents did provide details about what safety might look like for them. In some answers, safety considerations took the form of specific technological indicators for safety, while others focused on the safety for passengers, the safety for pedestrians, or both. Technical design specifications included making sure that brakes worked, there were impact avoidance technologies, and there were "built-in fail-safe options." Another respondent shared they wanted safety communication tools, such as "On Star type assistance. Alerts. Trip updates. Emergency alarms and procedures." These are all specific features survey participants wanted to be engineered into the car.

Others were less concerned about how to make it safe, but rather for whom to make it safe. Survey participants had different immediate perceptions about whom safety designers should consider in driverless vehicle technology development. One person only

thought about the "Safety for all drivers on the road with them," while another suggested the designers think about "not killing pedestrians." Several respondents mentioned considerations for multiple people were necessary for safe designs. The design for these users must be comprehensive, as one respondent wanted designers to know that "Safety of passengers and other vehicles and pedestrians must be the number one priority." Several even wanted safety considerations to expand to animals, as was the case in this person's recollection of their interactions with driverless vehicles to date: "Don't run anyone over. Especially be careful of my cat, since your vehicles like to drive through our apartment complex at night."

Responses indicated a strong need for personal control of the technology, as some answers exhibited a clear communication for an option for the driver to resume control of the vehicle to ensure safety while also increasing flexibility for the driver. One response indicated, "Driverless vehicles resonate lack of control. Perhaps even though it is driverless, arrange for the passenger to be able to sit in the driver's seat and take over control if needed." This respondent spoke to the importance of appealing to potential users' need for control to increase reassurance to enable driverless vehicle adoption. Part of this interest in control might stem from people's concern about unpredictable situations and other non-driverless vehicles on the road. Respondents shared a driver should have the opportunity to take control of the vehicle during an emergency and that perhaps there needs to be some design thinking about what happens when the passenger no longer wants to travel to a preplanned route. These responses speak to a lack of trust in technology, the human need for control, and the desire for flexibility. Personal control over technology is not unique to vehicle technology in particular. Indeed, "personal

control" as a concept can be linked to concepts of risk denial broadly, where people view themselves as being less at risk when they do something versus when others might do it (Sjoberg, 2000).

Stemming from concerns about control, a smaller, but related, thread across responses revolved around the arrogance of programming a vehicle and subsequently determining morality. Concerns about programming morality were communicated in several different ways, ranging from derision for thinking that artificial intelligence could be more advance than humans to concerns about fallible humans programming life and death decisions into a vehicle. One participant was concerned about the tension between robots and humans, with their request "to not let the AI outsmart human beings." Some respondents took the opposite stance and believed that a driverless vehicle would never be superior to a human driver. These responses included statements like "Artificial intelligence will never be as good as common sense," and "don't rely on technology only, the human brain can't be replaced." Two responses, in particular, questioned the developers of the technology to program driverless vehicles. One response wanted the developers to think about the "Moral implications of allowing life and death decisions up to a computer," while another response bemoaned that "Driverless cars will never be safe due to human error in the making of the cars." Such responses demonstrate a clear perspective that technology is inferior to humans, either due to its own technological limitations or its programming by other humans. These kinds of concerns are reminiscent of Noble (2018), who found the programming behind search engines reinforces racism. When cars are programming to make driving decisions, they are also programmed to make social decisions. With driverless vehicle technology appearing to be a "black box"

made even darker and denser through machine learning, neural networks, and deep learning (Castelvecchi, 2016), this makes trust in the technology and accountability difficult.

Another ethical consideration is accessibility, which was a predominant theme across responses. Financial accessibility was something that some respondents wanted the designers to consider, making the vehicle less cost-prohibitive. One user wanted the developers to keep "all people, poor, middle class, [and] rich" in mind as they build the technology. Many others were interested in making sure the driverless vehicles are designed equitably to accommodate specific bodily needs to serve a greater variety of people to increase their mobility. Respondents wanted the designers to think about building the technology for "taller people," "disabled people," and the elderly. One participant summed up a potential group advantage for those with mental and physical challenges, by stating "Ease of access for all individuals. I can see elderly and those with physical challenges using this technology as well as those with neuroses that prevent them from operating a vehicle." For these respondents, if designed right with the correct intentionality, driverless vehicles could be accessible and equitable across a range of people.

In particular, there was a lot of feedback about design strategies for the elderly. With 67.4% of participants being over the age of 60, some people spoke to their current experiences of being elderly, while younger respondents also imagined their future of growing older. Some participants shared their particular accessibility concerns, with one respondent stating, "I am a senior. I will have to give up driving unassisted in the near future and still need to travel in town. I think they need to include a program that drives

to appointments on the least congested roads." In this example, the design of the driverless vehicle should help the user meet their driving location needs. Other participants described the physical specifications needed for the car. One respondent stated, "Vehicles need to have easy egress into the vehicle and be comfortable for older users who can become disoriented in closed spaces. Headroom will relieve claustrophobic and anxiety affected riders." This statement reveals that the physical design of the vehicle will help with physical accessibility to get into the car, while also creating the condition for positive mental health experiences within the vehicle. These responses demonstrate the way that technology designed in particular ways can result in different uses and lived experiences for people, as was the case of women's alienation from cockpit design in Weber (1997) or the commentary that airline designs might not create comfortable experiences for taller or larger people (Rose & Blume, 2003).

In addition to creating a physical environment that is accessible to the elderly, while also have driving functions that are useful to them, several participants also wanted the developers to make sure there was a low barrier to use. For instance, one respondent wanted designers to think about "How they can be used to improve the quality of life for seniors, especially those who no longer drive. This means they would have to be very user friendly." Another respondent wanted developers to consider, "The ease of getting in and out of the vehicle; readability/understandability of instructions once vehicle arrives; Ease of scheduling ride online or otherwise." These responses suggest although it is vital to design the vehicle to help users physically access the car, it is also essential for the vehicle to be intuitive, with easy instructions for cognitive accessibility. The way in

which technology is implemented will impact whether or not people can access the technology easily or effectively.

Climate was another well-communicated design consideration. Survey responses include calls to make the driverless vehicles have "zero emissions" and be either "environmentally neutral or better for climate change." Another respondent was more specific, suggesting they would "like developers to work on designing driverless vehicles powered by non-carbon-based fuels," while another suggested, "they should be electric." These participants saw driverless vehicles as an opportunity to improve climate and energy-friendly transportation.

Comfort was a reoccurring motif in the design suggestions. Participants wanted a series of technology tools to help them be more comfortable while being a passenger in a driverless vehicle. One participant wanted designers to think about entertainment options like karaoke and games, as well as options for sleeping. Other participants wanted developers to make driverless vehicles not just a technology for travel, but also a technology that facilitates working. One survey participant responded with the following request for driverless transportation: "wireless access so I can work while being driven to the destination, a screen/monitor that I can sync to from my phone or tablet." Similarly, another respondent stated they wanted "room for me to work while traveling with access to my technology and use of power for maintaining my devices in a charged state." These suggestions demonstrate some respondents envision how their lived experiences within a vehicle could change with this emerging technology.

Although survey participants were multifaceted in their driverless vehicle design concerns, these responses mostly demonstrate concern for safety, control, ethics,

accessibility, climate, and new kinds of vehicle experiences. Participants appeared to be influenced by their own lived experiences and prior experience using non-driverless vehicles. Given the substantial interest in safety and mentions of pedestrian safety, it might also be possible that these responses are tied to significant current events around driverless vehicle testing, like the death of Elaine Herzberg. Regardless, participants leveraged their knowledge and imaginations to envision what sorts of designs they would like attended to in order to improve automated mobility futures.

Feedback for Regulators

Survey participants also had varied thoughts about the government's role and need to regulate driverless vehicle technology. Similar to considerations for the technology developers, safety continued to be the most prominent theme throughout the responses (See Figure 21). Other participants also continued to indicate they wanted the technology stopped, some way to manage human drivers on the road, and intentional ethics planning. Additional themes arose that differed from designer considerations, as well. Participants wanted less bureaucracy, revisited and reviewed rules, job retraining opportunities, and updated infrastructure.

Some survey respondents felt the government should have a minimal role in regulation. Two participants had strong feelings that decisions should be left up to technical experts, with one person advising, "When developing regulation, listen strongly to the manufacturers," with another demanding, "Keep government leaders and personnel out of the equation. Technology personnel should be at the forefront of this type of innovation." These responses indicate deference to engineers and the mistrust of governmental leaders in innovation.

Figure 21

Word Cloud of Free Responses Tied to Suggestions on Regulation the Technology

However, many others felt the government had different roles to play in the regulation of driverless vehicles. Consistent with responses related to the considerations for driverless vehicle developers, a handful of people continue to want driverless vehicles stopped before they come to market. The remaining answers differed on what they felt was the most critical role for the government.

Safety was the most commonly requested consideration for government leaders to consider while regulating driverless vehicle technology. Although many respondents just wrote the word “safety” and others suggesting “passenger safety,” another took a more holistic approach to safety by stating, “Safety for those who would potentially use the technology as well as the public who may be impacted by having driverless vehicles in

their communities." These responses indicate respondents perceive the government has a responsibility to protect the public.

The safety conversation would sometimes transition into a broader discussion related to ethics and responsibility. Two comments speak clearly to the relationship between safety considerations and ethical considerations. One participant remarked, "However, there will come a time where the driverless vehicle will have to make a decision as to whose life is more important. The government needs to provide guidance as to what those parameters should be." This participant believes that the government should be instrumental in dictating whose life to save in the case of an accident, not leaving it up to the technology or technical designer.

Several people called for proof, evidence, research, and transparency related to driverless vehicle outcomes to help advance both safety and innovation. One person wanted proof by being able to see the vehicle to human pass back through video materials, by wanting "Proof of a human that can take control at any time and proof of a working video." Another person wanted transparency around data to demonstrate success compared to human drivers by stating they needed "transparency on successes, failures, injuries, and deaths . . . and compared to auto statistics." In this theme, transparency, research, and proof would communicate to the public if the technology works, and then people could determine whether or not they were comfortable with the technology.

Survey respondents also communicated that government leaders should revisit existing rules related to process and liability. One person hoped that government leaders would reconsider "who should be allowed to operate a vehicle, including those who would not otherwise be qualified as licensed drivers (younger children, vision-impaired

or physically challenged people who might not be permitted to obtain a driver's license today)." Another participant hoped that the speed limits could be increased, given that the technology should be able to drive more safely at higher speeds. Another participant took the opposite stance by wanting to make sure that the rules did not change too much, in case someone had to resume control of the vehicle for whatever reason. To change the rules would mean the technology had to be perfect, without a need for human control or intervention. Infrequently, this thread of responsibility, regulations, and safety bled over into other consideration suggestions, characterized more in the format of liability, and ensuring clear lines of fault related to the legal and insurance system

Several survey respondents strongly articulated views that job retraining and education would be a critical consideration of the government. One participant stated:

> This technology will have a very big impact on transportation services. While they expand the use of driverless vehicles, I would like the government to ensure that people who may lose their jobs will have support transitioning to a new line of work.

Another person similarly questioned, "Also, what are they going to do with all the people this technology will put out of work? From gas station food marts to oil well drillers to truck drivers to traffic light repairmen etc." This response asks governmental leaders to consider an entire system built around the maintenance and continued use of human-driven vehicles, and in particular, those who may be professionally impacted by such a shift.

System concerns arose in other considerations besides job retraining. A couple of participants asked themselves how these technologies would exist alongside other human

drivers. Participants were concerned about the relationship between conventional, human-driven vehicles and driverless vehicles. For instance, one response ridiculed some Arizona residents when saying, “All the fool drivers in AZ and elsewhere who think it would be ‘cute’ to try to force these driverless vehicles off the road. You just can’t program for lack of common sense.” Other participants were merely concerned about how a human driver would interact with a driverless vehicle when negotiating the road together.

Many people wanted the government to think about regulation as it related to broader infrastructure and system concerns, although there was variance in the type of infrastructure considerations. A couple of respondents wanted government leaders to think about making the entire city more technologically sophisticated in the format of a smart city. One person wanted regulators to think about including “smart city and infrastructure needs in the plans and proposals” and that it would have “to be a holistic view of addressing how people commute, travel, and get from A to B—the vehicle is just one pawn, and advancements in only one pawn don’t allow the whole system to evolve.” Another respondent thought about the entire U.S. transportation system and wanted leaders to think about “how to ensure integration into and between communities and states.” Social infrastructure was also considered, with one person indicating they would like it if government leaders could be thoughtful related to emergency response needs. These responses saw driverless vehicles as a systematic shift that requires appropriate coordination and thoughtfulness.

Driverless Futures

The survey prompted participants to think about how driverless vehicles might impact their lives in the future. When asked if they agree with the statement, "I would enjoy using a driverless vehicle in the future," the responses were split between the agree (50.6%) and disagree responses (49.4%; see Table 15). Participants also responded with levels of agreement to the following statement "Driverless vehicles will be designed in a way that improves my quality of life." Responses were once again split between the disagree (46.1%) and agree (53.9%) answer choices (see Table 12).

Table 15

Please Indicate How Much You Agree or Disagree with the Following Statement: "I Would Enjoy Using a Driverless Vehicle in the Future."

		Frequency	Percentage	Valid Percentage
Valid	Strongly agree	54	12.6	12.7
	Agree	161	37.5	37.9
	Disagree	106	24.7	24.9
	Strongly disagree	104	24.2	24.5
	Total	425	99.1	100.0
Missing	(Missing)	4	0.9	
Total		429	100.0	

A free-response question encouraged participants to think about in what ways driverless vehicles might impact their lives in the future. Overwhelmingly, most respondents fell into one of three groups of answers: no impact or uncertainty, an advantage when aging, and safety. Conceptions of ownership clouded some respondents' perceptions of driverless vehicle impacts, where some participants felt the technology would not impact them if they did not own or drive the technology. This is at odds with

the larger news stories from the analysis in the preceding chapter that discussed the death of Elaine Herzberg. One respondent commented, “Not at all. Will not use one for my travels,” and another stated, “I do not think they will impact my life at all. I am 72 and have no intention of ever riding in a driverless vehicle.” These kinds of visions demonstrate imaginations of the future are fueled by the technology’s use or nonuse versus a broader understanding of the total impacts of having a technology operating in society. For instance, this kind of response might preclude someone from thinking that the vehicles might have an impact on pedestrian safety, climate, or the economy. Many responses also claimed they were uncertain about driverless vehicle future impacts. Given the extensive testing and development occurring in this community, driverless vehicles have probably already had some sort of impact on their life.

Table 16

Please Indicate How Much You Agree or Disagree with the Following Statement: “Driverless Vehicles Will Be Designed in a Way That Improves My Quality of Life.”

		Frequency	Percentage	Valid Percentage
Valid	Strongly agree	52	12.1	12.2
	Agree	178	41.5	41.7
	Disagree	126	29.4	29.5
	Strongly disagree	71	16.6	16.6
	Total	427	99.5	100.0
Missing	(Missing)	2	0.5	
Total		429	100.0	

Some participant responses appeared to be influenced by their current experience and needs, informed by their personal sense of aging, and imagined that the technology would be designed in a way that would help them. One participant very eloquently stated

driverless vehicles would impact them "very positively. As a Boomer, I cherish the thought that these cars will extend my driving--freedom--time beyond the age when I must stop driving. Eventually, they will mean fewer accidents." Many others invoked their age, or future age, in wanting this technology accessible to them.

A few responses mentioned safety concerns related to driverless vehicles. For those that voiced concerns about safety, some had high levels of fear and anxiety attached to it. For example, one person imagined that "I believe I'll be in an accident at some point caused by a driverless vehicle, and I hope I survive without serious injury." Another confessed, "They scare me, and I don't want them around me as I drive on the roads. Very unsafe vehicles to be on our roads and highways of our country of America." These examples demonstrate some members of the public already see themselves as a potential casualty of the technology.

These visions of the future stand in contrast to the responses gained related to thinking about regulation and design improvements. Although most respondents in both the development and regulatory space called for safety considerations, when asked to envision their future, safety was no longer the primary concern. Absent from most responses was emotion, either anxiety or excitement, as many people saw no impact for themselves or were uncertain about the effects in their future. Similarly, many more people thought about how driverless vehicles could help them as they age or confront disability, but these considerations were less frequent in requests for recommendations for developers and regulators. This could represent a disconnect between generally thinking about driverless vehicles, the act of making recommendations, and thinking about driverless cars in a personally contextualized future.

Driverless Vehicle Testing on Public Streets

After establishing how familiar they are with driverless vehicles and then providing feedback about future driverless vehicle designs, survey participants answered a series of questions to help them reflect on the potential impacts of driverless vehicle testing on public streets. Participants had numerous emotions about driverless vehicle testing and lacked agreement about whether or not the driverless vehicle testing benefits were worth the risks.

The driverless vehicle testing portion of the survey started by asking people to think about how they feel living in a metropolitan area where driverless vehicles are being tested on public streets, making the study feel personal and localized. A series of emotions were listed, with the option to provide alternative emotions. Participants could select as many emotions as they felt about living in a driverless vehicle test area. The top three chosen feelings were intrigued (39.9%), nervous (30.8%), and neutral (27.3%). Although previous free responses indicated safety was the primary concern for developers and regulators to think about, the feeling of "unsafe" was only selected by 20.8% of participants.

Then, survey participants indicated how much risk or benefit they perceived in allowing driverless vehicle testing on Phoenix metropolitan streets. Sixty-one percent said there was a medium or large risk, and 57.8% indicated a medium or large benefit. The technology's detractors were more prevalent than the ardent supports, with only 3.5% indicating there is no risk in allowing testing, while 19.6% found there to be no benefit (see Tables 17 and 18).

Table 17

How Much Risk Do You Think There Is in Allowing Driverless Vehicle Testing on Phoenix Metropolitan Public Streets?

		Frequency	Percentage	Valid Percentage
Valid	No risk	15	3.5	3.5
	Small risk	152	35.4	35.4
	Medium risk	152	35.4	35.4
	Large risk	110	25.6	25.6
	Total	429	100.0	100.0

Table 18

How Much Benefit Do You Think There Is in Allowing Driverless Vehicle Testing on Phoenix Metropolitan Public Streets?

		Frequency	Percentage	Valid Percentage
Valid	No benefit	84	19.6	19.6
	Small benefit	97	22.6	22.6
	Medium benefit	132	30.8	30.8
	Large benefit	116	27.0	27.0
	Total	429	100.0	100.0

Table 19

Please Indicate How Much You Agree or Disagree with the Following Statement: "The Benefit of Living in an Area with Driverless Vehicle Testing on Public Streets is Worth the Risk."

		Frequency	Percentage	Valid Percentage
Valid	Strongly agree	65	15.2	15.2
	Agree	189	44.1	44.1
	Disagree	99	23.1	23.1
	Strongly disagree	76	17.7	17.7
	Total	429	100.0	100.0

Participants weighed these risks and benefits against one another. Fifty-nine percent of survey respondents agreed the benefit of living in an area with driverless vehicle testing on public streets is worth the risk. Of those who were "intrigued," 14% felt the benefit was not worth the risk. There were several areas of potential internal dissonance. Of the people who felt unsafe, 11.2% felt the benefit was worth the risk of living in the testbed. Of those who felt nervous, 32.6% felt it was worth the risk.

Survey participants shared recommendations they would provide to Arizona leaders about driverless vehicle testing in Arizona. The suggestions varied but coalesced around a few themes touching on governmental roles, the technology's future, and testing parameters. People had different views about the regulation of testing driverless vehicles on public streets, which is most apparent in the comparison between those who outright want leaders to stop the technology or those who outright call for testing to continue. Several survey respondents took firm regulatory stances and recommended prohibiting driverless vehicle testing, while others advocated for very little or less regulation. For those that wanted driverless vehicle testing stopped, the response ranged from outright calls to "ban it" and "stop them." polite statements of "please reconsider," and more passionate calls to "stay the hell off the streets." For others, their primary recommendation was to continue the testing to support innovation and maintain momentum. Suggestions like these included statements to "Keep moving forward with allowing this technology to evolve" and "Continue to welcome the new technology."

Some recommendations demonstrated a lack of trust in politicians. One survey respondent claimed they "Do not trust AZ leaders to make good decisions [on their] behalf." Another recommendation suggested an alternative source of leadership by

stating, “Politician(s) are not qualified to make decisions on the implementation of driverless vehicles. [Use] Engineers and legal experts in liability & risk.” Another respondent wanted the power of decision-making in the hands of the citizens, lessening the role of Arizona leaders. The recommendation is as follows: “Ask the citizenry if they want to permit this and follow their decision; definitely advise everyone which streets will be used so those who do not want to possibly encounter the driverless vehicles can avoid those streets on the testing days.” These highlight varying beliefs about the role of the government, expertise, and how democratic decisions should be made.

Many respondents shared what they thought would be acceptable testing conditions. Some suggested considerations included the time of day, as well as the weather, location, and density of the area. Several respondents articulated strategies to create safer environments for testing, including calling for testing to “careful and cautious.” For instance, one respondent wanted to make sure that driverless vehicle testing did not occur in school zones. Other suggestions like this included recommendations for testing in areas with the fewest number of people, at night when fewer people were on the road and avoiding early morning traffic rushes, and on test tracks instead of public streets.

Other participants suggested testing parameters that would more fully assess their readiness. These recommendations included testing the vehicles in flood-prone areas, the mountains, and areas where they would ideally be used in conditions similar to regular traffic. One participant suggested, “Use different times of day to get a real conclusion,” while another similarly stated, “Test in all kinds of weather and all different driving situations (i.e., lots of traffic/no traffic, side streets/highways, etc.” These responses

suggest testing should continue full steam ahead in as many ways as possible to make sure they are fully ready for widespread adoption. However, a handful of respondents took a more metered approach between the two stances, suggesting starting testing at a cautious, small scale to enhance safety and then ramp up to larger-scale testing on public roads. For instance, one recommendation included, "Start with least risk type uses, then phase in riskier testing like crowded city streets." The difference between these two sets of responses demonstrates a different comfort level in testing emerging technology in public spaces.

Survey participants recommended an increase in marketing and communications related to testing locations and parameters. For some, this meant painting driverless vehicles a particular color or placing a symbol on them to make them more distinctive and recognizable. For others, the focus was less on creating signage for a driverless car, but instead on marking the test site to signal to drivers the potential risks of entering the area. The respondents wanted to either generally know they were in a testing location from communication efforts or specifically see signs warning citizens they are in a driverless vehicle testing zone. One respondent requested that announcements advise people to be careful when saying, "Please inform people living in Phoenix to be very aware and careful with the driverless vehicles present." Another participant wanted signage to warn the public to be more careful, "Put up signs in the area so those who are walking or driving know to be cautious and more careful." A different respondent wanted even more specific communications by saying, "Make sure it is well publicized, including dates, times and locations so people have the info needed to increase their personal safety." Although these three responses progress from general warnings to

specific warnings, they are all warnings nonetheless that encourage the public to take their safety into their own hands when given proper advance notice.

A reoccurring and consistent recommendation was to make sure that leaders thought about safety. These recommendations included calls to ensure that leaders would not put revenue ahead of safety and public interest by making sure they "place more value on human life." Specifically, many of these recommendations also tried to develop salutations to avoid what happened when the driverless vehicles struck and killed Elaine Herzberg. Survey respondents wanted accountability and better training for driverless vehicle attendants/safety drivers. One suggestion included to "ensure that the drivers who are testing the vehicles are fully qualified and that they can be trusted in such a position." Another response is a more directed suggestion, seemingly based on the Elain Herzberg incident, stating, "Human testers/co-pilots are not allowed to read or look at social media. Eyes on the road." Aside from focusing on training a safety driver, the concern for safety in testbed management is similar to the call for safety in driverless vehicle design and regulation.

The survey's final topical question provided a list of potential impacts of living in a metropolitan area where driverless vehicles are being tested on public streets. These answer responses were mostly populated using possible effects identified in the secondary data analysis. Participants could select multiple responses, fill in their responses, or select a "no impact" statement. The most common chosen impacts were "Driverless vehicle testing on Arizona public streets increases new research and development opportunities for Arizona businesses" (52.0%) and "Driverless vehicle testing on Arizona public streets increases mobility and transportation opportunities,

including opportunities for people with disabilities and the elderly" (49%). Interestingly, although many indicated testing was a way to give more people mobility opportunities, there were nearly half as many respondents suggesting testing increases equitable access to transportation.

More respondents selected that driverless vehicle testing was unsafe than safe. Thirty-nine percent of respondents felt it made them less safe while walking or riding a bicycle, and 34.5% felt it made them less safe while driving. Only 13.0% felt it made them safer while driving, and 6.8% felt it made them safer while walking or riding a bicycle. Although safety was a potential benefit in the future of driverless vehicles, participants do not overwhelmingly feel safer in the testbed.

Discussion

This research document the ways that the public is both active and passive participants in their testbed work that involves support and opposition to autonomous vehicles. Survey participants had varied experiences and approaches to both driverless vehicles and the testing of driverless cars. Although influences and knowledge about driverless vehicles primarily came from local sources, people's knowledge and experiences related to driverless vehicles were also tied to broader contexts, including both national and international sources of influence.

This chapter highlighted how the public could be unaware or uninterested in the testbed and its technology despite surrounding hype and many people working to make autonomous futures a reality. Participant responses demonstrated they had differing relationships with the technology and testbed in three key areas: knowledge, support, and engagement (see Table 20). For the first type of tenuous sociotechnical relationship,

people lack knowledge of either the testbed or technology, indicative of a communication and information gap. Another group lacks support for either the testbed or technology, suggesting challenges exist with consent and technology adoption. Finally, the third relationship type experience tension is tied to meaningful engagement with the technology or testbed. People in this group lack the ability to understand their relationship to the technology or testbed, and therefore how to envision their futures and meaningfully engage. They might support the technology, but cannot communicate how the technology might impact their lives or feel empowered to provide feedback. Although this summary comes from a deficit interpretation of these three relationships, they provide areas of opportunity for improving relationships between users/nonusers and emerging technologies.

Table 20

Three Types of Relationship Strain Between the Public and the Technology or Testbed

Type	Technology	Testbed	Issue
Knowledge	Unaware of technology	Unaware of testing	Information, communication
Support	Unsupportive of the technology	Unsupportive of testing	Consent, adoption
Engagement	Unable to see their own future with the technology.	Unable to understand their own role in the testing	Democracy, meaningful participation

To revisit the core questions of this research and tie it to public opinion, who are the users and what lives are they supposed to lead according to members of the public? The survey responses indicate some people view themselves as users, while others consider themselves as explicitly nonusers. Survey participants imagined what broader

social futures would be like, and saw it as potentially safer with more opportunities for improved mobility, environmental impact, and comfort. A major finding suggested members of the public might be passive about their own identity of being a driverless vehicle user, being neither a user nor nonuser. Respondent's concerns were more about the safety of the vehicles generally or about innovation in Arizona, but when asked to visualize their own future related to driverless cars, many were unable to do so.

The visibility of the driverless vehicle testbed appears unevenly distributed among the public. With only 83.7% of the survey respondents aware of driverless vehicle testing on public streets, this leaves 1 in 6 people potentially unaware that testing is occurring in their metropolitan area. Additionally, with 34.5% of survey respondents indicating they have never seen a driverless vehicle and 41.8% indicating they have never thought about a driverless vehicle, members of the public might not even recognize one on the road or know how to interact with one from experience. Driverless cars are a significant change to the transportation sociotechnological system, and for many members of the public, they are either unaware, unexposed, or unengaged in the development and roll-out. For some, this lack of knowledge can make them feel unempowered to provide feedback. One participant at the end of the survey shared, “I have never ridden in a driverless car. I don’t feel I am [able] to say anything bad or good about this driver-less car.” This marks an opportunity for increased awareness and communications about driverless vehicles, while also signaling a need to improve citizen engagement more broadly.

The survey demonstrated that the mental maps of the public are shifting as they engage in imaginative work about what their life might look like with driverless vehicles. This survey did not specify the modality that autonomous vehicle technology might

leverage, whether ridesharing, personal ownership, public goods delivery, or long-haul trucking goods delivery. Most participants, however, seemed to envision a modality that enabled personal travel through the technology. With this vision for the technology, many applied their own personal circumstance to imagine how the technology might be used.

Some participants identified as veterans, disabled or elderly, which impacted their position on driverless vehicle design and regulation. Participants could contextualize their response to driverless vehicles and driverless vehicle testing with their history and identity. With a majority of respondents being over the age of 60, it is no surprise that many people cited throughout their responses an interest in being able to have a driverless vehicle chauffer them when they are unable to transport themselves. Similarly, one person who mentioned their disability might cause them to give up independent driving, and another who was self-described as seeing-impaired were both supportive of driverless vehicles providing more mobility options. Other respondents also brought in their own experiences, especially related to their time working and commuting. For instance, a person who works still and talks to his coworkers about driverless cars imagines how these vehicles might help with multitasking during commutes to be more efficient. Another shared their background influencing their feedback when saying, “I travel an hour each way to work in rush hour traffic—any change is welcome.” Although these findings suggest the lives people will lead in a driverless vehicle future will result in more comfort, higher work output, and more mobility, the driverless vehicle testbed in a place of greater responsibility.

Some of the reactions documented in the survey are reminiscent of the backlash felt in the original scuffle between motorists and pedestrians in the 1900s. Norton (2011) wrote:

> Motorists arrived in American city streets as intruders, and had to fight for their rightful place to be there. They and their allies fought their battles in legislatures, courtrooms, newspapers' editorial pages, engineering offices, school classrooms, and the streets themselves. (p. 7)

Replacing the word "motorists" with the phrase "automated vehicles" would accurately describe the hidden and not so hidden battles for supremacy on mobility futures. The passage from Norton (2011) continued: "With their success came a new kind of city- a city that conforms to the needs of motorist" (p. 7). In the reapplication of this analysis to autonomous vehicles, how will the city be remade with driverless cars, and how will the city's inhabitants adjust? These kinds of moments of tension are testaments to the ways in which sociotechnical assemblages are being sorted out.

The shifting mental maps of the public are at least partially attributable to the places from which they get their information. Using a survey to understand the testbed and driverless future helps articulate the public's perceptions and imaginations. Although valuable to know public opinion, it is also worthwhile to know what might be coloring these positions. This helps articulate if people are relying on broader narratives about technology, influenced by other sources, and a part of an informational power dynamic. Many participants appear to be heavily influenced by the news stories covering the death of pedestrian Elaine Herzberg. Participants indicate they have primarily learned about driverless vehicles from the local news, and throughout free response answers bring up

safety concerns, especially related to the killing of pedestrians, making sure that the driverless vehicle tester is paying attention, and making sure the streets are well-lit enough for the driverless vehicle to navigate.

The public conducted evaluative and stabilizing work by commenting on what acceptable forms of testing would look like and how they would like the technology to be managed. Not only did people have clear, articulated thoughts on how to improve the technology, they also have well-defined suggestions on how to improve the testbed. Participants wanted the testbed design in a way that is transparent with clearly defined boundaries and outcomes. Although participants differed on accountability strategies around boundaries, participants implied that the testbed needed similar thoughtfulness in its design, as did the technology.

This chapter investigated how Phoenix metropolitan area residents thought about driverless vehicles and their associated futures to gain practical knowledge about expectations of the public and theoretical knowledge about the kinds of testbed work that the public engages in. Participants engage in their own internal assemblage building as they envision what life might look like living alongside these technologies, but at times, participants demonstrated difficulty in even imaginarily assembling themselves specifically with the technology, often based on their perceived lack of use or expertise. This demonstrates an opportunity for capacity building to help ensure that the public feels empowered to engage in their own testbed work of imagining and understanding how they fit together with technological advancements. Additionally, this research suggests that the public has many opinions and expectations around technology and its management. Being able to dial into these expectations, such as transparency around

testing and job retraining after implementation, allows for this information to be connected to those in the testbed who actively do this kind of work, translating it from an expectation to reality.

CHAPTER 7

ASSEMBLING THE TESTBED

"My personal belief is that it's been far too long and if we allow this to happen to without the required understanding of the level of risk that we are imposing on the general public and so my one of my passions and reason why I'm doing this because I'd like to help understand that risk and mitigate that risk."

– Interview Participant

Over the last six chapters, this dissertation outlined how testbeds assemble and negotiate sociotechnical relationships to recognize how testbed work creates futures and lived experiences. Such a research endeavor aims to make visible the work that goes on in a testbed to imagine, assemble, test, and stabilize sociotechnical relationships to then find opportunities for improvement to enhance sociotechnical outcomes, broadly. By looking at the Arizona public autonomous vehicle testbed, I explicated the work done by several members of the testbed, namely experts, institutions, news media, and the public, through selected mediums to start to document and reveal the immense amount of configuration work occurring in the testbed. As a result, this research describes the Arizona testbed and associated configuration work, while also using the lens of testbed configuration work to discuss ways to improve upon the Arizona testbed specifically and testbeds broadly for responsible innovation.

Chapter 7 synthesizes all of this information. I begin this chapter by assembling the different components of the testbed that were presented discretely in Chapter 3

through Chapter 6 and put them in conversation with one another to topically describe the Arizona autonomous vehicle testbed. Then, I discuss the testbed work in assembling and negotiating sociotechnical configurations within the testbed and then use this to provide insight into how to improve testbed management to achieve better sociotechnical outcomes.

Re-Assembling the Testbed

This research segmented the testbed into four concrete areas of analysis to begin to document the breadth of work occurring in the testbed by numerous groups of people, namely experts, institutions, newspapers, and the public. These groups, knowingly or unknowingly, form and evaluate sociotechnical relationships, testing not only the technology but futures visions of society. In this way, the building of the testbed becomes the unbuilding and rebuilding of the Phoenix metropolitan area, as new relationships, meanings, and practices are established within the area, while other relationships, meanings, and practices are dismantled. This section summarizes the four research chapters of the dissertation.

Chapter 3 combined both public event observations and semi-structured interviews to understand the kinds of work that experts do in the testbed to configure sociotechnical relationships in both public and private spaces. These experts took on multiple roles, including the facilitator, imaginer, educator, citizen activist, engineer, facilitator, partnership-builder, autonomous vehicle designer, and autonomous vehicle deployer. Increased safety was the main rationale for many working to promote automated mobility futures, although a couple of detractors were concerned that the complexity of driverless vehicle futures was a bit more complicated than originally

imagined. Autonomous vehicles in these stories became the necessary solution to safety and that if the technology was not presently safe, research and standards would allow it to become even safer. Those attached more directly to the autonomous vehicle industry discussed that since they are working on an emerging technology, their product must push themselves to be better than alternatives in both safety and other values, or otherwise, they would fail. Visions of users and nonusers were not always clear, but comments on opportunities for equity and access for different populations were often shared as a residual byproduct of creating a safe autonomous vehicle. However, the public events capitalized on opportunities to demonstrate the technology and bring different stakeholders together around collective automated mobility visions. Autonomous futures were varied between shuttle transit, product delivery, and personal transportation. Most interviewees also felt mass adoption of driverless vehicles was several decades away, but all were united in promoting a safe, automated future that, seemingly, lacked risk.

This chapter ultimately found that experts manage the scope of the conversation, make futures real, and build and dismantle momentum. In the framing of the value of the technology, safety became a driving force for the technology's sociotechnical future, and that many people are willing to work to make the technology fit this vision for the future, even if it might not fit it right now. Experts also engaged in future-making activities through visioning and performances to socialize their imaginations for the future to others. This was primarily done by demonstrating the technology and research to increase trust and bemoaning the status quo to build technologically deterministic momentum. More attention to the status quo of the testbed was attended to privately in interviews

than in public events, and most events focused on technology more than the social aspects. These examples of testbed work all help to shape the sociotechnical assemblages, and some areas, like how the technology is framed or talking more explicitly about the testbed in public spaces, could be improved to enhance sociotechnical futures.

In Chapter 4, I used a web content analysis of autonomous vehicle businesses, government entities, and academic institutions to begin identifying the kinds of work that institutions do in the testbed. The results illuminate how these three sectors engage in very different sociotechnical assemblage work. To share some examples, the automated industry websites were curated experiences and had the clearest visions of who their users would be through the development of testimonies and video footage engaging in both imaginative and assembly work. These websites work hard through imagery and story to transport viewers into this future and help them understand what an automated future might look like and why they might want it. Such visions of the future were filled with people in families, were elderly, had a disability, or were simply local to Arizona. Industry websites articulated the different paths to automated mobility (goods delivery versus personal transportation), while government and academia primarily focused on automated vehicles more broadly. University documents demonstrated both student and faculty interests in researching technical and social issues related to driverless vehicles, while some faculty also became educators and facilitators of knowledge both to students and the larger community. Government documents revealed less of an interest in explicitly developing users and nonusers of the technology, but rather focused on learning about the technology, promoting economic development, and enabling infrastructure that could create a path for the emerging technology. Across this chapter,

many instances of testbed work expand assemblage-making from just person-car relationships, but to other sorts of relationships like car-infrastructure configurations that help create paths for the technology's broader adoption.

Chapter 5 explored how the testbed activities are narrated through newspapers as mediators of the technology and testbed. By engaging in a newspaper content analysis, I find that journalists and the medium of newspaper articles actively engage in testbed work and do not just passively report on testbed happenings. This investigation revealed that most stories feature some reference to either the Governor's role in reducing regulation around testing to increase innovation or safety concerns due to Elaine Herzberg's death. Law enforcement and companies like Waymo were repeatedly consulted in stories for facts and insights, allowing their voices to be elevated through newspapers, while contributing to the narration through their perspective and expertise. Public voices were rarely heard directly through newspapers, although survey research, occasional interviews, and quotes about the public by others were used. Similarly, the technological "driver" had to be interpreted by others to understand the role it played in situations, which at times varied depending on who was doing the interpreting. Given that the newspaper often reported on events within the testbed, testing the vehicles appeared to be a fact of life with minimal opportunities to imagine the future, but instead react to current events and potential new activities within the testbed.

These results from the content analysis demonstrate the role that newspapers have in articulating the playing field, which involves identifying who is relevant and who has authority, while also promoting themes and values. News reporting has both stabilizing and destabilizing effects, as the reporting either promotes, normalizes, or criticizes the

testbed activities. News articles can actively structure how the public understands the relationships within the testbed and what kinds of relationships will exist in the future.

Chapter 6 looked to find out how members of the public experience the testbed and how they see their driverless future through survey research. Some findings revealed that one in six participants did not realize driverless vehicle testing was occurring on public streets, and less than 3% of participants had ever ridden in one, indicating that there is limited physical assembly work where people are directly interacting with the technology. Participants were split on whether or not the benefit of testing driverless vehicles on public streets was worth the risk. Participants wanted developers to think about safety, accessibility, control, ethics, and the environment, while they wanted the regulators to think about safety, jobs, proof, and liability. They also had very real concerns about transparency and communication about driverless vehicle testing. Interestingly, there was a disconnect between participants when thinking about driverless vehicles generally versus thinking about how driverless vehicles might impact them in particular. This disconnect suggests that participants do internal work to imagine sociotechnical futures and that some are unable to imagine their own reconfigurations.

The Arizona Testbed and How to Build a Better Model

By looking at the testbed work across the different sectors, this research was able to surface a lot about the Arizona autonomous vehicle testbed in terms of how it works, what actors in it value, and where there are inconsistencies. The following section will provide a brief overview of how all of the testbed work comes together to outline what the testbed is and how it functions, as well as where there are possible tensions within the

testbed itself. The autonomous vehicle testbed represents the intersection between a regional innovation system dedicated to an emerging technology, regulations allowing for public road testing, and the people that inhabit the region. It is filled with competing and noncompeting visions for the future, and different materials carry these visions forward. The testbed exists in an odd temporal space, located both in the distant future in the way it is justified and in the present. Summarizing how the testbed is bounded and perceived through leaders, narrators, and the public demonstrates the testbed's geographic breadth, temporal oscillations, competing values, and stakeholder activities that influence the lived experiences within the testbed both now and in the future.

Geographically, the testbed typically includes cities like Chandler, Mesa, Scottsdale, Tempe, Phoenix, and Peoria, although Tucson is often brought up in relation to TuSimple. Even though testing activities might occur specifically in those cities, these vehicles can also travel through nearby cities, like Gilbert, as well. Although many efforts come out of the Waymo partnership in Chandler, there are spillover effects to other cities, where testing occurs on their streets, citizens work in their jobs, and discussions about the technology might be occurring. It is locally expansive, permeating many of the local communities in the Phoenix metropolitan area.

Although the core of testing is a local experience, the Phoenix metropolitan autonomous vehicle testbed is both local and national. Interviews, news stories, and websites all articulate two scenarios where the local is impacted by the national. In the first scenario, groups within Arizona work across organizations through partnerships, serve on national committees, and work within federal regulations. In the second scenario, companies come into Arizona and use their regulatory environment. Some

autonomous vehicle companies simply test their vehicles in Arizona, create a few jobs, and then leave after collecting data. And even if autonomous vehicle companies do not leave, their headquarters where major decisions get made might be based in other states, like California.

This begs the question, what benefits and challenges come from external companies testing on public streets? Do external companies have the competencies to test in a local environment? And are the promises of job creation really there, or are they a way to bolster work in other companies, with minimal job gain in Arizona? And if these jobs are available, are they there in a way that allows the state to be a thought leader or just the place where testing occurs? These answers were addressed in different ways throughout the research, including noting that most current job postings at automated vehicle companies that were in leadership positions were often out-of-state or noting that the citizens testing get unique opportunities that others might now have available.

Within this geographic space is an assortment of people who contribute to the testbed, engage in their own testbed work, and ultimately are being shaped in their relationship to the technology. The key players in the testbed include autonomous vehicle companies, like Waymo, Uber (formerly in AZ), Nuro, and TuSimple, Governor Doug Ducey, city governments, university researchers, and to a lesser extent, the public. Elaine Herzberg also became a cornerstone in nearly all spaces. Events, interviews, newspaper articles, and the public all mentioned her untimely end from her experience with an autonomous vehicle (although not always by name). The testbed and imaginations of the autonomous mobility futures are populated by businesses, families, pedestrians, drivers, light rail riders, the disabled, and the elderly. According to autonomous vehicle

companies, these are people who would like to travel autonomously, opening up their time and improving their safety, as well as though who would like goods delivered to them cheaply and efficiently. For some, the future looks safer, more efficient, better accessible, and better for the environment. To make such futures a reality, there are numerous partnerships established to bring the technology to society. These partnerships include partnerships between automated vehicle companies and cities, disability groups, and governments, while other partnerships existed across government, industry, and academia more generally.

The testbed is narrated through newspaper articles that cover the following themes: new regulations, autonomous vehicle accidents, new autonomous vehicle pilots, and impact on the economy. Safety is the predominant value communicated across most stakeholder groups, although technological advancement and economic success were also values present across all modes of analysis. These newspaper stories rely on the expertise of business leaders like Waymo and incident investigators like law enforcement, which shape how the story is told about the activities and futures related to autonomous vehicles. Given that members of the public surveyed indicated they are heavily influenced by such local news stories, the topics covered, values shared, and expertise used all impact then how the public receives information and forms opinions about the technology.

The act of demo-ing is a recurring feature of the testbed, where through demonstrations of the technology, simulations, or video footage, the technology is 'proved' to the public. This creates a curated experience for the public, placing the demo-ers in a position of power and planning what they hope to share and demonstrate ahead of

time. Video footage and imagery create cinematic visualizations of what the future could be and do so in a way that makes it accessible to the public. These videos show one slice of what the future could look like, but in doing so, they make the technology more viable by socializing a consumer base early on. The hurdle for some service-delivery models of this technology is that the technology appears similar enough to an existing good, but is differentiated enough to require imagination and risk. The technology needs to be demonstrated to become an option for future consumers. To help make this technology seem real and viable, videos of consumer testimonies help increase confidence. Members of the Arizona public, and the Arizona landscape, are central to these images. This imagery can help localize and ground the technology to the Arizona public, while also making Arizona consumers and the Arizona landscape at the heart of broader autonomous vehicle demonstrations.

There is no singular public opinion on autonomous vehicles. Thoughts about autonomous vehicle testbed and futures varied across those surveyed, and to some extent, even differed internally within individuals. Some feel safer with the technology, while others feel less safe. For those that had safety concerns about driverless vehicles in public opinion research, their responses are at odds with how the expert stakeholders view the future of the technology. Newspaper articles report incidents of the public throwing rocks at autonomous vehicles. In one instance, a newspaper article documented a story about someone with a mental illness waving a gun at a driverless vehicle. Companies respond in these articles that members of the public who publicly demonstrate their displeasure with the technology as in the minority. Autonomous vehicle websites use videos of

testers to demonstrate these testers are satisfied with their experience. The public's experience is both varied and meaningful to their own contexts.

There are several key visions about what the future looks like with autonomous vehicles. Improved road safety was the clearest vision for the future. Users of this technology might see a decrease in car ownership in their future. In some accounts, users might lead a life that is less negatively impactful to the environment, as driverless vehicles were often talked about alongside electric vehicles. Second in frequency to road safety, websites, interviews, public events, newspapers, and the public all mentioned increases in accessibility to the disabled and elderly. This kind of visioning was clearest through materials produced by Waymo. Across all visions for the future, it was unclear if these abstract and general values would be translated into people's lived realities or simply marketing ads meant to drum up interest. Although future lived realities and marketing are not mutually exclusive, it is hard to tease out what the future might actually look like. With autonomous vehicles seeming to be the solution to everything, there is the risk that it is the solution to nothing.

The futures that autonomous vehicles are supposed to bring include safety, accessibility, and efficiency, as well as improved environmental outcomes. These values are ubiquitous and motivating, in the way that many people think about and want these values to be achieved. These values tell us about what the future might look like, but do not portray a clear picture of how these values might be designed for or achieved. To say that one is not in support of these values would seem criminal, as was indicated in some language at public events that society cannot afford to wait. The research on expert voices demonstrated, at this stage in the development, autonomous vehicle leaders

comment on the need to make it safer and then communicate the need to mobilize more research, partnerships, and thoughtfulness. It is unclear if these is an option not to proceed forward with the technology. By mobilizing motivational values and visions for the future, stakeholders create a path for the technology

Although the visions for autonomous mobility futures are broadly filled with numerous benefits such as improved mobility, accessibility, safety, environment, and comfort, there are very different autonomous vehicle technologies caught up in these futures. Not all autonomous technologies are the same, and therefore, their related autonomous futures can differ as well. Autonomous technologies vary substantially and include integration into rideshare, smaller public transit, personal goods delivery, and massive trucking delivery. Interpretative flexibility (Pinch & Bijker, 1984) occurs in the driverless vehicle space, as the definition of an autonomous vehicle is fluctuating across different ownership and service modalities, as well as different technologies that enable varying levels of automation. Although all of these groups mention safety, they also have different secondary values. For instance, both Nuro and TuSimple heavily envision a future with greater efficiency in goods delivery. Even the ways these futures get mobilized in their imagery varies- TuSimple imparts a sense of sleek, technological sophistication geared toward cultivating business partnerships, whereas Nuro demonstrates the technology's ease and friendliness.

Safety was the predominant driving value of autonomous mobility futures, as articulated in both leader feedback and stakeholder materials. Safety was also present in both the newspaper narration and public opinion research, but in both of these, safety was both used as a potential value-add of the technology and a detracting concern of the new

technology. When safety was called into question, it was most often called into question the technology's ability to be safe in a complex social environment. Increasing accessibility for those who need mobility options was also a prominent value across all modalities of analysis. Environmental impacts were the next most uniformly cited value, although substantially less than both safety and accessibility.

Job creation was a reoccurring theme in the analysis of websites, newspapers, public events, and surveys. The pipeline for jobs seems robust, with the review of university documents demonstrating students are actively building autonomous vehicle technology and thinking about its social implications. Career center staff are at events to learn about the development of new job arenas, while students also attend these events to network and learn from experts. Newspaper articles and autonomous vehicle websites demonstrate jobs are available, but often in the form of test drivers of fleet maintenance roles. Furthermore, the public would like the government to help connect those whom the technology would impact with new jobs and job training.

There was a gap between stakeholders, narrators, and the public in how testbed experiences were attended to in conversation. Missing from most stakeholder discourse on autonomous vehicles, either in interviews, public events, or websites, was a reflective conversation about testing on public streets and what that might mean for people. The newspaper analysis did the best job of making the implications of living in the testbed visible. Automated vehicle companies attempted to do this by showing the pilot programs in action, reinforcing these stories with a production of images, video, and audio of Arizona and the people that reside within it. Interviews and event leaders rarely touched on testbed experiences and more so focused on a somewhat homogenous conception of

autonomous driving technology, the unsafe status quo, and the possibilities for safety. At these events and on websites, video footage of driverless vehicle testing became a tool to demonstrate how the technology works safely and accomplishes a purpose. Many of those in industry, academia, and government discussed the future of the technology and its benefits, but for many in Arizona and as the newspapers are a testament to, the future is already here.

Thus far, a risk-benefit analysis has dominated the approach to the testbed. Leaders in both private spaces and public events discuss the benefits of the testbed in both present and future terms, bolstered by language from state executive orders. The testbed generates jobs, additional mobility or goods delivery for select participants, and economic development. The death of Elaine Herzberg is a reminder of the risks of the testbed, as cited directly or indirectly across leaders, materials, news articles, and the public. In the short term, it appears that the benefits are related to economic and technology gains, while the risks are on the public. In the long term, the benefits of safety, comfort, climate, and accessibility become more readily apparent as a potential benefit someday.

Responsibly Innovating in the Arizona Testbed

By looking at how the testbed simultaneously creates autonomous mobility lived experiences both presently and in the future through testbed work, this research provides insight into how to build better testbeds for improved social outcomes by meaningfully understanding the work that goes on to configure sociotechnical relationships. The goal of this dissertation was not to comment on whether or not testbed work was being conducted in ways that created better futures, but instead was about understanding

testbed work and where to intervene to responsibly innovate for better futures going forward. However, as a byproduct of the investigation, I found several areas of success and opportunity within the Arizona public autonomous vehicle testbed.

I start my assessment of the testbed by communicating my process of investigating the testbed. Collins and Pinch (2002) stated, “In science and technology, as in love, ‘distance lends enchantment’” (p. 2), and “science seems to be either all good or all bad” (p. 1). My evolution through this research of a technological testbed took me from enchantment to criticality through the research experience. After discussions with leaders and reflection on the analysis, I also arrived at appreciation and understanding the nuance of those working toward building a future with a transformative technology with seemingly infinite potential. In every conversation, there is a genuine recognition of the hard work that must go into making the technology viable and safe for the communities impacted by the technology. Like in many endeavors, however, there are moments of both successes and challenges.

That are several indicators of success in the testbed already. There is a lot of work being conducted by many stakeholders trying to get the technology tight to improve outcomes. There is also evidence of diverging opinions, which at least seems like the testbed environment is open to feedback. Public engagement activities were also sprinkled throughout the testbed, which showed attempts by institutions to make sure that either the technology and its trajectory are at least being linked to public input. Furthermore, there was a lot of evidence of cross-collaboration occurring in this testbed, where businesses, academia, and government come together to find solutions.

To provide some examples, stakeholders already engage in thorough technology assessment and, in some cases, develop capacity within other stakeholders to reflexively and thoughtfully think about the relationship between technology and society. For instance, as articulated at the Automated Mobility event hosted by the Chandler Chamber of Commerce, the City of Chandler has planned for multiple paths for the future in their infrastructure design. In the case of ASU, they hosted an event that allowed participants to form their own conclusions and examine them in the context of other stakeholder views to explore collective public futures. Several interviewees also mentioned the importance of cross-collaboration and translating concepts and values across stakeholders, facilitating learning, and encouraging public engagement to reach similar goals.

Between the technology's massive promises for the future, the differing modalities in which these autonomous futures can occur, and the ways that stakeholders are committed to making these futures a reality, the case for responsible innovation as a tenet of future-building is paramount, and even more so when testbeds become the location to advance these futures. Any feedback for improvements in responsible innovation is not meant to undermine the already genuine and multifaceted responsible innovation work that is already occurring; instead, these should be thought of as additive strategies with a lens on future-making through testbeds. Within the Arizona public autonomous vehicle testbed, several strategies can be applied to help responsibly innovate, including changes related to governance, transparency, value justification, and sociotechnical framing (see Table 21). I explore these suggestions further in this section.

Table 21

Success and Opportunities of the Arizona Autonomous Vehicle Testbed

Successes	Opportunities
• A lot of work by many stakeholders trying to get this right • Evidence of diverging opinions • Evidence of public engagement • Evidence of cross-collaboration	• Increase governance alongside loosened regulation • Improve clarity and transparency by making work more visible to all sets of testbed inhabitants. • Acknowledge present circumstances and the testbed publicly • Engage more critically with solutionism arguments • Leverage the assemblage work that is being done in pockets to potentially apply it to other areas. • Recognize that preexisting car-human relationships cannot just be replaced with AV-human relationships

Accountability and regulation are areas of opportunity in the testbed, as there is an abundance of visioning for the future and a lack of present regulation. Commentary from leaders in Chapter 3, newspaper stories in Chapter 5, and the public's feedback in Chapter 6 all suggest lessened regulation facilitated the existence of the current testbed. The minimal regulation allows companies to come in and easily test their technology, which is a boon to technology development. Resounding across discussions was a familiar trope of decreased regulation increases innovation and, in return, increases safety and jobs. As mentioned in Chapter 4, networked governance can make accountability ambiguous. Industry websites focused on developing visions for the future and increasing buy-in to these futures, while governments focused on infrastructure building and economic development. Across the visions and artifacts, regulatory conversations were lacking.

If networked governance already makes accountability challenging and Arizona is a testbed due to their deregulation, then the responsibility should be intentionally

addressed from a governance perspective, attuning to the regulatory needs voiced by the public. When regulation decreases, there are opportunities to allow for increased regulation elsewhere to improve accountability. The focus on loosened regulation as a way to increase innovation misses an opportunity to revisit regulation that would help promote and shape the regulatory side of the testbed (Engels et al., 2019). Survey research reveals that members of the public want the following attended to in terms of regulation: safety, job retraining, transparency, evidence, and security. Although the discourse about loose regulation to allow for innovation is an important part of the Phoenix metropolitan area autonomous vehicle testbed's origin story, there are opportunities for increases in regulation to allow for a better experience within the testbed and improved futures for the technology.

Increases in transparency and clarity about the technology and the testbed will help increase the public's understanding of the technology, navigate the testbed better, and have meaningful opinions about the testbed and technology. Three findings from the survey research speak to the importance of this. As a reminder, one in six people surveyed did not know the driverless vehicles were being tested in their communities. Secondly, participants indicated on several occasions they did not know enough about the technology to have an opinion or were unable to contextualize their feelings about technology development to their futures. Thirdly, some participants wanted increases in transparency and clarity so they can be more aware of how they interact with and live in the testbed. These findings indicate a knowledge problem where some members of the public are unaware of the testbed, some are unable to think about what the technology might mean for them, and some want to know more about the logistics. Indeed,

stakeholder interviews and materials suggest autonomous vehicles as a term is multifaceted and varying, yet all modalities of autonomous vehicles become lumped together in discourse. Increasing awareness about the testbed and the technology will allow members of the public to meaningfully engage with the technology and their own futures.

Calls for transparency suggest knowledge sharing must be both genuine and informative. This research has suggested, at times, the testbed feels like a marketing strategy or consumer acceptance testing space. Between the demonstrations of the technology at public events, online videos with tester testimonies, or newspaper articles sharing opportunities to test, at least part of the testbed is meant to socialize the technology and make people accustomed and invested in its success. Hommels (2005) found citizen opposition to changes in urban structures favored existing, obdurate technologies and led to delays in decision-making, but a slow introduction and socialization of technology might be a way to circumvent such delaying opposition. Knowledge sharing opens up vulnerabilities and can add a burden to companies. How to adequately inform the public about testing locations and risks involves effort and adequate communication strategies to share knowledge with people with differing levels of technological literacy and experience. A nonmarketing approach to the socialization of the risks and benefits, similar to the autonomous vehicle public forum, can help provide knowledge and do so in a way that attends to concerns related to transparency.

Thirdly, the testbed needs to be thought of as something that makes sociotechnical futures a reality now, instead of as a place where technologies are built and tested to promote sociotechnical futures later. When the automobile was released, Kline and Pinch

(1996) demonstrated in their assessments that users redefined the car to make the technology work for them. This flexibility does not exist in the testing environment present. Use is heavily prescribed by companies, and given that quick pilot programs come in and out of the region, users have not had the opportunity to interpret or reinterpret the technology. There is not a clear space for the testbed to be meaningfully thought about by inhabitants or stakeholders.

Interviews and public events, in particular, were heavily focused on how to build the technology now and test it now to create a better future. Very rarely was the status quo addressed, aside from disparaging traditional forms of transportation. The newspaper articles did the best job of contextualizing autonomous vehicles as something that is tested and exists now in local communities. By thinking about how research, development, and testing experiences impact local communities, the testbed would become a more well-thought-out sociotechnical artifact, where communities could understand the risks and benefits and the triple helix stakeholders could build better automated mobility futures now.

Finally, the Arizona testbed could benefit from improved framing related to autonomous vehicles. Focusing on solutionist arguments, where the technology is justified in terms of safety, can constrain the conversation from thinking about how to build the technology to support multiple outcomes or prevent a conversation from thinking about multiple technologies that might aid in solving problems. From talking with leaders and reviewing electronic documents of industry and government stakeholders, there was often evidence of a gap between the premise and the conclusion. Stakeholders might talk about how roads are currently unsafe and then transition to

talking about autonomous vehicles. In the minds of many stakeholders, it was a foregone conclusion. Autonomous vehicles might not be an answer to improved road safety, and if they are, they are certainly not the only solution. Numerous stakeholders, however, are committed to making this technology fit the visions of safety for the future. Additionally, in the current framing, the technology is described as being better than current cars, where the conversation treats the autonomous vehicle as a substitute good for human-driven cars. This further constrains the conversation in terms of imagination work, because the technology has the opportunity to be so much more than a better car.

Testbed Work and Assemblage Configurations

As determined through this research, testbed work occurs across a plethora of mediums and activities, including in the minds of the public, through public performances, within infrastructure building activities, and by way of narration. As found in public events and website materials, these assemblage building activities sometimes hid existing sociotechnical relationships in the testbed in favor of looking at abstract future ones. Such actions risk the public not understanding what is being assembled and tested in real-time, in favor of abstractly imagining what is happening in the future. These activities, as found in expert visioning, news articles, and website materials, can also narrow the solution set, but justify the technology in terms of safety, instead of either taking a broad approach to finding the multiple ways society can improve safety or finding the multiple ways autonomous vehicles can improve outcomes. Assemblage-building activities can also create path dependencies and momentum, as was the case in government work that created infrastructure assemblages with the technology. Finally,

within the narrative spaces, this research finds that testbed work done through newspapers can mediate the happenings of the testbed, determine who gets considered, what their roles are, and outline who has authority, ultimately documenting the social order around the technology.

Recognizing that testbeds and that the work that occurs in them to assemble relationships are building futures is foundational. Testbeds should become a unique site of analysis for emergent technologies, as a place where sociotechnical relationships are imagined, assembled, tested, and stabilized that structures associated sociotechnical futures. This dissertation leveraged a multi-method approach to understand the testbed site to get a pulse on who is being included in the design of autonomous vehicle futures within the testbed to illuminate how different groups of people do work to configure sociotechnical relationships. These methods proved to be useful.

This research reaffirms the importance of using communication investigations to understand how technology is being perceived or integrated into society. Reviewing news articles can be helpful to understand prevailing narratives, key stakeholders, and technological aspirations, and how relationships are being assembled. This technology assessment strategy is critical to revealing which stakeholders are actively shaping perceptions and the future through their articulation of events, winners and losers, and opportunities in real-time. In the newspaper analysis presented in this research, by looking at who is speaking and telling and interpreting the story of the testbed activities, law enforcement became a critical voice for assessing emerging technology, its acceptance, and assigning blame. When the success of autonomous vehicles is predicated

on the notion that they are safer than the status quo, assignment of fault becomes critical, especially as the public learns and grapples with their own sociotechnical futures.

By taking the approach of understanding the testbed as a place where sociotechnical relationships are imagined, assembled, evaluated, and stabilized in the testbed, this research can point to a few areas within a testbed where responsible innovation work can improve how these configurations get formed for improving sociotechnical futures. Researchers and innovators should recognize that testbeds configure sociotechnical relationships, not just test technologies, and then engage in ongoing multi-method analysis of the testbed site to get a pulse on who is being included/excluded and where there are tensions. This research recommends that those people within the testbed trying to use the testbed as space to innovate responsibly locate the following places to intervene and engage:

- Find assemblages that are being negotiated and see how they are being socialized. What is left out of those performances or interpretations?
- Find where visions of the future and the perceived lived experiences of testbed inhabitants do not align with testbed realities.
- Find where testbed work does not align across different groups. Why is this?

Responsible innovation will promote better sociotechnical futures for autonomous vehicles, as well as other emerging or emergent technology, and testbeds are an important site where this kind of work can occur. These strategies reveal where there are disconnects, harmonies, and power dynamics in future-building activities and attune to how futures are situated in the present and how that impacts both society and the future of

the technology. Such knowledge can ultimately improve lived experiences for those in the testbed, those in the future, and potentially the technology itself.

Reflections on Assembling the Testbed

Through this research, I was able to interrogate the work of the testbed in creating and negotiating sociotechnical assemblages and futures using the Arizona public autonomous vehicle testbed. This research broke apart pieces of the testbed in the Phoenix metropolitan area to investigate the work that different actors do in the testbed to create autonomous vehicle futures by looking at visions, materials, storytelling, and experiences shared by these groups. Upon reassembling the testbed, this chapter has documented not only the Arizona testbed and the work that occurs there, but also provided strategies to enhance the testbed and add to the literature on responsible innovation management by honing in on testbeds as a site of analysis.

However, there is much work left to do on the testbed. Alternate and additional methods can help articulate how researchers can investigate the work of the testbed to improve outcomes by focusing on sociotechnical assemblage building between invention and broader adoption. This research could benefit from a broadening of scope and comparative analyses to continue to use case study work to explicate the testbed and its importance.

This dissertation made several decisions about the scope to manage both the breadth and depth of the research. By leveraging a case study approach to investigate how testbeds work to configure sociotechnical relationships and what that might mean for both the future and immediate lived experiences of people, this research required a broad

approach to delve into the multitude of people who do work in the testbed. In this case, information produced by experts, institutions, newspapers, and the public was explored to extrapolate meaning to understand the testbed work. By narrowing the groups used for this research to four and further unpacking how they build sociotechnical assemblages in specific mediums, this research constrains the testbed in terms of both scope and methodology. In terms of scope, there are many other actors in the testbed that engage in testbed work that can become the site of future analyses. For instance, those in insurance companies, legal professions, and construction all likely engage in work related to building sociotechnical assemblages.

In terms of methodology, the mediums used for this analysis were limited in the way that no private, internal documents. If possible, being embedded within an autonomous vehicle company would provide greater insight into the visioning practices, decision making, and user building that occurs in a specific way versus the general and marketing ways that might come about through interviews or public materials analysis. Indeed, schematics of technologies might demonstrate more nuances about dimensions and design considerations to see how engineers and the technology's designs facilitate or prevent sociotechnical assemblages from being formed. Although this research uses autonomous vehicles as the central technology in the testbed case study, this work prioritized humans over technology in analysis, typically looking for how people construct assemblages versus how technologies might facilitate relationships. A broadening of materials for analysis could help with this scope problem.

Another interesting area of inquiry for this research would be to further understand how testbeds change over time. In particular, it would be helpful to know

where there are moments when the assemblages within the testbed transition from needing to be worked out to something that is more stabilized. This kind of research would help with forecasting the trajectory of the testbed as the technology potentially reaches broader adoption or loses momentum as the testbed begins to wind down.

Additionally, as with any case study approach, broadening the analysis to include other testbed sites would help articulate what other kinds of work occur in testbeds, if there are resilient features and trends for all testbeds, and if there are good testbed practices that can be shared as standards. For example, investigating testbed differences and their related social outcomes, as well as imagined futures across the Phoenix testbed and a testbed located in Chicago, could provide two different stories, influenced by cultural, social, or environmental factors. Understanding these factors in a comparative context would enable an improved understanding of the transition of implementing technologies via testbeds to broad implementation. These additional inquiries add depth and breadth to analysis, enabling researchers to continue improving driverless vehicle testbeds topically, testbeds theoretically, and responsible innovation strategies broadly.

REFERENCES

ADOT. (n.d.). *Autonomous Vehicles Testing and Operating in the State of Arizona | ADOT*. https://azdot.gov/motor-vehicles/professional-services/autonomous-vehicles-testing-and-operating-state-arizona

Akrich, M. (1992). The de-scription of technical objects. In W. Bijker & J. Law (Eds.), *Shaping technology/building society* (pp. 205-224). MIT Press.

Anania, E. C., Rice, S., Walters, N. W., Pierce, M., Winter, S. R., & Milner, M. N. (2018). The effects of positive and negative information on consumers' willingness to ride in a driverless vehicle. *Transport Policy*, *72*, 218–224. https://doi.org/10.1016/j.tranpol.2018.04.002

Anand, N., & Jones, B. C. (2008). Tournament rituals, category dynamics, and field configuration: The case of the Booker Prize. *Journal of Management Studies*, *45*(6), 1036-1060.

Archive.org. (2018, June 23). *Keys to the Future (1956)* [Video]. Internet Archive. https://archive.org/details/motorama_201806

ASU & City of Tempe. (2019, April). *Autonomous Vehicles in Tempe: Opportunities and Risks | Transportation*. ASU. https://transportation.asu.edu/projects/autonomous-vehicles-tempe-opportunities-and-risks

Bach, A. S., & Kroløkke, C. (2020). Hope and happy futurity in the cryotank: Biomedical imaginaries of ovarian tissue freezing. *Science as Culture*, *29*(3), 425–449. https://doi.org/10.1080/09505431.2019.1681953

Bansal, P., & Kockelman, K. M. (2017). Forecasting Americans' long-term adoption of connected and autonomous vehicle technologies. *Transportation Research Part A: Policy and Practice*, *95*, 49–63. https://doi.org/10.1016/j.tra.2016.10.013

Bissell, D., Birtchnell, T., Elliott, A., & Hsu, E. L. (2020). Autonomous automobilities: The social impacts of driverless vehicles. *Current Sociology*, *68*(1), 116-134.

Bowers, P. J., Meyers, C., & Babbili, A. (2004). Power, ethics, and journalism: Toward an integrative approach. *Journal of Mass Media Ethics*, *19*(3–4), 223–246. https://doi.org/10.1080/08900523.2004.9679690

Broussard, M. (2018). *Artificial unintelligence: How computers misunderstand the world*. MIT Press.

Burns, L., & Shulgan, C. (2018). *Autonomy : the quest to build the driverless car--and how it will reshape our world* . Ecco, an imprint of HarperCollins Publishers.

Callon, M. (1984). Some elements of a sociology of translation: Domestication of the scallops and the fishermen of St. Brieuc Bay. *The Sociological Review*, *32*(1_suppl), 196–233. https://doi.org/10.1111/j.1467-954X.1984.tb00113.x

Castelvecchi, D. (2016). Can we open the black box of AI? *Nature News*, *538*(7623), 20-23. https://doi.org/10.1038/538020a

Cicalò, E. (2015, June). *Dreaming Utopia. Images for a better world* [Paper presentation]. 3rd International Conference New Urban Languages, Delft, NL. https://www.researchgate.net/publication/283498080_Dreaming_Utopia_Images_for_a_better_world

City of Chandler. (2021, March 5). *Zoning Code and Amendments*. https://www.chandleraz.gov/government/departments/development-services/planning-and-zoning/zoning-code-and-zoning-code-amendments

City of Peoria. (2020). *Robo Ride Autonomous Shuttle | City of Peoria*. https://www.peoriaaz.gov/government/departments/public-works/transportation/autonomous-shuttle

Collins, H., & Pinch, T. (2002). The golem at large: What you should know about technology. In *The golem at large*. Cambridge University Press. https://doi.org/10.1017/CBO9780511541353

Consortium for Science, Policy & Outcomes. (2019, June 6). *Our Driverless Futures Forum Sites*. https://cspo.org/research/driverless-vehicles/forum-sites/

Cunningham, M. L., Regan, M. A., Ledger, S. A., & Bennett, J. M. (2019). To buy or not to buy? Predicting willingness to pay for automated vehicles based on public opinion. *Transportation Research Part F: Traffic Psychology and Behaviour*, *65*(X), 418–438. https://doi.org/10.1016/j.trf.2019.08.012

DiMaggio, P. J., & Powell, W. W. (1983). The iron cage revisited: Institutional isomorphism and collective rationality in organizational fields. *American Sociological Review*, *48*(2), 147–160. https://doi.org/10.2307/2095101

Engels, F., Wentland, A., & Pfotenhauer, S. M. (2019). Testing future societies? Developing a framework for test beds and living labs as instruments of innovation governance. *Research Policy*, *48*(9), 103826. https://doi.org/10.1016/j.respol.2019.103826

Etzkowitz, H. (2003). Innovation in innovation: The triple helix of university-industry-government relations. *Social science information*, *42*(3), 293-337.

Etzkowitz, H., & Leydesdorff, L. (2000). The dynamics of innovation: From national systems and "Mode 2" to a triple helix of university–industry–government

relations. *Research Policy*, *29*(2), 109–123. https://doi.org/10.1016/S0048-7333(99)00055-4

Etzkowitz, H., & Zhou, C. (2017). *The triple helix: University–industry–government innovation and entrepreneurship*. Routledge.

Eubanks, V. (2017). *Automating inequality: How high-tech tools profile, police, and punish the poor*. St. Martin's Press.

Exec. Order No. 2015-09, Arizona Governor Doug Ducey, "Self-Driving Vehicle Testing and Piloting in the State of Arizona; Self-Driving Vehicle Oversight Committee" (2015).

Exec. Order No. 2018-04, Arizona Governor Doug Ducey, "Advancing Autonomous Vehicle Testing and Operating; Prioritizing Public Safety" (2018).

Exec. Order No. 2018-09, Arizona Governor Doug Ducey, "Establishment of the Institute of Automated Mobility (IAM)," (2018).

Farias, I., & Bender, T. (2010). *Urban assemblages: How actor-network theory changes urban studies*. Routledge.

Farias, I. & Blok, A. (2017). "STS in the City," in Felt, U., Fouche, R., Miller, C. A., & Smith-Doerr, L. eds., *The Handbook of Science and Technology Studies* (fourth edition, pp. 55–82). The MIT Press.

Farinha, L., Ferreira, J., & Gouveia, B. (2014). Networks of innovation and competitiveness: A triple helix case study. *Journal of the Knowledge Economy*, *7*(1), 259–275. https://doi.org/10.1007/s13132-014-0218-3

Felt, U., & Fochler, M. (2010). Machineries for making publics: Inscribing and de-scribing publics in public engagement. *Minerva*, *48*(3), 219–238. https://doi.org/10.1007/s11024-010-9155-x

Fogelberg, H., & Thorpenberg, S. (2012). Regional innovation policy and public-private partnership: The case of triple helix arenas in Western Sweden. *Science and Public Policy*, *39*(3), 347–356. https://doi.org/10.1093/scipol/scs023

Foley, R. W., & Wiek, A. (2013). Patterns of nanotechnology innovation and governance within a metropolitan area. *Technology in Society*, *35*(4), 233–247. https://doi.org/10.1016/j.techsoc.2013.10.004

Forlano, L. (2019). Stabilizing/destabilizing the driverless city: Speculative futures and autonomous vehicles. *International Journal of Communication*, *13*, 2811–2838. https://ijoc.org/index.php/ijoc/article/view/8844/2694

Fotsch, P. M. (2001). The building of a superhighway future at the New York World's Fair. *Cultural critique*, (48), 65-97.

Fouché, R. (2006). Say it loud, I'm Black and I'm proud: African Americans, American artifactual culture, and Black vernacular technological creativity. *American Quarterly*, *58*(3), 639–661. http://www.jstor.org/stable/40068387

Galis, V. (2011). Enacting disability: How can science and technology studies inform disability studies? *Disability & Society*, *26*(7), 825–838. https://doi.org/10.1080/09687599.2011.618737

Garland-Thomson, R. (2011). Misfits: A feminist materialist disability concept. *Hypatia*, *26*(3), 591–609. https://doi.org/10.1111/j.1527-2001.2011.01206.x

General Motors. (2009, July 22). *GM Desert Proving Ground-Yuma Officially Open For Business* [Press release]. https://media.gm.com/media/us/en/gm/news.detail.html/content/Pages/news/us/en/2009/Jul/0722_NewProvingGround.html

Gross, G., & Blundo, R. (2005). Viagra: Medical technology constructing aging masculinity. *Journal of Sociology and Social Welfare*, *32*(1), 85–97.

Guggenheim, M. (2010). Mutable immobiles: building conversion as a problem of quasi-technologies. In I. Farias & T. Bender (Eds.), *Urban assemblages: How actor-network theory changes urban studies* (pp. 123-138). Routledge.

Guston, D. H., & Sarewitz, D. (2002). Real-time technology assessment. *Technology in Society*, *24*(1–2), 93–109. https://doi.org/10.1016/S0160-791X(01)00047-1

Haddow, G., King, E., Kunkler, I., & McLaren, D. (2015). Cyborgs in the everyday: Masculinity and biosensing prostate cancer. *Science as Culture*, *24*(4), 484–506. https://doi.org/10.1080/09505431.2015.1063597

Hildebrand, J. M., & Sheller, M. (2018). Media ecologies of autonomous automobility: Gendered and racial dimensions of future concept cars. *Transfers*, *8*(1), 64–85. https://doi.org/10.3167/TRANS.2018.080106

Hommels, A. (2005). *Unbuilding cities: Obduracy in urban socio-technical change*. MIT Press.

JafariNaimi, N. (2018). Our bodies in the trolley's path, or why self-driving cars must *not* be programmed to kill. *Science, Technology, & Human Values*, *43*(2), 302–323. https://doi.org/10.1177/0162243917718942

Jasanoff, S. (2004). *States of knowledge: The co-production of science and the social order*. Routledge.

Jasanoff, S., & Kim, S. (2015). . (2015). *Dreamscapes of modernity: Sociotechnical imaginaries and the fabrication of power: Sociotechnical imaginaries and the fabrication of power*. The University of Chicago Press.

Jorgensen, D. (1989). *Participant observation a methodology for human studies*. Sage Publications.

Joyce et al (2017). Aging: The sociomaterial constitution of later life. In U. Felte et al. (Eds.), *The handbook of science and technology studies* (4th ed., pp. 915-943). MIT Press.

Karvonen, A. (2020). Urban techno-politics: Knowing, governing, and imagining the city. *Science as Culture*, *29*(3), 417–424. https://doi.org/10.1080/09505431.2020.1766011

Khayatian, M., Lou, Y., Mehrabian, M., & Shrivastava, A. (2020). Crossroads+: A time-aware approach for intersection management of connected autonomous vehicles. *ACM Transactions on Cyber-Physical Systems*, *4*(2). https://doi.org/10.1145/3364182

Kline, R., & Pinch, T. (1996). Users as agents of technological change: The social construction of the automobile in the rural United States. *Technology and Culture*, *37*(4), 763–795. https://doi.org/10.2307/3107097

Knight, M. (2018, April 8). IndyCar pushes back against self-driving car races. *Arizona Republic*. https://eu.azcentral.com/story/sports/motor/2018/04/07/indycar-pushes-back-against-self-driving-car-races/496589002/

Kröger, F. (2016). Automated driving in its social, historical and cultural contexts. In *Autonomous Driving* (pp. 41-68). Springer, Berlin, Heidelberg.

Latour, B. (1992) "Where are the Missing Masses? The Sociology of a Few Mundane Artifacts," in W. Bijker and J. Law, eds., *Shaping Society / Building Technology*. MIT Press.

Lee, C.-J., & Scheufele, D. A. (2006). The influence of knowledge and deference toward scientific authority: A media effects model for public attitudes toward nanotechnology. *Journalism & Mass Communication Quarterly*, *83*(4), 819–834. https://doi.org/10.1177/107769900608300406

Local Motors. (2020, April 1). *Local Motors*. https://localmotors.com/

Martin, M., & Schinzinger, R. (1996). *Ethics in engineering* (3rd ed.). McGraw-Hill.

Meuser, M., & Nagel, U. (2009). The expert interview and changes in knowledge production. In *Interviewing experts* (pp. 17-42). Palgrave Macmillan, London.

Miller, C. A., & Bennett, I. (2008). Thinking longer term about technology: Is there value in science fiction-inspired approaches to constructing futures? *Science and Public Policy*, *35*(8), 597–606. https://doi.org/10.3152/030234208X370666

Morozov, E. (2013). *To save everything, click here: The folly of technological solutionism*. Public Affairs.

Moser, I. (2006). Disability and the promises of technology: Technology, subjectivity and embodiment within an order of the normal. *Information, Communication & Society*, *9*(3), 373–395. https://doi.org/10.1080/13691180600751348

Mumford, L. (1967). *The myth of the machine* (1st ed.). Harcourt, Brace & World.

Nair, G. S., Astroza, S., Bhat, C. R., Khoeini, S., & Pendyala, R. M. (2018). An application of a rank ordered probit modeling approach to understanding level of interest in autonomous vehicles. *Transportation*, *45*(6), 1623–1637. https://doi.org/10.1007/s11116-018-9945-9

Nelson, J., & Gorichanaz, T. (2019). Trust as an ethical value in emerging technology governance: The case of drone regulation. *Technology in Society*, *59*, 101131. https://doi.org/10.1016/j.techsoc.2019.04.007

Nisbet, M. C., Brossard, D., & Kroepsch, A. (2003). Framing science: The stem cell controversy in an age of press/politics. *Harvard International Journal of Press/Politics*, *8*(2), 36–70. https://doi.org/10.1177/1081180X02251047

Nisbet, M. C., & Lewenstein, B. V. (2002). Biotechnology and the American media: The policy process and the elite press, 1970 to 1999. *Science Communication*, *23*(4), 359–391. https://doi.org/10.1177/107554700202300401

Noble, S. U. (2018). *Algorithms of oppression: How search engines reinforce racism*. University Press.

Norton, P. D. (2011). *Fighting traffic—The dawn of the motor age in the American city*. MIT Press.

Nuro. (2020). *Safety*. https://www.nuro.ai/safety

Nye, D. E. A. (1992). *Electrifying America: Social meanings of a new technology*. MIT Press.

Owen, R., Macnaghten, P., & Stilgoe, J. (2012). Responsible research and innovation: From science in society to science for society, with society. *Science and public policy*, *39*(6), 751-760.

Oudshoorn, N., & Pinch, T. (2003). *How users matter: the co-construction of users and technologies*. MIT Press.

Palm, A., & Lantz, B. (2020). Information dissemination and residential solar PV adoption rates: The effect of an information campaign in Sweden. *Energy Policy*, *142*, 111540. https://doi.org/10.1016/j.enpol.2020.111540

Penmetsa, P., Adanu, E. K., Wood, D., Wang, T., & Jones, S. L. (2019). Perceptions and expectations of autonomous vehicles – A snapshot of vulnerable road user opinion. *Technological Forecasting and Social Change*, *143*, 9–13. https://doi.org/10.1016/j.techfore.2019.02.010

Pinch, T. J. (2003). Giving birth to new users: How the Minimoog was sold to rock and roll. In N. Oudshoorn & T. Pinch. (2003), *How users matter: The co-construction of users and technologies* (pp. 247-270). MIT Press.

Pinch, T. J., & Bijker, W. E. (1984). The social construction of facts and artefacts: Or how the sociology of science and the sociology of technology might benefit each other. *Social Studies of Science*, *14*(3), 399–441. http://www.jstor.org/stable/285355

Podestà, M., & Richards, G. (2018). Creating knowledge spillovers through knowledge-based festivals: The case of Mantua, Italy. *Journal of Policy Research in Tourism, Leisure and Events*, *10*(1), 1–16. https://doi.org/10.1080/19407963.2017.1344244

Radazzo, R. (2016, September 19). Three crashes so far with Google self-driving cars in Chandler. *Arizona Republic*. https://eu.azcentral.com/story/money/business/tech/2016/09/19/three-crashes-so-far-google-self-driving-cars-chandler/90411940/

Radazzo, R. (2018, December 14). A slashed tire, a pointed gun, bullies on the road: Why do Waymo self-driving vans get so much hate? *Arizona Republic*. https://eu.azcentral.com/story/money/business/tech/2018/12/11/waymo-self-driving-vehicles-face-harassment-road-rage-phoenix-area/2198220002/

Randazzo, R. (2017a, April 25). Waymo seeks Arizona volunteers for rides in self-driving cars. *Arizona Republic*. https://eu.azcentral.com/story/money/business/tech/2017/04/25/google-self-driving-cars-phoenix-area-residents/100875448/

Randazzo, R. (2017b, November 7). Waymo self-driving cars in Arizona now truly driverless. *The Republic | Azcentral.Com*. https://eu.azcentral.com/story/money/business/tech/2017/11/07/waymo-self-driving-cars-arizona-now-truly-driverless/837721001/

Randazzo, R. (2019, January 24). Self-driving robots can deliver your groceries from Fry's in Scottsdale. *Arizona Republic*. https://eu.azcentral.com/story/money/business/tech/2019/01/24/nuro-autonomous-vehicles-deliver-groceries-frys-scottsdale-arizona/2644324002/

Rogers, E. M. (2010). *Diffusion of innovations*. Simon and Schuster.

Rose, D., & Blume, S. (2003). Citizens as users of technology: An exploratory study of vaccines and vaccination. In N. Oudshoorn & T. Pinch. (2003), *How users matter: The co-construction of users and technologies* (pp. 103-131). MIT Press.

Rosental, C. (2013). Toward a sociology of public demonstrations. *Sociological Theory*, *31*(4), 343–365. https://doi.org/10.1177/0735275113513454

Sadowski, J. (2014). Exoskeletons in a disabilities context: The need for social and ethical research. *Journal of Responsible Innovation*, *1*(2), 214–219. https://doi.org/10.1080/23299460.2014.918727

Sadowski, J., & Bendor, R. (2019). Selling smartness: Corporate narratives and the smart city as a sociotechnical imaginary. *Science, Technology, & Human Values*, *44*(3), 540–563. https://doi.org/10.1177/0162243918806061

Scheufele, D. (2000). Agenda-Setting, Priming, and Framing Revisited: Another Look at Cognitive Effects of Political Communication. *Mass Communication & Society.*, *3*(2-3), 297–316. https://doi.org/info:doi/

Scheufele, D., & Lewenstein, B. (2005). The Public and Nanotechnology: How Citizens Make Sense of Emerging Technologies. *Journal of Nanoparticle Research: An Interdisciplinary Forum for Nanoscale Science and Technology*, *7*(6), 659–667. https://doi.org/10.1007/s11051-005-7526-2

Schillmeier, M. (2010). Assembling money and the sense: revisiting George Simmel and the city. In I. Farias & T. Bender (Eds.), *Urban assemblages: How actor-network theory changes urban studies* (pp. 229-252). Routledge.

Schot, J., & de la Bruheze, A. (2003). The mediated design of products, consumption, and consumers in the twentieth century. In N. Oudshoorn & T. Pinch (Eds.), *How users matter: The co-construction of users and technologies* (pp. 229-245). MIT Press.

Seiler, C. (2009). *Republic of drivers: A cultural history of automobility in America*. University of Chicago Press.

Selinger, E., & Crease, R. (2006). *The philosophy of expertise*. Columbia University Press.

Simakova, E. (2010). RFID 'Theatre of the proof': Product launch and technology demonstration as corporate practices. *Social Studies of Science*, *40*(4), 549–576. https://doi.org/10.1177/0306312710365587

Sjöberg, L. (2000). Factors in risk perception. *Risk Analysis*, *20*(1), 1–12. https://doi.org/10.1111/0272-4332.00001

Slota, S.C. & Bowker, G.C. (2017). "STS in the City," in Felt, U., Fouche, R., Miller, C. A., & Smith-Doerr, L. eds., *The Handbook of Science and Technology Studies* (fourth edition, pp. 55–82). The MIT Press.

Smith, M. R. (1994). Technological determinism in American culture. In M. R. Smith & L. Marx. (Eds), *Does technology drive history? the dilemma of technological determinism* (pp. 1–35). MIT Press.

Smith, M. L. (1994). Recourse of empire: Landscapes of progress in technological America. In M. R. Smith & L. Marx (Eds), *Does technology drive history? the dilemma of technological determinism* (pp. 37–32). MIT Press.

Smouse, B. (2016, December 24). Gov. Doug Ducey welcomes Uber self-driving cars with open arms. *Arizona Republic*. https://eu.azcentral.com/story/money/business/tech/2016/12/23/arizona-governor-doug-ducey-welcomes-uber-driverless-cars-open-arms/95793110/

Steen, K., & van Bueren, E. (2017). The defining characteristics of urban living labs. *Technology Innovation Management Review*, *7*(7), 21–33. https://www.doi.org/10.22215/timreview/1088

Stilgoe, J. (2018). Machine learning, social learning and the governance of self-driving cars. *Social studies of science*, *48*(1), 25-56.

Stilgoe, J. (2019) "Who's Driving Innovation?" Palgrave Macmillion.

Stilgoe, J., Owen, R., & Macnaghten, P. (2013). Developing a framework for responsible innovation. *Research Policy*, *42*(9), 1568–1580. https://doi.org/10.1016/j.respol.2013.05.008

Strand, R., Saltelli, A., Giampietro, M., Rommetveit, K., & Funtowicz, S. (2018). New narratives for innovation. *Journal of Cleaner Production*, *197*(Part 2), 1849–1853. https://doi.org/10.1016/j.jclepro.2016.10.194

Sun, S., Zhai, Y., Shen, B., & Chen, Y. (2020). Newspaper coverage of artificial intelligence: A perspective of emerging technologies. *Telematics and Informatics*, 53. https://doi.org/10.1016/j.tele.2020.101433

Taylor, C. (2004). *Modern Social Imaginaries*. Durham; London: Duke University Press. Retrieved April 21, 2021, from http://www.jstor.org/stable/j.ctv11hpgvt

test bed. (n.d.). The Merriam-Webster.Com Dictionary. Retrieved October 15, 2019, from https://www.merriam-webster.com/dictionary/test%20bed

The Tesla Team. (2017, November 30). *Your Autopilot has arrived*. Tesla. https://www.tesla.com/blog/your-autopilot-has-arrived

Thompson, C. (2005). *Making parents: The ontological choreography of reproductive technologies.* MIT Press.

Tozer, L., & Klenk, N. (2018). Discourses of carbon neutrality and imaginaries of urban futures. *Energy Research & Social Science*, *35*, 174–181. https://doi.org/10.1016/j.erss.2017.10.017

TuSimple. (2021). *Autonomous Trucks | Self-Driving Truck | Driverless Vehicles*. https://www.tusimple.com/

Valderrama Pineda, A. (2010). How do we co-produce urban transport systems and the city? The case of Transmilenio and Bogota. In I. Farias & T. Bender (Eds.), *Urban assemblages: How actor-network theory changes urban studies* (pp. 123-138). Routledge.

van Oost, E. (2003). Materialized gender: How shavers configure the users' femininity and masculinity. In N. Oudshoorn & T. Pinch (Eds), *How users matter: The co-construction of users and technologies* (pp. 193-208). MIT Press.

Von Schomberg, R. (2013). A vision of responsible research and innovation. *Responsible innovation: Managing the responsible emergence of science and innovation in society*, 51-74.

Waymo. (2020, September). *Safety Report and Whitepapers*. https://waymo.com/safety/

Weber, R. N. (1997). Manufacturing gender in commercial and military cockpit design. *Science, technology, & human values*, *22*(2), 235-253.

Wetmore, J. M. (2007). Amish technology: Reinforcing values and building community. *IEEE Technology and Society Magazine*, *26*(2), 10–21. https://doi.org/10.1109/MTAS.2007.371278

Wetmore, J. (2004). Redefining Risks and Redistributing Responsibilities: Building Networks to Increase Automobile Safety. *Science, Technology, & Human Values*, *29*(3), 377–405. https://doi.org/10.1177/0162243904264486

Wetmore, J. M. (2020). Reflecting on the Dream of Automated Vehicles. Visions of Hands Free Driving over the past 80 years/Überlegungen zum Traum vom automatisierten Fahrzeug. Visionen selbsttätigen Fahrens aus den letzten 80 Jahren. *TG Technikgeschichte*, *87*(1), 69-94.

Wilsdon, J., & Willis, R. (2004). *See-through science: Why public engagement needs to move upstream*. Demos.

Winner, L. (1986). *The whale and the reactor: a search for limits in an age of high technology*. The University of Chicago Press.

Winner, L. (2014). Technologies as forms of life. In *Ethics and emerging technologies* (pp. 48-60). Palgrave Macmillan, London.

Wolbring, G. (2011). *Ableism and favoritism for abilities governance, ethics and studies: new tools for nanoscale and nanoscale-enabled science and technology governance* (pp. 89–104). https://doi.org/10.1007/978-90-481-9615-9_5

Wolbring, G. (2016). Employment, disabled people and robots: What is the narrative in the academic literature and Canadian newspapers? *Societies*, *6*(2), 15–. https://doi.org/10.3390/soc6020015

Woolgar, S. 1991. Configuring the user—The case of usability trials. In J. Law (Ed.), *A sociology of monsters—Essays on power, technology and domination* (pp. 58–99). London: Routledge.

Zappala, O. (2017, December 25). Car companies come to Arizona to test their vehicles. Here's why. *Arizona Republic*. https://eu.azcentral.com/story/money/business/tech/2017/12/25/car-companies-come-arizona-test-their-vehicles-heres-why/965235001/

Zarhin, D. (2018). "I don't want to see myself as a disabled person": Continuous positive airway pressure devices and the emergence of (dis)ability as subjectivity. *Science, Technology, & Human Values*, *43*(2), 224–246. https://doi.org/10.1177/0162243917711006