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Autonomous Vehicles:

Land Use Implications for Austin, Texas

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Autonomous Vehicles: Land Use Implications for Austin, Texas

by

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Abstract

Autonomous Vehicles: Land Use Implications for Austin, Texas

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Autonomous vehicles are said to be a disruptive technology that will transform the way we live in coming decades. Drawing from the historical context of conventional vehicles and their subsequent transformation of land use development patterns, this paper seeks to understand the ancillary implications of such advances in transport. I assert the argument that Austin will be amongst the first cities to experience these shifts due to its history of economic development strategy, large populous of technology 'first-adopters,' the city's struggle to accommodate rapid growth, and Austin's context within Texas' business-friendly regulatory environment. The literature review aims to cover a broad, high-level view of the current status of autonomous vehicle development and provide context for how the academy is researching the possibilities for autonomous vehicle commercialization. A second portion of this report summarizes the views of Austin-based traffic engineers, transit researchers, attorneys, and other experts serving on various policy advisory councils in Austin, Travis County, and Central Texas.

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Chapter 1: Introduction

Autonomous vehicles are being presented as a preventative measure in saving thousands of lives while also improving traffic on our roads. The progress that has been made on the technology over the past few years has been wildly impressive, yet many problems remain unsolved. While this progress continues forward, very little is being said in urban planning communities regarding the potential for such tremendous change. In this paper, I will explore various facets of current knowledge on the topic to provide a base line of understanding in a field of study that is still in its infancy. The first chapter of this paper will explore the fundamental assumptions that precede the literature review. I review the ways in which history can teach us about predictions related to technology, the consequential land use changes that occurred after the commercialization of the original automobile, and how it is possible that autonomous vehicles (AVs) could be a disruptive technology. A "disruptive technology" is one that essentially creates an entirely new market, thus "disrupting" the existing market to make space for a new set of values. Finally, I will review the current status of autonomous vehicles from a methods and product perspective.

HISTORY OF FUTURISTS

At some basic level, all planners are concerned with futures, whether that be on a short-term horizon or in the creation of a long-term city plan based on 30 year projections. While this is true, few planners would consider themselves to be "futurists," as this refers to an entirely different and specific set of individuals who "use foresight to describe what *could* happen in the future and, in some cases, what *could* happen in the future."[1] Futurists

[1] "What is a Futurist?" Copyright 2015. Accessed August 07, 2015, http://associationofprofessionalfuturists.org/futurists

are not necessarily making predictions about the future but instead are using an analytical process to review a range of possible outcomes. The field of urban planning is concerned with implementing policy that has some weight in our cities, and how they grow and change over time. Whether we aspire to promoting certain ideals in our planning practice is a personal choice, but the field as a whole is and should be mostly concerned with solving problems.

Science Fiction often serves as a heuristic for thinking about the future in both practical and ethical terms. Books, films, and other artists have been able to paint both optimistic and dystopian pictures of the future through the art of storytelling. These stories have spurred the imagination of children and adults and served as a thought experiment in evaluating our values. These stories often begin to shape the way we see the world by offering new perspective, eliminating all that is familiar so that we are able to focus fundamental values related to the human experience. This is only one arena in which humanity has been contemplating the changes that can occur and how our actions directly influence the lives of those who will be born long after us.

Speculations about the future of technology have been prolific and many predictions have been made regarding information and telecommunication technology (ICT) since the invention of the telephone. In 1893, it was envisioned that by 1993 most people would live exclusively indoors, conducting their business solely through ICT and only physically interacting with others on special occasions.[2] Geels, et al. point out that futurists were illustrating the possibility of automated vehicles as far back as the 1939 World Fair in New York in a Futurama exhibit hosted by GM.[3] [As we come incrementally

[2] Frank W. Geels and Wim A. Smit, "Failed Technology Futures: Pitfalls and Lessons from a Historical Survey." *Futures* (2000): 868.
[3] Frank W. Geels and Wim A. Smit, "Failed Technology Futures," 870.

closer to realizing AV technology, interestingly, it is the auto manufacturers of the world who are resisting this type of technological advancement in society, for reasons to be discussed later in this report]. In the 1960s and 70s, scientists and engineers were predicting a world in which a centralized computer could serve to optimize efficient traffic flows in a city. Geels, et al. cite several books and illustrations that were published in the U.S. and in The Netherlands depicting these futuristic scenarios. In the 1980s, new ideas for the application of communication technology in transportation ushered in various new predictions about the future. Telematics is a field of study concerned with "telecommunication, mass-communication, data-communication and data-processing,"[4] and has produced various products such as vehicle tracking, navigation systems, car sharing, and emergency warning systems. Initial speculations about how these technologies would manifest commercially were made in silos but eventually turned into more integrated solutions that include data collection by sensors, satellites, and cameras; data processing through central computers; and the means by which data is transferred (largely imagined as vehicle-to-infrastructure, or "V2I").[5]

Long before these capabilities ever made their way into the mainstream consumer's life, people were talking about these ideas and how they could change the way that the world does business. For example, it was predicted that the use of teleconferencing would significantly reduce the need for business travel – this idea was based on an assumption that the number of business contacts one keeps will remain static. The concern at that time was that teleconferencing would have to improve in terms of high-definition quality, color, and audio so that physical expressions would be conveyed (nuance is an important consideration in communication). What this prediction did not account for, however, was

[4] Frank W. Geels and Wim A. Smit, "Failed Technology Futures," 870.
[5] Frank W. Geels and Wim A. Smit, "Failed Technology Futures," 870.

that the expansion of telecommunication would actually increase a person's network, thus nullifying the base assumption. Concern for the technical barriers to replacing business travel with teleconferencing overlooked some of the more jarring problems associated the underlying assumption that this technology would reduce business travel.

The Geels, et. al. article produced several interesting findings from evaluating a number of predictions made about ICT and the future. Of these findings, it was noted that ones' cultural lens was a significant influence that assisted in crafting predictions about the future applications of ICT. Meaning, popular concerns of the day are projected into expectations for improving on those issues.

> …the popularity of speculations on automated cars and roads in the second half of the 1930s may be explained partly as a reaction to the first years of the 1930s, which were characterized by worldwide economic depression and unemployment. The Futurama-exhibition by General Motors can then be interpreted as a wider cultural promise of a better society through technology…[6]

We often make predictions about the future of technology based on what we know about current technologies. Rather, people tend to view the future as an extension of what currently exists – essentially, we visualize these technologies as providing the same functions as the existing model. There are many tools at our disposal that help us to make predictions about the future but these are simply tools and it is true that even with these massive sets of data and sophisticated modeling tools, we have been impressively poor at predicting events and applications of new technologies. Geels, et al point to the concept of the "paperless society" that was predicted to be an outcome of the growing capacities of electronic information storage and transmission technology. While there has been a reduction in the amount of paper that is required to conduct daily business, but as of 2015, we are not living in a society that is entirely "paperless." The new has not replaced the old

[6] Frank W. Geels and Wim A. Smit, "Failed Technology Futures," 877.

– they coexist.[7] In a book written by a notorious professor of risk engineering at the Polytechnic Institute of New York University, Nassim Nicholas Taleb asserts that humanity is eager to "impose narratives on the world," in spite of the fact that "large, improbable and highly consequential events like World War I or the rise of the Internet – are not predictable."[8] Looking back at the predictions that were once made about present day phenomena is a helpful reminder that even some of the greatest minds have been unable to account for some of the factors that were significant barriers to the implementation of their ideals. This will certainly be true for aspects of AV technology. It is impossible to know exactly how this technology will play out in reality – let alone identify which barriers could eventually cripple or slow the production of AVs.

LAND USE IMPLICATIONS OF THE AUTOMOBILE

The automobile and land use have been inherently intertwined since the very invention of the motorized vehicle. This feat of mechanical engineering was disruptive in the way that people lived their lives and did business on a daily basis. Cars were able to replace horses as the primary form of transportation, alleviating some problems facing cities (such as waste on public streets). The conventional automobile represented a shift in the places that people lived and expanded business as ventures were now able to reach out further through a more efficient method of transportation. As with many other mechanical inventions, there was an interim period where both the new and the old methods of getting around operated side by side on the same street. Cars, pedestrians, horses, and wagons all fought for the same space in that intermediate timeframe. As anyone who has visited a sprawling metropolis in the United States can report, cars eventually won that war and have

[7] Frank W. Geels and Wim A. Smit, "Failed Technology Futures," 877.
[8] "You Are all Soft! Embrace Chaos! 'Antifragile' Book Review." The New York Times. Last Modified December 16, 2012. http://www.nytimes.com/2012/12/17/books/antifragile-by-nassim-nicholas-taleb.html?_r=0

taken over all but only the tiniest slivers of (often dangerous) sidewalks and bike lanes, dominating the ways in which we organize our communities. The overarching problems in many cities are about traffic and parking. Interestingly, people were questioning the wisdom of the ways we chose to implement the vehicle as early as 1924. John Ihlder, a manager in the Civic Development Department for the U.S. Chamber of Commerce, wrote, "Probably if we had realized back in 1900 just how drastic are the changes which the automobile is forcing upon us we would have organized a crusade against it."[9] To provide some context for this quote, he wrote this in an article that discusses the counter effects of each iteration of modernization, particularly where the automobile made both the suburbs and the cities more accessible to a larger number of people. His writing advocates for zoning as a solution for dealing with the capacity limitations and traffic issues of the streets at that time. He asked several key questions about parking – should cities provide parking free of charge? Is parking an amenity that should be paid for by car owners? Where will we accommodate parking – on city streets or on private land? This was a point in time where some very strategic decisions were being made about "norms" for accommodating the vehicle in America. John wrote this article during the time that a Standard State Zoning Enabling Act was being developed and refined.[10] Because the way in which we live and do business is so heavily tied to the way that we use transit – any drastic changes in transit capabilities and methods will have implications for land use and planning.

AUTONOMOUS VEHICLES: DISRUPTIVE TECHNOLOGY?

The world is rapidly urbanizing at the same time population growth is occurring, and cities are trying desperately to grapple with the indirect effects of these trends. Patterns

[9] John Ihlder, "The Automobile and Community Planning." *Annals of the American Academy of Political and Social Science Vol. 116* (1924): 199.

[10] "Standard State Zoning Enabling Act and Standard City Planning Enabling Act." Accessed August 11, 2015, https://www.planning.org/growingsmart/enablingacts.htm

of sprawling real estate development are finally being re-considered. Cities are looking for any and all solutions to solving traffic capacity issues. Planners are coming to the conclusion that we have essentially built housing unreasonably far from employment centers, necessitating the need for additional capacity on the roads. Americans are slowly beginning to realize that we cannot financially maintain the infrastructure that is required to sustain such unsustainable land use patterns. Social development has been defined by Ian Morris (author of the book *Why the West Rules – For Now*) as “a group’s ability to master its physical and intellectual environment to get things done.” [11] It is easy to find indicators that show we have made changes that have improved the efficiency of the ways in which we ‘get things done.’ However, as a whole, we have made some poor strategic decisions about the implementation of mechanical power on a large scale. This explains why there is so much optimism around the idea that AVs could assist us in altering the current course of unsustainable development in America.

The Industrial Revolution was certainly disruptive. Humanity found ways to generate mechanical power and harness that power to vastly improve lives while altering the trajectory of the economy forever. Today we are attempting a new kind of revolution – one in which we produce massive metal power. “Using our brains to understand and shape our environments – what the steam engine and its decedents did for muscle power.”[12] Surely this generation of mental power will do just as much for society as the previous boost to muscle power.

> Every generation has perceived the limits to growth that finite resources and undesirable side effects would pose if no new […] ideas were discovered. And every generation has underestimated the potential for finding new [...] ideas. We

[11] Erik Brynjolfsson and Andrew McAfee. *The Second Machine* Age. Brynjolfsson, Erik. 2014 (New York: W.W. Norton, 2014), 4.

[12] Brynjolfsson and McAfee, *The Second Machine Age*, 7.

> consistently fail to grasp how many ideas remain to be discovered […] Possibilities do not merely add up; they multiply.[13]

This generation is struggling with many of the same problems that previous generations have grappled with – hunger, water scarcity, and poverty. None of these problems have been eradicated in spite of the immense amount of wealth and capabilities that have emerged from the products of mental power. Fortunately, communication tools have only expanded in number, providing several different forums for developing ideas that have the potential to solve some of these issues. During these huge cultural shifts and improvements in efficiency, there will always be winners and losers. Jobs that were once steady and well-paid will become completely irrelevant and those who have devoted their lives to mastering their craft could find themselves unemployed. Entire industries will go under, leaving many struggling to re-establish themselves in a new economy. Proponents of AV technology will have to face the fact that these new capabilities will, in the short term at least, harm many people who are already struggling to make ends meet. It is possible that AVs will take attention away from services like public buses and trains that many depend on to get to work. It could be that federal agencies that typically fund large public infrastructure projects start to make determinations on which projects to fund based on an "AV filter," much like the current NEPA structure of evaluating projects based on environmental factors. Labor and public transportation are not the only elements that could drastically change in coming years, but these are certainly the most evident "pangs" of societal change as a result of this massive infusion of mental power.

McKinsey Global Institute notes that disruptive technologies demonstrate a rate of change in either performance or price that is far beyond the abilities of alternatives. Additionally, these technologies must have global reach serving as a new 'general purpose

[13] Brynjolfsson and McAfee, *The Second Machine Age*, 79.

technology.’ Disruptive technologies may be mono-functional, but they give rise to a wide range of new products, services, and even industries. These technologies directly affect the ways that people all over the globe live their lives and will have huge economic value, not just in the sense that they improve efficiency over existing technologies – but also because of the fact that new methods of generating revenue arise.[14]

CURRENT STATUS OF AV TECHNOLOGY

The media is very interested in watching AV technology progress and is active in marking any incremental advancement of its development. As a preface for the rest of this paper, it is important to understand the current status of the technology today (in 2015). It is also helpful to review the distinctions between levels of autonomy and the various methods that are being advocated by OEMs (original equipment manufacturers).

There are two sets of definitions that are commonly cited by researchers and practitioners. The NHTSA (National Highway Traffic Safety Administration) published a set of five levels of autonomy (this is perhaps the most frequently cited):

> No-Automation (Level 0): The driver is in complete and sole control of the primary vehicle controls – brake, steering, throttle, and motive power – at all times.
> Function-specific Automation (Level 1): Automation at this level involves one or more specific control functions. Examples include electronic stability control or pre-charged brakes, where the vehicle automatically assists with braking to enable the driver to regain control of the vehicle or stop faster than possible by acting alone.
>
> Combined Function Automation (Level 2): This level involves automation of at least two primary control functions designed to work in unison to relieve the driver of control of those functions. An example of combined functions enabling a Level 2 system is adaptive cruise control in combination with lane centering.

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[14] James Manyika, et. al., “Disruptive technologies: Advances that will transform life, business, and the global economy.” (White paper produced by the McKinsey Global Institute, 2013), 3.

Limited Self-Driving Automation (Level 3): Vehicles at this level of automation enable the driver to cede full control of all safety-critical functions under certain traffic or environmental conditions and in those conditions to rely heavily on the vehicle to monitor for changes in those conditions requiring transition back to driver control. The driver is expected to be available for occasional control, but with sufficiently comfortable transition time. The Google car is an example of limited self-driving automation.

Full Self-Driving Automation (Level 4): The vehicle is designed to perform all safety-critical driving functions and monitor roadway conditions for an entire trip. Such design anticipates that the driver will provide destination or navigation input, but is not expected to be available for control at any time during this trip. This includes both occupied and unoccupied vehicles.[15]

The second set of levels of autonomy that is commonly referenced is one that was published by SAE International (Society of Automotive Engineers). This definition includes six levels of autonomy, including:

Level 0 – No Automation: the full-time performance by the *human driver* of all aspects of the *dynamic driving task*, even when enhanced by warning or intervention systems.

Level 1 – Driver Assistance: the *driving mode*-specific execution by a driver assistance system of either steering or acceleration/deceleration using information about the driving environment and with the expectation that the *human driver* perform all remaining aspects of the *dynamic driving task*

Level 2 – Partial Automation: the *driving mode*-specific execution by one or more driver assistance systems of both steering and acceleration/deceleration using information about the driving environment and with the expectation that the *human driver* perform all remaining aspects of the *dynamic driving task*

Level 3 – Conditional Automation: the *driving mode*-specific performance by an *automated driving system* of all aspects of the *dynamic driving task* with the

[15] "U.S. Department of Transportation Releases Policy on Automated Vehicle Development." Last Updated May 30, 2013. http://www.nhtsa.gov/About+NHTSA/Press+Releases/U.S.+Department+of+Transportation+Releases+Policy+on+Automated+Vehicle+Development

expectation that the *human driver* will respond appropriately to a *request to intervene*

Level 4 – High Automation: the *driving mode*-specific performance by an *automated driving system* of all aspects of the *dynamic driving task*, even if a *human driver* does not respond appropriately to a *request to intervene*

Level 5 – Full Automation: the full-time performance by an *automated driving system* of all aspects of the *dynamic driving task* under all roadway and environmental conditions that can be managed by a *human driver*[16]

A high-level description of the other distinctions in AV developments also requires defining some terms and elaborating on their intersections. V2I refers to "vehicle to infrastructure," wherein there is communication between the vehicle and infrastructure. V2V (vehicle to vehicle) refers to vehicles communicating amongst each other. It would be difficult for AVs to rely too heavily on any V2I due to the sheer cost of implementing these systems consistently and widely. As of 2015, there has not been a clear business case being made for this method of data transmission.

Traditional automakers are taking a vastly different approach to developing AVs than that of Google. Mercedes, Audi, and Nissan have all been revealing automated features, but incrementally. In contrast, Google has taken an "all or nothing" approach by going straight toward Level 3 automation (see NHTSA standards). In doing so, Google is making the statement that they see the future very differently from the status-quo. Traditional automakers may not be as keen on ushering in the future very quickly – as there is no real incentive for them to see the market change in any way. Current market conditions of mass production are favorable.

On the international front, Shaldover reviewed AV activity in the international arena. This article outlines the most recent studies that have been conducted internationally

[16] "SAE Levels of Driving Automation." Last Updated December 18, 2013 by Bryant Walker Smith. http://cyberlaw.stanford.edu/blog/2013/12/sae-levels-driving-automation

(largely in Japan and through the European Commission, but also the US and various small countries). Most notably, the literature that was available at the time of the study (December, 2012) was based largely on either partially-automated personal vehicle applications or on fully-automated public transit and trucking. There have been many demonstrations throughout the past ten years in major world expo settings. The article discusses university projects and research being conducted by auto manufacturers across the world. It is interesting to note that German car manufacturers are less inclined to be optimistic about these automated features, except in remote applications or professional driving simulations. French projects are more theoretically-oriented and academic in nature whereas the Japanese projects are highly-technical and demonstrative of successful engineering feats. Most of the research that has been conducted in Japan and Europe have been federally funded whereas the US research has been conducted largely by corporations such as Toyota.[17] What this suggests to me is that the public sector in other countries may view AV technology as a public good, a partial solution to transit woes. However, the view that is popular (and also true) in the U.S. is that those who are able to produce AV technology and create a socially appropriate platform will be the next generation of highly profitable automakers.

CONTEXT: AUSTIN'S RELATIONSHIP WITH THE TECHNOLOGY SECTOR

The rise and fall of cities like Detroit have highlighted the dangers of cities concentrating their economies in a single sector. As America began its fascination with the car and Fordist policies enabled the mass proliferation of vehicle ownership amongst middle class Americans, Detroit was a clear "economic winner," creating and maintaining a vast amount of jobs. While I do not intend to draw a direct parallel between Detroit and

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[17] Shladover, S.E., "Literature Review on Recent International Activity in Cooperative Vehicle – Highway Automation Systems," *PATH Research Report* (2012): 1-32.

Austin (Austin's economy is fairly diversified for a mid-size city), I do assert that Austin is poised to benefit from the upswing of the commercialization of AVs. One strong indicator of this possibility is due to the history of Austin's efforts to recruit and maintain companies in the technology sector. Companies in Austin are already designing and manufacturing elements that are being used in AVs. For example, Freescale (based in Austin) recently "unveiled the S32V microprocessor, which is the first automotive vision SoC ["System on Chip" – integrated circuit that brings all components of an electronic system onto a single chip] that will provide safety, reliability, and security in the automation and co-pilot driving of self-driving vehicles."[18] Additionally, Austin has a cultural base that would be apt to adopt these technologies for personal use rather quickly upon their unveiling.

In a report that examines Austin's willingness to adopt this technology, researchers Prateek Bansal, et al. note that, "…males with higher household income, living in urban neighborhoods, who travel more, all other attributes remaining constant, are estimated to have a practically significant inclination to adopt AVs."[19] It's reasonable to assume that in Austin's male-dominated tech sector (where Census data shows 79% of the tech talent in Austin is male),[20] the city would see a rather friendly set of early adopters. In contrast, the researchers found that the elderly population (a market that has been targeted as prime benefactors of AV technology) is less apt to have an interest in using AVs. The reasons for

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[18] "Freescale Launches S32V Vision Microprocessor: Self-Driving Cars Are About to Get Smarter." Last Updated March 2, 2015. http://www.techtimes.com/articles/36487/20150302/freescale-launches-s32v-vision-microprocessor-self-driving-cars-are-about-to-get-smarter.htm

[19] Prateek Bansal, Kara M. Kockelman, Amit Singh. "Assessing Public Opinions Of and Interest In New Vehicle Technologies: An Austin Perspective," *Under Review for Publication in Transportation Research Part C* (2015): 16.

[20] CBRE, "Scoring Tech Talent: Influencing Innovation, Economic and Real Estate Growth in 50 U.S. Markets" (White Paper, CBRE Research, 2015): 34.

this were unknown to surveyors, but it was suggested that it is a possible lack of faith in the technology or an unwillingness to learn how to interface with the vehicles.

Austin's relationship with the technology sector has been forged through many economic development activities going back to 1957, when the Austin Area Economic Development Foundation set out a "blueprint of the future" – outlining strategies to recruit companies that were complementary to Austin's existing industry. It is clear that Austin's technology development plan was derived from similar plans coming out of Silicon Valley. These strategies included, "creating science parks; investing in university research; providing capital assistance; creating small business incubators; building necessary infrastructure such as roads, airports, housing, ad telecommunication networks; playing up quality-of-life factors; investing in education and training programs; and creating public-private partnerships."[21] These strategies have served Austin well – in 1963, IBM moved their Selectric typewriter facility to Austin; Texas Instruments set up shop in 1967; Motorola made an appearance in 1974; and the Dell era roared through the 1990s. As with all growth, there were portions of the community that were not entirely happy with the changes happening around the city.

In a book published by the University of Texas, researchers explored the history of the technology industry in the city of Austin and referred to the formation of this industry as the "technopolis." In the book, it is noted that the City of Austin has repeatedly been accused of 'buying off' companies through incentive packages. Microelectronics and Computer Technology Corporation (MCC) was offered hefty financial packages, when the University of Texas agreed to lease out the Balcones Research Center to MCC for a "nominal cost." The city even offered subsidized mortgages to the employees of MCC

[21] Straubhaar, Joseph, et al., *Inequity in the Technopolis* (Austin: University of Texas Press, 2012), 72.

(valued at approximately $20M). The state of Texas encouraged the University of Texas faculty to "conduct applied research by allowing [them] to be shareholders in private companies that emerge from their research."[22] Certainly there are positive outcomes that have benefited the lives of Austinites, as there has been a relatively strong rate of growth in well-paid jobs for the highly-skilled worker. It is important to remember, however, that a high rate of growth emerging from a small base is not necessarily indicative of the magnitude of success that is often portrayed to the public. It is also important to remember that, while proponents of these "technopolis strategies" would point to job creation as an indicator of overall economic health, these jobs are largely for the "symbolic-analytic" worker – highly educated, skilled "mind-workers" who are "less and less definable by the old loyalties of nation, corporation, or place." In other words, these are "problem-solving, problem-identifying, and strategic-brokering jobs." While this infusion of wealth has largely benefited the city of Austin, it has disproportionately affected the middle and lower class through an increase in the cost of living, property taxes, and widening labor divisions. "A 2000 article in the alternative weekly the *Austin Chronicle* asks whether the price of success has been too high if the result is an ever-widening income and knowledge gap." [23] Those who oppose the city of Austin's choice to actively promote the proliferation of the "technopolis" believe that the cost of pursuing these benefits has not been consistent with outcomes that are beneficial to all segments of society in Austin. At the heart of the opposition is the concern that Austin will become a place that is no longer concerned with the plight of the middle and lower class. Questions of value aside, the global marketplace has rapidly shifted into a 'new information society.' Daniel Bell, a theorist, argued that these changes will "fundamentally change the structure of work and power relations at

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[22] Straubhaar, Joseph, et al., *Inequity in the Technopolis* (Austin: University of Texas Press, 2012), 71.
[23] Straubhaar, Joseph, et al., *Inequity in the Technopolis* (Austin: University of Texas Press, 2012), 73.

work, increasing the power of the skilled knowledge worker and thus expanding the base of meritocracy, since social mobility will no longer be limited to access to capital, the critical resource of the industrial society."[24] This optimistic view of societal change implies that education will become the new method by which driven individuals will be able to adapt to the coming changes of the workforce.

In a recent CBRE Research white paper, Austin came in as number 9 in the list of top cities in the United States for tech talent. Austin receives such high marks due to its high levels of educational attainment and low cost of living (when compared to other cities listed in the report). Additionally, there has been a great deal of growth for "millennials in their 20s" since 2009 (6.8%, based on US Census Bureau statistics from 2014).[25] "…nearly 75% of the top 50 [US] markets have an educational attainment rate greater than the US average." CBRE notes that tech talent comprises only 3.4% of the total U.S. workforce. "Though small in size, this labor force has grown at a rapid pace, and has been one of the most influential factors in the recent U.S. economic recovery."[26] Why are these facts important to consider when discussing the commercialization of AV technology in Austin? From an economic development standpoint, there are many firms in the city that are already working on (and others that are poised to generate) components that are potential solutions to the technology required for autonomous vehicles. Secondly, with a high concentration of "top tech talent" comes a tendency to be amongst the first populations to adopt new technology. Additionally, Texas has traditionally been hesitant to adopt new legislation that would hinder the development of new technologies. All of these factors could lead to a fast adoption rate of AVs. In fact, Google has even begun testing their AVs on Austin

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[24] Straubhaar, Joseph, et al., *Inequity in the Technopolis* (Austin: University of Texas Press, 2012), 87.
[25] CBRE, "Scoring Tech Talent: Influencing Innovation, Economic and Real Estate Growth in 50 U.S. Markets" (White Paper, CBRE Research, 2015): 34.
[26] CBRE, "Scoring Tech Talent," (White Paper, CBRE Research, 2015): 5.

streets.[27] For those in Austin who have questioned the viability of AVs, this news comes as an awakening to the possibilities surrounding new transit options that could assist in alleviating the capacity challenges that the city is facing in the next 30 years. The Texas Department of Transportation (TxDOT) reports that 180,000 vehicles drive on I-35 between US 183 and SH 71, which is considered the "central artery for travel and commerce in Austin."[28] The Texas Transportation Institute (TTI) also reports that Austin regional population is estimated to grow to approximately 3.25 million by the year 2035 ("nearly double today").[29]

[27] "Google Testing Self-Driving Cars in Austin." Last Updated July 7, 2015. http://www.texastribune.org/2015/07/07/google-testing-self-driving-vehicles-austin/

[28] "TTI's Advanced Traffic Forecasting Helps Austin Prepare for 2035." Last Updated February 19, 2014. http://tti.tamu.edu/policy/tti-advanced-traffic-forecasting-helps-austin-prepare-for-2035/

[29] "TTI's Advanced Traffic Forecasting."

Chapter 2: Literature Review

In order to understand the current status of AV development, I reviewed a wide range of literature. Often there is a huge disparity between the pace of technology advancement and the ability of governing bodies to adapt or prepare for these massive changes. Lee Walker, former Board Chair at Capital Metro once stated, "In high-tech, you need to go from idea to the marketplace in 90 days or you're chopped liver. In 90 days at Capital Metro, I can't get a resolution to sing a hymn to the Blessed Virgin Mary."[30] This is the context under which planners must assess their options when making decisions on 30 year horizons. On the one hand, there are few directives or policies being initiated from the top-down, but planners cannot ignore the strong possibilities of these drastic changes and both the positive aspects and negative externalities associated with them.

SAFETY

> I saw six people die horribly in an accident. I walked home holding on to walls and trees. It took me months to begin to function again. So I don't drive. But whether I drive or not is irrelevant. The automobile is the most dangerous weapon in our society – cars kill more than wars do.
>
> –Ray Bradbury, legendary science fiction writer[31]

There is clear incentive to develop this technology from a safety standpoint. Car crashes are the number one cause of fatalities amongst young people – not only this, but everyone feels the fire of fear as virtually nobody is immune from this risk. EnoTrans notes that high cost of AVs will be a primary barrier to mass consumer availability. Authors outline some of the benefits of AV technology – chiefly safety. Autonomous Vehicles nearly eliminate problems that are known to frequently cause accidents. AVs do not drink

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[30] Straubhaar, Joseph, et al., *Inequity in the Technopolis* (Austin: University of Texas Press, 2012), 76.
[31] "10 Things You Should Know About Ray Bradbury," Last Modified August 26, 2013, http://mentalfloss.com/article/52385/10-things-you-should-know-about-ray-bradbury

and drive, become distracted, and would be more regimented in following traffic laws. Since nearly 40% of fatal crashes are caused by alcohol or fatigue, the implementation of AVs could dramatically reduce traffic fatalities. Nearly every journal article I reviewed stressed the fact that car accidents are the primary cause of death for Americans between 15 and 24 years of age.[32]

In a study produced by the Texas A&M Transportation Institute, researchers estimated the indirect safety benefits of AV technology. "It is doubtful that automated vehicles can be programmed for every feasible roadway or pre-crash scenario, and the efficacy of machine learning and decision making does not yet match the human capability to decide and react to unexpected, even unknowable, scenarios."[33] In a simple sensitivity analysis, the researchers looked at factors such as "lost earnings, willingness to pay to avoid a fatality" to determine the economic impact of lives saved due to automated vehicle technology. The authors estimate that a 50% reduction in road fatalities (over base year 2011) would result in 16,183 lives saved and $147 billion in economic impact. In Texas alone, 1,508 fatalities could be avoided in a 50% reduction scenario.[34] One might question the ability of researchers to quantify the value of a life – and this is an incredibly valid concern. It's almost astounding that federal agencies have even attempted to take on this task at all because the language in which policymakers speak is stripped of its complexity (to the point of humor) and reduced to simple numeric terms that are often a result of primitive modeling. Authors of the Texas A&M Transportation Institute study explain that, "The USDOT determines the value of a statistical life (VSL) by synthesizing previous

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[32] Daniel J. Fagnant and Kara M. Kockelman, "Preparing a Nation for Autonomous Vehicles" (White Paper by Eno Center for Transportation, 2013).
[33] Wagner, Jason, et al., "Automated Vehicles: Policy Implications Scoping Study" (Sponsored by Southwest Region University Transportation Center, Texas A&M Transportation Institute, 2013), 13.
[34] Wagner, Jason, et al., "Automated Vehicles: Policy Implications Scoping Study," 14.

attempts to value life, drawing on empirical estimates, practical adaptations, and social policies. These measures can include lost earnings, willingness to avoid fatalities, and other aspects."[35] What these figures actually do is represent the value that society is willing to place on a human life – which seems like an impossible task, but are nonetheless used for illustrative purposes.

POLICY

The literature on policy related to AVs is vast – in this arena, researchers have recognized that it is important to educate policymakers so that they are able to understand the implications of any regulations placed on testing and commercializing AVs. It is a delicate balance between ensuring the safety of the general public and allowing R&D to flourish in smart ways. Too much regulation can stifle innovation and thus delay or prevent the realization of AV technology. Some states have been aggressive in forming regulations that enable AV testing but, in some cases, may not have fully understood the needs of developers when drafting the legislation (according to the Texas Transportation Institute). Several guides produced by think tanks (of all political persuasions) have been produced as a method of educating policymakers, including EnoTrans, RAND, Cato Institute, The Texas Transportation Institute at Texas A&M University, Carnegie Mellon University, and materials produced by the Transportation Research Board.

A very recent piece of research argues that the rollout of AVs could occur quickly and states that policymakers in Canada will need to act quickly in forming regulations. The report provides some guidance on how the public and private sectors can respond to this (potentially) disruptive technology. There are numerous issues that need to be addressed through planning, which are highlighted. As with other policy-oriented reports, this guide

[35] Wagner, Jason, et al., "Automated Vehicles: Policy Implications Scoping Study," 14.

is revealing about the factors addressed and broaches the topic of equitable distributions being considered in decision-making. This white paper is highly focused on the economic effects of AV technology from an economic development perspective, but also acknowledging that these advances will cause changes to the pocketbook of all citizens. Researchers are urging Canada to find ways to plug into the manufacture of AV technology so that Canada does not fall behind in benefiting from new advances in technology as they start to come on-line in the future. One of the themes that remains consistent throughout this research piece is a shift in money flows as AV technology becomes widespread. Several additional questions focused on land use patterns and changes in a consumers' preference for housing. For example, one of the concerns that was raised was, 'will property values drop as people decide they are more tolerant of longer commutes?'[36] These questions are being asked by planners everywhere, as much of the best practices developed over the past several years have been working to reverse the pattern of sprawl.

Andrew Mondschein with the NYU Wagner Rudin Center performed a literature review in 2014 on the key elements of AV technology, revealing how unprepared we are to adapt to this technology. The key question explored in this literature review relates to how planners, policymakers, and other practitioners should begin preparing for ICTs in autonomous applications. Three bodies of literature are reviewed in order to understand overarching trends in research, including: History of Technologies, Social and Applied Science, and Technological Press. The author outlines the existing knowledge while demonstrating gaps in research that must be addressed in coming years. It is argued that planners are not prepared to adapt or shape the future of ICTs within our cities. Much of the research focuses on social changes and travel pattern shifts. It is noted that there is a

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[36] Godsmark, Paul, et al., "Automated Vehicles: The Coming of the Next Disruptive Technology." *The Conference Board of Canada* (2015): 1-72.

gap in literature on ICT impacts on transportation equity and sustainability.[37] The author suggests that planning practice is highly segmented which leads to disjointed efforts in transportation and land use planning. This is problematic because planning history shows that transportation and land use are intrinsically intertwined. Another question that remains to be answered is whether the implementation of ICTs will cause cognitive degradation in individuals. Additionally, there is concern that ICTs will reduce resilience in existing transportation systems. It has been recommended that planners utilize TSM and TDM frameworks to "provide useful practical approaches for supporting or seeking to mitigate many of the ICTs now being deployed."[38]

Narrowing into Texas, Jason Wagner, et al. contemplate the implications of AV legislation on the industry. His article addresses some of the reasons the state of Texas might consider drafting legislation for the testing of automated vehicles. Safety, the authors claim, should be the number one reason that lawmakers consider legislation associated with the testing of these vehicles. Additionally, the authors cite "economic development" as a secondary factor. Researchers claim that implementing rules regarding automated vehicles testing could potentially draw companies into Texas since they would be able to predict the regulatory environment in which they are working. However, "there is insufficient data to determine the effect of legislative measures on AV industry development."[39] The authors then consider an alternative: what about waiting it out? Currently, it may not be necessary at all – since, at the time of the report, there were no known vehicles being tested in the state of Texas (by contrast, California and Nevada are states in which developers are

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[37] Andrew Mondschein. "Re-Programming Mobility Literature Review," *NYU Wagner Rudin Center,* (2014): 42.

[38] Andrew Mondschein. "Re-Programming Mobility Literature Review," *NYU Wagner Rudin Center,* (2014)

[39] Jason Wagner. "Policy Considerations for Automated Vehicle Testing in Texas," *Texas A&M Transportation Institute* (2015): 2.

working on automated vehicles). More recently, Google has begun testing AVs in the city of Austin. Since the industry is still in the beginning stages of developing this technology, allowing them to progress at their own pace might be the best option for lawmakers – since they will be able to generate legislation that is more refined by the time the technology is more fully developed. Authors note that Texas could look to the legislation already enacted in California, Nevada, Florida, and Michigan. The National Highway and Traffic Safety Administration has published a guide full of recommendations for states that are considering legislation. Some of these recommendations include licensing, establishing reporting for testing of AV technology, requirements for hardware that detects and records notifications to operators of any malfunctions. All states that currently have legislation on AV agree that the vehicle must have a human operator that can take over control of the vehicle (this could be a remote person, not necessarily an individual riding in the car).[40]

The RAND Corporation produced a 217 page guide which is intended to be a reference for American policymakers in understanding autonomous vehicle technology and the implications of the adoption of such technology. The RAND Guide covers a wide range of topics including the effect of autonomous vehicles on land use, congestion, energy, emissions, safety, legal, insurance, commercial development, security, and social environments. The study conducted by RAND provides a fairly comprehensive overview of the current status of autonomous vehicles in the United States and will continue to serve as a baseline of knowledge for continued study on autonomous vehicles. Additionally, this work is of high importance in that it is illustrative of the type of information and values that are distributed to policymakers.[41] In reviewing the gaps of knowledge and literature in

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[40] Jason Wagner. "Policy Considerations for Automated Vehicle Testing in Texas," *Texas A&M Transportation Institute* (2015).
[41] James Anderson and Karla Nidhi. "Autonomous Vehicle Technology: A Guide for Policymakers," *RAND* Corporation (2014).

AV adoption, Cohen, et al. produced a paper asking the question, "does knowledge underpin policy?" There are two prongs to the research conducted by Cohen, et al. concerning knowledge gaps in AV technology for policymakers. First, they state that there is a hole in the information being fed to policymakers on the actual effects of AV technology in solving urban problems. The second point is related to cultural and language gaps between scientists and policymakers. This piece is complementary to the RAND Corporation research in that it provides a counterpoint or critique of the information that is being distributed to policymakers.[42] EnoTrans completed a report on the opportunities, barriers, and policy recommendations for AVs. Much like the RAND Corporation report, the authors have taken on a comprehensive overview of the potential benefits (safety, congestion reduction, travel-behavior impacts, freight transportation) and the barriers to implementation (cost, licensing, litigation, security, privacy). EnoTrans notes that high cost of AVs will be one of the top barriers to mass consumer availability Noting that vehicles would be able to travel closer together, an increase in highway capacity is expected. The possibility of long term changes in infrastructure, including signal control with intersection management, could improve the efficiency of roadways. While these autonomous intersection management technologies are exciting, they likely would not be implemented for some time (possibly not until AV-market penetration reaches 95%). One could reasonably expect that there would be an increase in roadway capacity demand as people who were once unable to drive (elderly, disabled, young children) would be given the autonomy to travel by car. EnoTrans also gives an overview of the current status in autonomous freight transportation. "The mining company Rio Tinto is already using 10

[42] Galit Cohen and Peter Nijkamp. "Information-Communications Technologies (ICT) and Transport: Does Knowledge Underpin Policy?" *Telecommunications Policy* (2002): 7.

self-driving ore trucks, with plans to expand to 150 vehicles within four years."[43] Researchers speculate that labor groups would most certainly resist a transition to autonomous vehicles alongside the freight railroad industry (or other competing industries). The labor side of freight transportation would not be completely eliminated, however, since workers would still be necessary to load and unload trucks and provide security. EnoTrans also evaluated the barriers to implementation of AV technology. Regarding the cost barriers to market penetration, "at current high technology costs of $100,000 or more, benefits are mostly small compared to purchase prices, except for individuals with very high values of time. Once prices come down to $37,500, persons with high values of travel time and/or parking costs may find the technology a worthwhile investment. Only at the $10,000 added price does the technology become a realistic investment for many, with even with a $1 per hour time value and $1 daily parking cost generating a 13% rate of return."[44] Affordability can be achieved through mass production and prices are expected to fall over time. Research has suggested that, if AV prices inch closer to the cost of conventional vehicles, the market would readily respond. On the topic of electronic security, many policymakers and manufacturers are concerned about possible breaches (whether by hackers, terrorist organizations, or even simply disgruntled employees). While many bleak scenarios could easily be painted, some security professionals point out that the vast majority of cyber-attacks are typically acts of espionage and not necessarily acts of sabotage. In other words, hackers are typically more interested in information than they are performing acts of violence. Espionage is not the only concern when it comes to privacy and data. Since AV technology suppliers will likely

[43] Daniel J. Fagnant and Kara M. Kockelman, "Preparing a Nation for Autonomous Vehicles" (White Paper by Eno Center for Transportation, 2013): 7.
[44] Daniel J. Fagnant and Kara M. Kockelman, "Preparing a Nation for Autonomous Vehicles" (White Paper by Eno Center for Transportation, 2013): 9.

hold liability in the event of a crash, it is almost certain that suppliers would retain the crash data stored in the vehicles. In essence, the concern here is that there would be private corporations that retain the data that can be used against individuals in court. EnoTrans researchers found a gap in the research on cyber security and resiliency, data ownership, human factors and human-machine interaction. In conclusion, EnoTrans offers policy recommendations and an outline of missing research that would assist in creating frameworks for policy-related decisions.[45]

INSURANCE

While it appears that much of what we know today regarding car insurance will be similar in an AV-dominated marketplace, Lloyds produced a white paper on the topic, providing some more clarity and exploration into insurance for AV applications. This white paper addresses insurance issues that have arisen through the advancement of AV technology. In the UK, current liability lies with the user of the car, regardless of the cause of any accident. The one caveat to this standard is a failure of technology – in which case, the liability lies with the manufacturer. While laws will vary across country (and state), the risks remain the same. Lloyds outlines these risks, showing that there will be a large transfer or risk from the driver to the machine. Lloyd emphasizes the fact that there will need to be redundancies in the system in order to reduce risk assigned to car manufacturers. While it is expected that autonomous vehicle technology will reduce the overall number of crashes (due to the fact that most car accidents are due to human error), there will still be residual driver error. A “driver/passenger” may be inclined to misjudge how much responsibility has been assigned to them and alternate to different modes at inappropriate times. Reduced situational awareness is a possible outcome if drivers perceive that they are

[45] Daniel J. Fagnant and Kara M. Kockelman, “Preparing a Nation for Autonomous Vehicles” (White Paper by Eno Center for Transportation, 2013).

not needed to operate the vehicle. This, of course, is analogous to the affect of GPS directions causing people to "turn off common sense" and follow voice commands. Reputational risk will also be a challenge that car manufacturers will be forced to address. While this has always been an issue for these businesses, any failure of an AV will initially come under increased scrutiny. Manufacturer recalls are not uncommon in the current era of car manufacture, but the increased publicity that will be afforded AVs in the initial offerings will heighten reputational risk. The final risk listed by Lloyds is cyber risk. This not only refers to the potential for computational malfunction, but the safety implications associated with connectivity. Networking with other vehicles, tablets, computers, or infrastructure pose opportunities for malicious interference. Data security would become a challenge that will have to be addressed not only by engineers, but also by policymakers, insurance companies, and the individual user. When it comes to the development of new types of insurance to accommodate the transformation of driving, Lloyds notes that Cyber Coverage is a new form of insurance policy that is being considered by insurance companies (a policy which would offer coverage for issues arising from cybersecurity breaches). The stakeholders that will need to consider cyber coverage will include "operators, systems designers, manufacturers, and infrastructure providers."[46] "For users, there will be scope for exposure to the costs of investigating data breaches or malicious interference, for defending violated privacy and for repairing damaged systems."[47] Insurance companies will be faced with making distinctions between terrorist insurance and cyber security as well. The Lloyds white paper seems to imply that there is worry in the insurance community that a reduction in insurance claims would result in lower

[46] Gillian Yeomans. "Autonomous Vehicles. Handing Over Control: Opportunities and Risk for Insurance," *Lloyds* (2014): 18.
[47] Gillian Yeomans. "Autonomous Vehicles. Handing Over Control," 18.

premiums and tighter profit margins. Risk of theft could potentially be transferred to renters insurance.

SMART CITIES LITERATURE

The smart cities movement is interesting to review since there are numerous overlapping aspects of planning for smart cities and the commercialization of AVs. They share similarities in that they each seek to harness data collected through various forms of technologies in city management decision-making. It is undeniable that these forms of technology have the potential to drastically improve standards of living for humanity, but it is also difficult to readily accept many of the claims made by proponents of smart cities since there are obvious financial incentives involved. Some of the largest proponents of the smart city movement include IBM and Cisco. Political allegiances have the potential to amass wealth for these companies. Much of the marketing copy is heavily weighted in value-claims that are strategic in nature. As Rob Kitchin states,

> It is noticeable, for example, how smart city vendors such as IBM and Cisco have started to alter the discursive emphasis of some of their initiatives of being top-down managerially focused to stressing inclusivity and citizen empowerment. Through such discursive moves, advocates seek to silence or turn detractors and bring them into the fold while keeping their central mission of capital accumulation and technocratic governance intact.[48]

There have been multiple terms used to refer to this concept in the literature, including Wired City, Smart City, Digital City, and Intelligent City. In 2012, A. Cocchia performed some research on the most widely used terms in the literature but was unable to find precise definitions of these terms. "The label "smart city" […] is a fuzzy concept and

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[48] Rob Kitchin. "Making sense of smart cities: addressing present shortcomings." *Cambridge Journal of Regions, Economy, and Society.* (2015): 133. Accessed August 4, 2015. doi:10.1093/cjres/rsu027

it is used in ways that are not always in accordance with each other."[49] One insightful definition partitioned "smart cities" into three different dimensions, as follows:

> 1. *Technology dimension;* based on infrastructure, particularly ICT, to improve lives
> 2. *Human dimension;* based on educating people and thus improving the 'smart city.'
> 3. *Institutional dimension;* based on governance and policy[50]

Much of the literature in the social sciences is concerned with how these dimensions interact with one another in these applications of technology. Other definitions of "smart cities" focus on the ways in which cities perform in forward-looking ways. In another review of the smart cities literature, researchers state that,

> given the conceptual comprehensiveness of a smart city, it could be thought of as a large organic system connecting many subsystems and components [...]. Dirks and Keeling consider a smart city as the organic integration of systems. The interrelationship between a smart city's core systems is taken into account to make the system of systems smarter. No system operates in isolation.[51]

Making the distinction between a smart city and a non-smart city can be complex without consensus on the definition of 'smart city.' Nonetheless, it is generally agreed upon that smart cities implement ICT with the objective of gathering data to assist in making more informed decisions. Within the context of policy, it is noted that making the switch to a "smart city" entails removing regulatory barriers that would prohibit cities

[49] Annalisa Cocchia. "Smart and Digital City: A Systematic Literature Review." *Smart City.* (2014): 14. Accessed August 2, 2015. doi:10.1007/978-3-319-06160-3_2
[50] Annalise Coochia, "Smart and Digital City," 18.
[51] Hafedh Chourabi, et al. "Understanding Smart Cities: An Integrative Framework." *2012 45th Hawaii International Conference on System Sciences: IEEE Computer Society*. (2012): 2290. Accessed August 6, 2015. doi 10.1109/HICSS.2012.615

from collecting certain data. Beyond collecting this data, there is the issue of whether a city has the fortitude to make regulatory shifts based on the findings of the research. Amy Glasmeier and Susan Christopherson point to Sheridan Tatsuno of NeoConcepts (a consultant for the Institute of Constructive Capitalism at UT Austin in the 1980s) as one of the original minds behind the "smart city." Tatsuno was working in an environment that lauded Silicon Valley as the pinnacle of city making. During this time, the Research Triangle Park in North Carolina was working on developing plans to emulate the Valley. Tatsuno is associated with the "age of the technopolis" and some of the events discussed in previous sections of this paper on Austin. Rob Kitchin pointed out that the 1980s were also a time of "smart city" exploration as city managers worked to implement policies that encouraged entrepreneurial activities and regulations that allowed for flexibility in responding to global market conditions. Glasmeier and Christopherson believe that there has been a shift in the ideas of what constitutes a "smart city" in present day (2015) as the emphasis has moved from hosting the technology sector as an economic development strategy to being a place where technologies are applied.

One strong underlying criticism of smart cities agenda is the lack of concern for issues of poverty. Glasmeier and Christopherson make this note, "[smart city planners] may solve traffic problems, but it is not clear how they will regenerate failing schools or find ways to include neighborhoods facing disinvestment."[52] Further, it is important to remember that a lot of the benefits of data collection being used in smart cities are likely

[52] Amy Glasmeier and Susan Christopherson. "Thinking about smart cities." *Cambridge Journal of Regions, Economy and Society.* (2015): 6. Accessed August 6, 2015. doi.10.193/cjres/rsu034

to skirt low-income neighborhoods as much of the crowdsourced data will be collected from users of smart phones (middle and upper-class). The un-informed, the elderly, the homeless – these are already the most vulnerable populations in any city. Smart city initiatives have the potential to further aggravate these problems unless city planners are able to complement data obtained through technology with data that reflects the realities of those who are unable to contribute to these data sets.

Tim Bunnell writes on "smart city returns" in comparing the historical outcomes of the Multimedia Super Corridor in Malaysia (1990s) to the smart city plans in India that are currently underway. This piece provides an excellent narrative about the dangers associated with allowing corporations to have such high levels of discretion in city planning [Bunnell argues that this is 'unprecedented' – however, reviewing the history of the automaker's impact on American cities speaks to a different reality]. Bunnell's criticism of MSC in Malaysia is that these plans largely benefited the IT companies that were given incentives to locate in the corridor. He notes that the biggest losers of this plan were those who were evicted in order to make way for these new top-down city plans.

Cities will have to think carefully about the value that these companies and technologies can add to their communities and be prepared to use any negative externalities associated with allowing these infrastructure(s) to be implemented as negotiating leverage. Additionally, cities must recognize that they have the ability to review and alter the neoliberal forms of government practice that invite criticism.

Economic Development

Disruptive technologies imply massive changes in the ways that cities, businesses, and people benefit, or do not benefit. Many researchers are predicting an uphill battle with labor across various industries; a vast shift in the flow of capital; and a widening bifurcation between the classes. The cities that could benefit have the potential to successfully attract OEMs (original equipment manufacturers) and other companies that produce complementary components to AVs. These locales will benefit from an infusion of wealth as these companies and their employees find success. Surely there will be places, much like the "rust belt" of America, which will fail to adapt and thus forego certain opportunities (recall the urge of researchers in Canada to leaders, asking them to seek AV commercialization activity in order to stay competitive).

For the most part, companies that have been at the forefront of aggressive development of AVs have been technology companies (Google, Tesla). Automakers in the US have started implementing level 1 and 2 automation into their vehicles, but have done so almost as a reaction to the work that is being done on the technology side. In large part, traditional automakers are not necessarily known to be innovative. The fact is, conventional automakers must be worried about the proliferation of AV technology as it directly challenges their position of power in the US. For decades, these companies have produced vehicles at a level that is affordable to the majority of Americans (though, in reality, many of the components of keeping these cars affordable are subsidized by the federal government). Originally, as a response to the fact that cars were attainable by many, cities adapted streets that were previously used for horses to be used by vehicles. Real estate development expanded from the center as people were now able to tolerate further commutes thanks to mechanical power. At this point in history, it is absolutely necessary for most Americans to own a car due to the nature of their work or the remote location of their homes. Urban planners have been encouraging more dense development in the central cities, which could alleviate the necessity of vehicle ownership, but restrictions on real estate development have prevented the densification of American cities thus far. Public transportation solutions are expensive, especially if ridership is low and heavily subsidized by local jurisdictions. Municipalities already struggle to maintain the existing roadways and bridges, let alone find room in the budget (or convince voters to fund) new public transportation infrastructure. Most American cities have essentially built themselves into a sprawling suburban environment – generating the necessity of vehicles for most people. New urbanists have suggested that we go back to a time where cars were not the primary form of transportation, a time when we built for the pedestrian. While this solution is beautiful in concept, realized versions of this philosophy have been almost entirely unattainable for the middle class. This is a solution that works well for one segment of society, provided they are not in an industry or job that requires travel outside sites that are accessible by public transportation. All this is to note, automakers continue to thrive in today’s built environment because it does not take much to convince a consumer that a car is a necessity (in many cases, lifestyle changes do not eliminate the necessity of a vehicle).

Consider what would occur to conventional automakers if the model that becomes most widely accepted in the US is a shared AV model. The number of vehicles that would need to be manufactured and sold would be significantly reduced. There would be a shift in the auto body repair business as mechanics would be required to understand a new level of complexity in relation to the software components. The existing business model for conventional automakers would be forced to completely transform. For this reason, it seems clear that the emergence of AV technology is not necessarily a welcome change in this industry.

NEW PLAYERS

Morgan Stanley published a blue paper in 2013 that produced a sweeping overview of the effects of AV technology on the OEM industry, the regulatory regime in the US, and consumer preferences. The researchers speculated as to which technologies will win in the battle to produce a level 4 autonomous vehicle, while keeping a running tally on then-current research and projects being funded by US companies. A brief introduction to autonomous vehicles led to predictions on a timeline for adoption and the potential economic benefits that could be gleaned by society if AV technology reached widespread adoption. This piece of research is particularly interesting from the perspective of the automotive industry and the shifting environment created by Google that has and will continue to force the auto industry to prepare for integration with more complex hardware, software, and content created by third-parties.[53] The article discusses the environmental framework that would be necessary for the existence of AVs on the road. First, data network coverage will become a challenge since coverage would need to be expanded into suburban and rural areas. Patterns of data usage would fundamentally alter since current coverage is largely centered in urban areas and has predictable peaks during specific times of day.

> Cisco forecasts that mobile internet traffic will rise at 68% CAGR through 2017, while internet video use will rise at a 29% rate over the same time period. Growth in data demand from autonomous vehicle usage may become a key contributor to continued mobile and internet video growth beyond 2017[54]

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[53] Ravi, Shanker, et al. "Autonomous Cars: Self-Driving the New Auto Industry Paradigm." *Morgan Stanley Blue Paper* (2013).

[54] Ravi Shanker, et al. "Autonomous Cars: Self-Driving the New Auto Industry Paradigm," 59.

Network usage will be necessary as AVs would be transferring data between each other, and transferring data between AV and infrastructure. Additionally, the Morgan Stanley report states that drivers network usage will rise simply due to the fact that they will be able to consume content in their vehicles while in transit. Researchers estimate that US drivers currently spend 75 billion hours in the car on a yearly basis – no doubt this time will be utilized for surfing the web, watching videos, communication with others, and receiving ads; businesses realize they now have an even more captive audience. Between the AVs continually using the network and the driver's personal consumption of data, carriers could find themselves with a new revenue opportunity. It is estimated that the average American spends about an hour in the car every day, potentially increasing in-car mobile usage by 167%. When it comes to access, the Federal Communications Commission regulates wireless bands in the US (for example, the military has a dedicated spectrum for its communications, which is an entirely different spectrum from which consumers access data through their wireless devices). The FCC in allocating space in the 5 GHz band for the transportation industry, which has been contentious. This spectrum would likely be used for dedicated short range communications (DSRC).[55]

Today's conventional vehicle has value primarily in its hardware (according to Morgan Stanley, this figure is about 90%). In the event that there is a transition to AVs, hardware components will be reduced to about 40% of its total value. Software will

[55] Ravi Shanker, et al. "Autonomous Cars: Self-Driving the New Auto Industry Paradigm," 60.

comprise about 40% and the final 20% of value will be attributed to content. From these estimates, it is clear that the space in which OEMs are competing will be changing in nature. In conventional vehicles, the software that is required exists in individual silos. This will not be applicable in the AV, as there will be a centralized system and a great deal of cross-over between components. “All the systems in autonomous car will need to be brought together within a central managing “brain” that can supervise and control almost every function of the car at all times.”[56] There will be segments of the industry that will focus entirely on the software component in building an operating system. It is likely that they will have higher margins than hardware manufacturers. Morgan Stanley predicts that this will mirror the PC and smartphone industry, where there are hardware, software, and integrated experience specialists.

The hardware providers will be current conventional auto OEMs and suppliers. They will perform many of the same functions they already engage in, from assembling the “powertrain, body shell, lighting, seats, sensors, radars, and interface.” This industry will continue to remain much the same as it currently exists and Morgan Stanley describes them as the “HPs/Dells of the auto industry.” Again, these companies will have the lowest margins. The second segment will be the automotive software providers, essentially the operating system suppliers such as tech companies, companies with autonomous OS (operating system) products, and a few OEMs. They will be concerned with functionality, the “infotainment system” (media which provides entertainment and information), machine

[56] Ravi Shanker, et al. “Autonomous Cars: Self-Driving the New Auto Industry Paradigm,” 69.

interface, and autonomous features. Morgan Stanley likens these software providers to the "Microsoft/Linux of the auto industry." It is expected that the profit margins for these companies will be better than hardware providers, but below those of the content/experience providers. Finally, this third segment (content providers) will be compromised of tech companies that are experienced in OS and applications. These will be the companies that will craft the "infotainment" environment and increase the productivity of the passenger through content. They are described as the "Apple/Google of the auto industry," with the highest segment margins. These three segments represent a change that would be a threat to many existing players, but could also allow space for new ventures. OEMs will be forced to reinvent themselves if they plan to continue operating in the auto space. Much of the contention will lie in the battle for content as this is where there is the most opportunity for revenue generation.

COMMERCIALIZATION

While the technical challenges are vast, there are other barriers to entry that encompass more than just the ability to bring a product to a level of safety that would enable commodification. There are numerous factors that will either promote AV commercialization or prove detrimental. One of these factors is whether society will choose to accept the idea of getting into a car that is not being manned by a human. It is not only the relinquishment of control that scares society – there are decades of romantic ideals that have been spoon fed to us through film and ad agencies. For years, auto manufacturers have advertised their wares (cars) in a way that conjures up images of sunny days and coastal roadways as an expression of freedom. A car is not simply sold as a unit of utility

– but an extension of a persons' identity and image. Society has become accustomed to associating cars with all of these idealized aspects of their features – exactly as we have been asked to do by auto manufacturers. Stripping these qualities from the minds of consumers will certainly prove difficult because it is deeply ingrained in our psyche after generations of experience and stories.

One of the primary questions regarding commercialization has focused on whether we will utilize a "shared economy" approach to AV technology. The market seems to be moving in this direction, as evidenced by Uber's recent "poaching" of top robotics scientists and researchers from Carnegie Mellon University.[57] What began as a partnership with the university quickly turned into a controversial 'coup' as the shared economy giant started offering enormous signing bonuses and salary increases to robotics experts. This was highly troubling for Carnegie Mellon as it saw a reduction in research grants with the Department of Defense and other organizations. Uber recently raised $5B, which allowed them to acquire some of the best talent in the country and their new research facility in Pittsburgh. These decisions are an indicator that the ride-sharing company intends to replace its human drivers with AV technology in the future, and they want to avoid being heavily reliant on Silicon Valley. Many researchers have been speculating that a shared vehicle approach could be the most efficient way to handle the cost barrier to AV entry in the market. There are, as many see it, a few options to introducing AV to consumers. In order to sell AVs to the general consumer, the cost of the technology will have to be significantly cheaper than it is currently. In order to achieve this, mass production and faster chips would have to become a reality. This still relies heavily on the assumption that AVs would be widely accepted and that the market would support the volume that is

[57] "Is Uber a Friend or Foe of Carnegie Mellon in Robotics." Mike Ramsey and Douglas MacMillian. Last Updated May 31, 2015. *Wall Street Journal*. Accessed July 14, 2015. http://www.wsj.com/articles/is-uber-a-friend-or-foe-of-carnegie-mellon-in-robotics-1433084582

produced in order to reach that price point. For this reason, it seems more likely that a shared-AV approach would be more practical as either an overall method for transitioning from a model where individuals and families own cars that are used only a fraction of the time they are owned. Companies like Uber could absorb the high cost of the technology for their fleet and the vehicles, allowing these services to be even more efficient and potentially more profitable. Not only does this have the potential to reduce the number of vehicles on the road, but it serves as a way to introduce consumers to the technology without the exorbitant investment required to own a personal AV. As people become accustomed to riding in or seeing vehicles without a human driver, society could become more comfortable with the idea of relying on technology to navigate the streets safely.

Researchers at the University of Texas have looked at these "car sharing" programs as having a great deal of potential to transform the AV horizon. Using agent-based model scenarios, this research seeks to understand the environmental and travel implications of AV technologies through car sharing programs such as Car2Go and Zip Car. The authors explain that these companies are attempting to change overarching perspectives on sharing vehicles. An understanding of these facets of the shared vehicle industry assist in evaluating the incremental changes to transportation norms.[58] Vehicle relocation strategies and fleet sizes have been evaluated to calculate the most efficient methods of conducting business as a car sharing company in an urban setting. It is obvious that the conventional form of vehicle ownership is inefficient and cost prohibitive for many Americans, which is one of the reasons that car sharing companies have been so successful in recent past. Many urbanites would prefer to not own a car, assuming their lifestyle lends itself to staying

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[58] Daniel J. Fagnant and Kara M. Kockelman. "Operations of a Shared Autonomous Vehicle Fleet for the Austin, Texas Market." *94th Annual Meeting of the Transportation Research Board in Washington DC, January 2015.* (2015).

within the city. Many are viewing the cost of car ownership - the maintenance, fuel, and parking is simply unnecessary and a budgeting nightmare.

Researchers in Canada argue that AV technology, in what they have titled the TaaS model (Transportation as a Service – Uber/Lyft) at least, will also encourage more compact downtown living as it could eliminate the need for people to purchase a car. These funds could be shifted in the household budget from car ownership and maintenance into the car service. Along those lines, researchers point to the fact that Google has recently invested in Uber. But the car sharing company has not only been investing in the car sharing platform, they have also been acquiring robotics companies.[59]

The OECD (Organization for Economic Co-operation and Development) produced a white paper that analyzed the effects of two different models of shared AVs. This study reviewed two self-driving car scenarios in a mid-sized European city. The concepts are titled “TaxiBot” (self- driving cars that can be shared by multiple passengers), and “AutoVot” (self-driving cars that pick up and drop off single passengers). In designing this study, researchers assumed that these shared AVs will deliver the same baseline trips as today in terms of origin, destination, and timing. It is also assumed that these trips will replace all car and bus trips. The study found that, if TaxiBots were combined with high-capacity public transport, 9 out of every 10 cars could be replaced. In other words, “nearly the same mobility can be delivered with 10% of the cars.”[60] Additionally, there could be a 6% increase in volume of car travel (kilometers). In contrast, an AutoVot system (no high-capacity public transport) will nearly double car-kilometers travel (+89%). As suspected, self-driving shared cars could completely remove the need for on-street parking, which is

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[59] Paul Godsmark and Barrie Kirk, et al. “Automated Vehicles: The Coming of the Next Disruptive Technology,” *The Conference Board of Canada* (2015).

[60] Organization for Economic Co-operation and Development, International Transport Forum. “Urban Mobility System Upgrade: How Shared Self-Driving Cars Could Change City Traffic,” *Corporate Partnership Board Report* (2015): 5.

equivalent to 210 football fields based on the model city curb-to-curb street space in the model city. Researchers found that 80% of off-street parking could also be removed, which provides multiple opportunities for improved use of city space. One interesting insight that came to light during this research was the fact that, regardless of availability of high-capacity transport, if there is only a 50% adoption of shared AVs total vehicle travel would increase between 30-90%. While researchers note that self-driving AVs could "completely obviate the need for traditional public transport," there is no evaluation of what kind of impact this might have on household economics/cost to passengers. Shared AVs would incur a great deal more "wear and tear" than the average personally-owned vehicle, as they would be in active use for approximately 12 hours per day (in contrast, personal vehicles average 50 minutes per day in this model city).[61]

Singapore has been identified as a city that is most likely to adopt shared AVs as a method of transportation due to its aggressive smart city approach of planning. The purpose of this study was to validate the financial feasibility of a shared autonomous vehicle structure (and begin to evaluate what size of fleet is necessary to serve the current needs of Singapore). It was determined that it is possible to serve the same number of trips with 1/3 of the current number of vehicles on the road, given shared AV implementation. Present-day single occupancy, individually owned cars typically operate only 10% of the time. This is highly inefficient when a shared AV model could potentially handle single-direction trips with less hassle. The authors of this paper mused about the difficulty of utilizing current shared car services such as Zipcar, where users are required to return the car to a specified point. In fact, AVs are viewed by these researchers as being the enabling factor for widespread shared car systems. "if shared cars were able to return to a parking or charging

[61] Organization for Economic Co-operation and Development, International Transport Forum. "Urban Mobility System Upgrade: How Shared Self-Driving Cars Could Change City Traffic," *Corporate Partnership Board Report* (2015).

station, or drive to pick up the next customer by themselves, sharing would indeed provide a similar level of convenience as private cars, while provide the sustainability of public transport. Financially, car sharing distributes the cost of purchasing, maintaining, and insuring vehicles across a large user-base, leveraging economies of scale to reduce the cost of personal mobility."[62] One of the consequences of the proliferation of AVs could be the reduction of ridership on public transit, since some of the advantages to riding mass transit include having the ability to multi-task and increased mobility for those who are otherwise unable to drive themselves. Additionally, there are concerns that the legislative framework that currently exists (only in a select number of states) will only cause problems since it is a patchwork solution. It is stressed that studying autonomous vehicles is important to address right away since the technology is maturing quickly. "Every major commercial automaker is engaged in research in this area and full-scale commercial introduction of truly autonomous (including driverless) vehicles are being predicted to occur within five to 20 years."[63] The article reviews a body of literature that studies the external costs of driving, noting that these include accidents, congestion, noise, air pollution and greenhouse gas emissions.[64]

SOCIAL FACTORS

Beyond the transformative transit experience that could change the way that we live our everyday lives, there are implications in the social realm. Certainly there are improvements, like the increased independence of senior citizens and the disabled. AVs

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[62] Spieser, Kevin and Kyle Ballantyne, et al. "Toward a Systematic Approach to the Design and Evaluation of Automated Mobilityon-Demand Systems A Case Study in Singapore." in Gereon Meyer, Sven Beiker (editors). Road Vehicle Automation, (LectureNotes in Mobility), Springer, 2014.

[63] Spieser, Kevin et al. "Toward a Systematic Approach to the Design and Evaluation of Automated Mobility on-Demand Systems A Case Study in Singapore," 4.

[64] Spieser, Kevin et al. "Toward a Systematic Approach to the Design and Evaluation of Automated Mobilityon-Demand Systems A Case Study in Singapore," 4.

could provide a much needed chauffer to the soccer practice, allowing parents a more flexible work schedule. Increased efficiency in the way that we get around could allow for increased social time, including phone calls while riding in the car, and increased mobility to areas of town that were previously inaccessible for those without the ability to own a personal vehicle.

BEHAVIOR

Sivak and Schoettle engaged in an opinion survey of 3,255 adults in the U.S., China, India, Japan, the U.K., and Australia to get an understanding of the types of activities that people would chose to engage in if they utilized fully self-driving vehicles. The findings of this article show there will be an overall increase in motion sickness due to the fact that all persons in an autonomous vehicle would be passengers. Research has shown that drivers rarely, if ever, experience motion sickness. A passenger's frequency of motion sickness is related to the activities they chose to engage in while riding in a vehicle. This paper explores the effects of activities on their propensity to increase the likelihood of motion sickness. The authors explain that motion sickness is related to three primary factors: "conflict between vestibular and visual inputs, inability to anticipate the direction of motion, and lack of control over the direction of motion." This report suspects that 6-10% of American adults "riding in fully self-driving vehicles would be expected to often, usually, or always experience some level of motion sickness." Design features of the vehicles can have an impact on the severity of the conflict between vestibular and visual inputs – features such as "narrow or small widows, opaque or reduced-visibility windows, side or rear-facing seating" are noted in the study. Surprisingly, the survey results indicate that 23% American adults report that they would not ride in a self-driving vehicle at all.

While these non-adoption results are of interest, the acceptance of new technologies can take more time for some segments of the population than others. Additionally, it would be interesting to note the frequency and severity of motion sickness for passengers in non-autonomous vehicles to make get a clearer picture of the severity of this problem.[65]

HUMAN DEVELOPMENT & SPATIAL UNDERSTANDING

Some studies have looked at the ways that modes of transportation influence an individual's geographic knowledge and understanding. It is important to review these findings because it assists in thinking about what could be lost through these innovations. In 2010, researchers published an article in *Urban Studies* examining these issues. This paper researches the possibility of cognitive mapping being related to travel mode. Cognitive maps are developed over time, with age and travel. Spatial learning takes place primarily through travel, but can also be influenced by maps and conversations.[66] It is believed that spatial learning progresses in three stages, from "landmark," to "route," up to a "survey" level of understanding. This piece is important in gaining an understanding of potential effects of AV technology on the spatial knowledge of various groups of end-users (which, could be argued, is a specific type of capital). Cognitive mapping has been defined as, "a construct which encompasses those cognitive processes which enable people to acquire code, recall, and manipulate information about the nature of their spatial environment. This information refers to the attributes and relative locations of people and objects in the environment, and is an essential component in the adaptive process of spatial decision making."[67] Researchers have found that social and economic factors are potentially the cause for differences between cognitive mapping across individuals.

[65] Michael Sivak and Brandon Schoettle. "Motion Sickness in Self-Driving Vehicles," *University of Michigan Transportation Research Institute* (2015).
[66] Roger Downs and David Stea. Eds., 1977, "Maps in Minds," New York: Harper and Row.
[67] Roger Downs and David Stea, eds., 1973, "Image and the Environment," Chicago: Aldine. xiv

Socioeconomic attributes are often cited as one of the primary differences across several studies. While many studies on psychological analysis and the sociological characteristics that could account for big differences in cognitive mapping have been completed, there is less literature on travel modes and cognitive maps. "…the limited research to date suggests that transport infrastructure and wayfinding on overlapping, distinct modal networks – sidewalks, bike lanes, transit routes, local streets and roads, and freeway networks – affect the development of cognitive maps and, in turn, travel behavior."[68] Modes of travel may significantly affect the cognitive development of children – as noted by Hart in 1981 – who found that the quality and detail of spatial maps were of higher caliber amongst children who commuted to school through an 'active' mode of travel (walking, biking) than those who commuted through a 'passive' mode (car, bus). "…this research underscores that differences in spatial knowledge due to the spatial learning process are not only the result of where we travel, but how we travel. Differences between active and passive travel and their effects on learning are realized in the everyday travel modes of individuals in the city."[69] Helen Couclelis reviewed information communication technology (ICT) in the same light. "Time geography" is a method by which we track and study individual activity in space and time – this was developed in the 1960s by Hagerstrand and the Lund School. Essentially, the idea is that humans are goal-oriented and there is a notion that a series of activities will lead to the completion of a 'project.' This framework has been used to study goal orientation and social behavior. Couclelis argues that the traditional time geography framework is limited and does not encompass the cyber-dimension in which many people spend a tremendous amount of time. She proposes that there be an extension of the space-

[68] Andrew Mondschein and Evelyn Blumenberg. "Accessibility and Cognition: The Effect of Transport Mode on Spatial Knowledge," *Urban Studies* (2010): 860.
[69] Andrew Mondschein and Evelyn Blumenberg. "Accessibility and Cognition," 869.

time path so that meaningful human activity can more accurately be studied. She notes that there are three novel concepts that should be studied in relation to ICT, "cyberspace, the shrinking and shriveling world, and individual extensibility."[70] Urban planners have used classical time geography frameworks to study human behavior for decades. With the proliferation of ICTs, it has become problematic for urban planners in terms of mapping people's daily activities since it is now possible to conduct business in different ways, through new channels of communication, and in varying locations. There are three constraints associated with classical time geography – "capability, authority, and coupling," whose boundaries are constantly being pushed through ICTs.[71] Due to these changing conditions, she suggests that we may see some changes in associations that have often been made in the study of time geography. These include a shift between the connection between activity and place (now that places will often host various activities and those same activities can occur in several settings). Additionally, and perhaps most important in relation to the topic of AVs, there may be a shift in the association between time and activity through the improvement of transportation (specifically any reductions in the time required to transition to a new activity – but also changes in cost). These factors contribute to the basis of the author's "fragmentation of activity" hypothesis.

Further, on the topic of ICTs and transportation research, an article funded by the French National Research Agency explores the relationship between mobile technologies and the travel behaviors of users. The authors argue that the research on this topic is somewhat futile in that current knowledge suggests that the rise of ICTs has not reduced the number of trips, even if the types of trips have altered somewhat. In conclusion, the

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[70] Helen Couclelis. "Rethinking time geography in the information age." *Environment and Planning Volume 41* (2009): 1558.
[71] Helen Couclelis. "Rethinking time geography," 1559.

paper states that further investigation should explore the influence of ICT ownership on the "spatiotemporal distribution of both private and professional activities." This article has significance to the study of autonomous vehicle technology because it is an indicator of potential sociological issues associated with the introduction of new technologies on the lifestyles of users.[72]

In essence, most people would lose a lot of knowledge of their surroundings through riding in a car as a passenger, particularly if that time is being held captive through video, social media, and other content opportunities that companies exploit to generate new revenue. These possibilities are very real and could mean that the human brain will develop in different ways than it has in the past. Scientists are constantly studying the effects of the screen (TV, phone, computer) on the brain as it is – imagine how much more severe these effects could be on a population that was born into an environment where much of their time is held captive by these screens.

ETHICS

There are significant ethical issues in the development of AV technology. On one hand, this technology could save an incredible number of lives. However, there will most certainly be lives lost due to faulty issues with the vehicles. From a utilitarian standpoint, it naturally makes sense to save hundreds of thousands of lives by inadvertently "sacrificing" a few. A study with the Virginia Center for Transportation Innovation and Research reviewed the ethical decision making issues surrounding programing AVs in crash avoidance. This study underscores the fact that crashes in automated vehicles are inevitable, that the AV itself will be responsible for "pre-crash behavior," and that there is

[72] Anne Aguilera, Caroline Guillot, Alain Rallet. "Mobile ICTs and physical mobility: Review and research agenda," *Transportation Research Part A: Policy and Practice* (2012).

"no obvious way to effectively encode complex human morals in software."[73] To address these discrepancies, researchers present a three-phase approach to creating ethical crashing algorithms for implementation in AVs as the technology advances. These approaches are defined as, "a rational approach," "an artificial intelligence approach," and a "natural language requirement." Researchers state that, using a Poisson distribution and mileage/crash estimates, AV testers will need to drive approximately 725,000 miles on roadways without a crash in order to claim with 99% confidence that they are safer than a human driver. A Poisson distribution refers to a common statistical distribution measure that shows the probability of a certain number of events occurring during a fixed interval of time or space. In this article, the author references Asimov's Law of Robotics and argues that these three laws are actually a literary device that serve to reveal flaws in this type of system. "Machines are incredibly literal, and any system of ethics with only three rules requires the follower possess some common sense or intuition, particularly if there is a conflict between the rules or within a single rule."[74] It is proposed that consequentialism could be the rational approach for addressing AV ethics. In other words, vehicles will make a selection amongst possible crash trajectories where the end result minimizes global harm or damage. This logic seems simple enough for an engineer to implement into AVs, and when the options are simplistic and clear, it could allow for a clean solution. However, there are idiosyncrasies that make this solution difficult in practice. The underlying assumptions that could inform these decisions would likely be reduced to cost. Quantifying damage through a traditional cost/benefit analysis could have problematic results. The authors note an example where, in a crash, the AV is forced to make a decision between

[73] Noah Goodall. "Ethical Decision Making During Automated Vehicle Crashes," *AHB30 – Vehicle Highway Automation – TRB Annual Meeting* (2014): 1.
[74] Noah Goodall, "Ethical Decision Making," 8.

two different cars. Will it chose the car with the highest safety rating, thus unfairly placing cars with good safety ratings at higher risk? Alternatively, will the AV chose to collide with the less valuable car – putting those at a socioeconomic disadvantage at higher risk? This problem addresses the question of what kind of information should be included in the programming of these complex AVs. Should AVs consider the demographic information of each passenger? Statistics tell us that certain characteristics put people at higher risk of injury or fatality than others (women are 28% more likely to die than men of the same age; older passengers are more likely to die than younger passengers). The second ethical decision making tool that could be utilized is the "artificial intelligence approach." In this scenario, algorithms study and learn language automatically (sans rules previously discussed). The difficulty in this approach lies in the fact that artificial intelligence may pick up on human behaviors that are not necessarily ethical (self-preservation instinct can often override ethical decision making).[75]

EQUITY

Todd Litman produced a report that includes predictions on the impacts of AVs and analyzes the potential for such vehicles to increase mobility of "affluent non-drivers." This research was presented at the 2015 Transportation Research Board's Annual Meeting. Litman directly addresses the issue of equity in this report, predicting that the benefits to low-income people will only be realized after widespread use has occurred, likely in 2040-60. He states that the initial benefits will flow to the most affluent. The importance of this article lies in its speculation on the benefits of AV technology at various time horizons. "Advocates predict that consumers will soon be able to purchase affordable self-driving vehicles that can greatly reduce traffic and parking costs, accidents and pollution

[75] Noah Goodall, "Ethical Decision Making," 8.

emissions, and chauffeur non-drivers around their communities reducing highway costs, eliminating the need for conventional public transit services."[76]There are some problems with these predictions, namely, the affordability of the vehicles. Again, Litman suggests that widespread adoption may not occur until 2040-60. Litman makes a counter argument to the majority of proponents who state that human error accounts for 90% of all car accidents by stating that autonomous vehicle technology will actually introduce new forms of risk. Some of these include cyberterrorism, "increased vehicle travel resulting from faster or cheaper travel," "the tendency of road users to take additional risks when they feel safer," and system failures.[77]

ENVIRONMENTAL FACTORS

In an analysis of potential energy effects of automated vehicles, researchers Brown and Gonder reviewed some of the potential environmental benefits of the proliferation of this technology. This paper was submitted in 2013 to the TRB 2014 annual board meeting. In this paper, authors suggest that AVs create the possibility of reducing the emissions of carbon dioxide into the atmosphere, depending on their ability to improve efficiency and lower traffic congestion. However, the research raises concerns that the possibility of increased suburbanization could affect the net effect of greenhouse gas emissions, thereby reducing the positive effects typically associated with AVs. In essence, the researchers are careful to note that while preliminary analysis suggests that there is great potential, there are still various unknowns that will dramatically shift the optimistic hopes for energy use reduction thanks to AVs. This work analyzes the energy savings of the segment of vehicles that constitute the highest amount of fuel consumption in the US (approximately 59%).

[76] Todd Litman. "Autonomous Vehicle Implementation Predictions: Implications for Transport Planning," *Victoria Transport Policy Institute.* (2014): 3.
[77] Todd Litman. "Autonomous Vehicle Implementation Predictions," 4.

The use of platooning (wherein vehicles travel close together at a high speed) has significant potential for fuel savings because they log a high percentage of highway cruising miles. In terms of individual passenger cars, one way in which fuel savings would be realized would be through smoother starts and stops (aggressive drivers would see the highest savings in this arena – between 20-30% improvement in fuel efficiency). A challenge in making estimates on potential energy impacts is the fact that it is difficult to understand how many people who currently are unable to travel by car due to physical handicap or age would actually travel more in an AV.

Increasing the safety on highways, AVs have the potential to allow for faster travel on highways. "Faster travel is known to increase air resistance energy loss with the square of velocity. Because of this, drag losses could become very significant at high speeds." [78] Authors utilized data from a study produced by fueleconomy.gov, which estimated that for every 10-mph increase in speed there is a 13.9% increase in efficiency of fuel use. Considering these factors, authors believe that lifting highway speed restrictions to 100-mph could result in a 30% aggregate increase in energy intensity. Vehicles could also utilize lighter materials when operating in fleets,

> allow[ing] vehicles to be dramatically lightweighted and have more efficiency-optimized powertrains. This is partially because collision safety features might be obviated and partially because, in a shared-use model, the vehicle used could be matched to the duty cycle required.[79]

Realization of these benefits would take a long time to occur since safety at this level is difficult to achieve and could take years to come to fruition as the technical problems are

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[78] Austin Brown and Jeffrey Gonder. "An Analysis of Possible Energy Impacts of Autonomous Vehicles," *National Renewable Energy Laboratory* (2013): 6.
[79] Austin Brown and Jeffrey Gonder. "An Analysis of Possible Energy Impacts," 6.

worked out and consumers become more willing to ride in vehicles with lower perceived safety from a hardware standpoint. Brown, et al. cite a previous article by Burns, which suggests that there is a 6%-8% energy impact reduction every time the vehicle fleet becomes 10% lighter. The fuel required to keep a vehicle running while simply looking for parking is a waste of energy that could be eliminated with the shared automated vehicle model of commercialization – the Texas Transportation Institute estimates that this works out to approximately 19 gallons per person every year.[80] There are a host of other effects that are listed in this report, including the possibility that fleet turnover would be faster – since cars would be utilized at a more constant rate than they are in today's conventional vehicle fleet. The benefit here is that new technologies could be implemented on a faster timeframe (however, energy required for manufacturing would not be affected). Air quality may not be significantly affected if there is a net wash in VMT, but the use of alternative fuels in AV models could reduce the number of vehicles utilizing fossil fuels for energy. There is also a possibility that an air quality tax could be assessed for people who take pollution-causing trips on days where the air quality is already poor.

CYBERSECURITY & BIG DATA

Research about cybersecurity in AVs centered around two types of security; in-vehicle security (refers to mechanisms put in place to protect computerized systems from interference either inside or outside the vehicle), and "cyber" security (referencing security protections for systems that communicate with other systems or vehicles). The current

[80] Austin Brown and Jeffrey Gonder. "An Analysis of Possible Energy Impacts," 8.

environment for policy-making has been focused on "cyber security," with the US Department of Transportation providing input for the National Highway Traffic Safety Administration's recommendations for regulation of connected vehicles.[81] Additionally, there are prevalent concerns regarding the vast amounts of data that will be collected from the users of AVs, who owns that data, who has access to the data, and how this data may be used or studied for various purposes. From a city planning perspective, the availability of this type of data could allow planners and policymakers to make more informed decisions about capital expenditures, land use planning, and infrastructure needs.

"The tsunami of data is increasingly impacting the commercial and academic spheres."[82] Non-profits, quasi-governmental institutions, and the academy are finding new sources of data that can assist in serving humanity by finding ways to solve problems. There are those who will be quick to demonize corporations or the government in their access to and manipulation of data – but it is important to remember that there is also a positive side to the increase in data available. Debates will rage on over numerous subjects regarding big data and there is certainly a need to confront the new realities of what it means to be able to collect data, thanks to advancing technologies. What is important here is to note that we have entered a new era where data is a form of capital. In past years, we have discarded portions of data due to technical limitations in an effort to optimize operations. However, improvements in microprocessors are allowing for the collection of even larger sets of data since we often do not know that pieces of information are important at the time of collection but find new uses for them or discover insights at a later date. In other words, we are collecting more data through each existing source while increasing the

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[81] Dominie Garcia and Chris Hill, et al. "Cybersecurity Considerations for Connected and Automated Vehicle Policy," *Texas A&M Transportation Institute* (2015).

[82] Julia Lane and Victoria Stodden, et al. (eds) *Privacy, Big Data, and the Public Good: Frameworks for Engagement*. (Cambridge: Cambridge University Press, 2014): 137.

number and types of sources that are on the market. Data is valuable – it is being called the "new oil" or the newest resource of the 21st century by the World Economic Forum.[83] Data is being commodified, and because of this, ownership rights need to be clearly defined. Some researchers are calling this "The New Deal on Data," declaring that this information is essentially "digital breadcrumbs," clues as to who we are, what we do, and what our preferences might be. This personal data is incredibly useful for both the public good and for the marketing purposes of private companies.

Privacy is one of the primary concerns associated with big data today. Various laws and best practices exist in order to guard against the misuse of personal data and to protect users. In an article discussing the analytic insights that are made available through big data, researchers Barcoas and Nissenbaum discuss how big data has evaded the concepts of anonymity and consent as methods of protecting users' identity. For example, anonymity has often been lauded as a method of protecting privacy by removing personal identifying information from data sets. However, "anonymity is not unassailable."[84] There are many methods by which companies are able to identify individuals without the use of a name, obscuring many of the ideas that were put in place to protect an individual's name. Barocas and Nissenbaum state,

> The concerns we have are neither about whether anonymization is possible nor about how serious a problem it poses for practical purposes; they are whether, in the first place, anonymization addresses privacy and related ethical issues of big data.[85]

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[83] Julia Lane and Victoria Stodden, et al. (eds) *Privacy, Big Data, and the Public Good: Frameworks for Engagement*. 196.
[84] Julia Lane and Victoria Stodden, et al. (eds) *Privacy, Big Data, and the Public Good: Frameworks for Engagement*. 49.
[85] Julia Lane and Victoria Stodden, et al. (eds) *Privacy, Big Data, and the Public Good: Frameworks for Engagement*. 51.

The question here is not, “is it possible to ensure anonymity?” But rather, “why do we think that anonymity solves privacy problems?” When the crux of the argument for anonymity lies in simply removing the name from the data, anonymity becomes ineffective at its core. If the value of anonymity is simply “namelessness,” or “removal of uniquely identifying information,” this ignores the fact that individuals are still “reachable” – with or without access to this information. Companies have been able to leverage information from a small minority of people that are willing to provide certain details and extrapolate assumptions about their market at large. In other words, willing participants in surveys are often unwittingly ‘out-ing’ the rest of the market. Inferences can be made from the patterns of these participants and used as predictive models for others in the market – the authors cite Target as a prime example of this method. Target been known to follow the shopping pattern habits of women who have disclosed that they have had babies and thus develop a “pregnancy prediction score.”[86]

LAND USE & TRANSIT

There has been much speculation regarding the land use impacts of AVs – particularly in the area of parking lots and garages, which represent a large swath of underutilized land in both cities and in suburban settings. From an environmental standpoint, this is excellent news. This could lead to repurposing this land for green space, which has the potential to reconnect ecosystems, handle stormwater, provide habitat, improve air quality, and reduce the urban heat island effect. Certainly not all of the space would be transformed into green space – but nearly any other use will also have

[86] Julia Lane and Victoria Stodden, et al. (eds) *Privacy, Big Data, and the Public Good: Frameworks for Engagement*. 62.

environmental benefits that allow cities to build in a more dense fashion. If shared AVs were implemented properly and widely, this change would be welcomed by urban planners and real estate developers alike. Reducing or eliminating the need to provide parking spaces improves the developer's ability to use land in different and better ways, increasing their revenue. It is often difficult to implement progressive policies when scarcity of land limits the financial viability of dedicating a certain amount of space to uses that benefit the city as a whole. Cities have toyed with increasing FAR or compromising other planning tools to compensate developers for implementing ideas that force them to reduce their net rentable square footage. Most planners and progressive developers would agree that the space used to house a car is an inefficient use of land. Because past land use patterns have allocated so much space to these vehicles, it has become expected that companies provide parking spaces for their employees, or that multi-family housing developers provide enough space to host between 1 and 2 cars per unit. As cities have become more populated, everyone has started making incremental changes in the availability or price of parking. Imagine how much more efficiently cities could accommodate new growth if parking issues were altered such that we were not required to provide space for idle vehicles. Under current 'rules of thumb' for real estate developers, a single parking space requires between 350-480 SF, whereas offices estimate between 180-250 SF of space per employee. It is obvious that parking space allocation is wasteful.

Malecki explores both the incremental and disruptive technologies that have the potential to be adopted by cities in coming years and argues that if cities want to remain competitive on an economic development basis, they must be prepared to adopt these technologies. He calls these places "connected cities," and argues that there five factors for "confronting change: technological (hardware), information (software), decision-making and institutional (orgware), efficiency and financial (finware), and environmental and safety (ecoware)."[87] In describing technologies, Malecki states that most technological advances are often incremental but can have disruptive effects in the ways that they integrate with other existing systems or applications. He makes note of the fact that "significant technological change has been scant" in the automotive industry, largely due to the power wielded by automotive manufacturers. Further, he poses the statement that we will continue to become more mobile and this mobility will increase in speed and efficiency in the coming years. Current research (as of the time of writing, 2013) has focused largely on land use and transportation, but most "urban futures" has been centered on individual cities. He stresses that new technologies must be complemented by appropriate policies and a shift in social attitudes.

Marletto reviews three alternative futures of transportation in urban environments leading up to the year 2030. In this analysis, he notes that business models, propulsion technologies, and power will be the largest factors in determining which scenario will prevail. Of these scenarios, the first is only minimally more advanced than our current day mobility situation. Scenario "AUTO-city" features a change in the major power in the energy industry, moving from an oil & gas dominated present-day reality to one where individual cars are powered through battery. Here, the producers of battery become the key benefactor in the transition. The second scenario is titled "ECO-city," in which local coalitions become more powerful and there is an integration of "all non-car modes of transport." Finally, an "ELECTRI-city" urban reality could be realized through electric operators producing electric vehicles and smart grids. Marletto notes that socio-technical scholars largely agree that the research regarding scenarios and transition pathways is often bifurcated from those of political issues. As such, there is a hole in the literature as to

[87] Edward Malecki. "Connecting the fragments: Looking at the connected city in 2050." *Applied Geography* (2014): 12.

whether the inclusion of actors in research would, in fact, provide further insight into macro-level phenomena.

Chapter 3: A Discussion on AVs - Interviews

I spent a lot of time interviewing several individuals in the Austin area that have been involved in planning for AVs over the past few years. The interviewees were practitioners in many different professions including practicing attorneys, traffic engineers, technology consultants, and researchers of AV and CAV (connected autonomous vehicle) technologies. What's interesting here is that, while there was unanimous consensus on some concepts, there were also wildly differing professional opinions on other forecasts. While reports and media blurbs about AV testing and commercialization are reaching the front pages of the news on a more regular basis, the fact is that it is still too early to know how this technology will affect various aspects of modern day society. In an environment where most of the people who will be planning for and implementing AVs on our roadways are under-informed and under-educated on the topic of AVs, it may be a long road to implementation. Below I will discuss some of the insights I gleaned from interviews with these individuals and emphasize points on which there is consensus and areas in which there are different opinions about the future of AVs.

AUTONOMOUS VEHICLES IN AUSTIN

The traffic problems that are facing Austin are tremendous; one of the interviewees noted that many of the solutions that are being proposed are simply taking us down the wrong path. The cost of building new roads seems to be increasing faster than inflation and our ability to generate more revenue. Our infrastructure is constant need of repair and the cost of both land and concrete are increasing. We are facing an ever-widening gap. This is where my interviewee, a former engineer and practicing technology lawyer, realized that Texas must turn its focus from raising funds for new roads to applying innovative technologies to increase throughput without having to spend additional funds on new roads.

In addition to shifting our focus from raising funds to focusing on implementing new technology – this interviewee pointed out that there is a big problem with lawmakers and agencies in Texas in terms of education. Not only are they uninformed on the current status of AV testing, they are woefully uneducated about the topic in general. This is one of the challenges that Texas has recognized when working on an AV freight bill introduced in the 2015 legislative session. The hesitation to implement any new regulations partially stem from the state's acknowledgement that lawmakers are not properly educated in a way that would lead to proper drafts of legislation. It's not just a question of whether they are educated about the status of technology development, it is that decision makers are not necessarily understanding the underlying drivers of a tech based economy or the implications of AV technology on various sectors of the public they are asked to serve. At the end of the day, however, TxDOT's mandate is not only to provide roads, but to provide safe highways. If there are technologies that are available that will accomplish this, TxDOT will be forced to tackle these issues head on.

Another barrier to the entry of AVs in Texas is the fact that the legislature meets every two years, which is a slow pace when compared to the five year development cycle of companies like Google. All of the interviewees that I spoke with made some mention of the fact that there will have to be significant coordination between the market that is commercializing AVs and the states/federal government in terms of infrastructure. There are many different approaches that are being proposed regarding how infrastructure will play out in a post-conventional vehicle world. What's troubling is that there must be a cohesive standard across state lines, which will require a great deal of negotiation and coordination. As the technology industry is lapping state agencies, we may find that there will be delays in implementation due to this difference in pace. On the other hand, the market may push the public sector to adapt quickly – in which case, the public sector may be placed in a position where they are making hasty decisions and implementing policies that have not been fully vetted. This is an important reason to become more diligent in educating transportation agencies and lawmakers in Texas. Most everyone agrees that this kind of work needs to be done, but there are few that are willing to pay for the educational process to begin on a large scale. This is an immediate challenge in Texas as Austin is already seeing Google testing AVs on its streets.

AUSTIN'S PLACE IN THE PRODUCTION OF AUTONOMOUS VEHICLES

One of the questions I asked interviewees was how they view Austin as a competitor in the AV world from an economic development perspective. Most agreed that Austin is well situated in coming years to embrace and benefit from the changes that are coming to the auto industry. For example, Austin is already home to Freescale, which makes most of the actual micro-controller chips that are being used in the auto industry. From a software an interface perspective, one challenge that Austin will face is being able to attract the right kind of software developers for AVs. In most cases, software developers are creating technologies that transfer information – the threshold for failure in that regard is fairly high. In general, if something goes poorly in this situation, there are no lives on the line. However, when you extend this to AVs (similar to the military or airline industry), lives are at stake so careful testing methodology will be necessary for these systems.

POLICY

During my review of the various white papers that have been published on AVs, one of the perceived barriers to the implementation of AVs has been the question regarding insurance. For this reason, I included insurance as a question in my interviews. The attorney that I interviewed did not see any reason that insurance would be a hindrance to the commercialization of AVs. He believes that insurance will continue to work in roughly the same ways that it does today. Essentially, whoever owns the vehicle at fault will defer to their insurance policy. The insurance provider has the right of subjugation – if something goes awry with the software of the AV, it is a product liability claim. For example, he said, "if we had a microprocessor that was controlling the fuel injection and it went out and the car was rear-ended as a result, the legal analysis would be the same as it is today in conventional vehicles." I asked if he thought that OEMs would be able to absorb the risk that is associated with this liability. Recent news has shown that there has been a rise in car recalls during the summer of 2015.[88] He agreed that this is an issue that will always be a concern for automakers, and it will continue to be a problem with the implementation of AVs. That being said, these risks will have to be accepted if these companies want to remain competitive in today's market. Circling back to the issue of liability and traffic violations, my interviewee was quick to point out that law enforcement could handle a lot these problems through traffic violations. Unfortunately, today's traffic laws would be out of sync with the technological capabilities of AVs – officials would therefore have to revisit traffic laws in order to stay relevant to the realities of the function of AVs on the streets.

There were different opinions amongst my interviewees as to why Texas has been hesitant to regulate AV testing. One view is that, by refraining from regulating, states are allowing research and development to flourish faster and unrestricted. One interviewee pointed out that Nevada has been one of the states that was quick to implement regulations, thinking that this would encourage OEMs to locate or do research on its streets but what actually happened was that the regulations became a barrier. This unintentional consequence of regulation could be another reason that Texas has been slow to implement regulations. There was general consensus about the fact that Texas lawmakers are not being

[88] Spector, Mike and McGitny, Tom. 6 Aug 2015. http://www.wsj.com/articles/spike-in-u-s-car-recalls-continues-1438833840

well informed and do not possess the education to handle these challenges so they have decided to table these issues until more can be known and understood about AV implications. While this seems to be a prudent option, another interviewee expressed concern that failure to regulate could result in over-regulation following an incident that sparks public outrage. These wild swings in regulation are generally not beneficial to any of the parties involved.

CONCERNS REGARDING AUTONOMOUS VEHICLES

The top concern that was listed amongst interviewees was cybersecurity – particularly the potential misuse or overriding of systems. The concern was not necessarily tied to "big government tracking your whereabouts," but the potential for hacking. One father mentioned that he is concerned about the idea that it would be possible for hackers to know where his children are at all times. The big government concern was not voiced because, as one of the interviewees noted, we are "already there." Adding AVs to the data trail of your everyday life is not significantly more intrusive than what is already on record about you. One of my interviewees responded that he was concerned that there should always be a driver in the seat of these vehicles – that the manual override would always exist and take precedent over any potential misuse of the system. While this idea would seem to be ideal in the near future, I question how this issue will be handled in the extended future where people may no longer be familiar with driving cars – where there are no licenses and hand-eye coordination is not trained in the same way it is today. Would the manual override work to the same effect?

Another common concern that was mentioned had to do with ethical concerns surrounding the fact that there will be deaths in autonomous vehicles. It is difficult to predict how society will chose to make decisions on the responsibility we take in creating an autonomous vehicle that will, at some point, be faced with decisions on when and how to crash a car. How will we be programming these vehicles to make decisions at the moment of impact? One interviewee said that he feels as if the tort environment in America will make this a difficult subject to tackle in courtrooms. Are we willing to accept the fact that there will be casualties due to the engineering decisions that are made in isolation and perhaps even many years prior to an accident resulting in fatalities?

Aside from public entities being unable to keep pace with the technological advancements, some respondents noted that the auto industry itself may be a significant barrier to the AV entry in the market. The view in general was that the traditional auto industry is not interested in advancing this type of technology because they are aware of the fact that the most prevalent model being proposed today is a shared AV network – in which case, there is a significant drop in the number of cars that would be needed to be produced. If, for example, Fagnant et al. are correct in their modeling of SAV (shared autonomous vehicle) services in the Austin area, between 9[89] and 10.77[90] conventional cars could be replaced by a single SAV. This fact should be startling to automakers as it emphasizes the potential of the SAV model to completely disrupt the industry as we know it. Since much of their business is dependent upon production in large volume, the shift to shared AV fleets is highly unwelcome. The vast majority of the push to produce AVs is coming from technology companies - not conventional automakers. Those that have begun working on implementing this technology into their vehicles are the ones that have taken notice of the fact that they will be left behind should they fail to adapt.

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89 Daniel J. Fagnant, Kara M. Kockelman, Prateek Bansal. "Operations of a Shared Autonomous Vehicle Fleet for the Austin, Texas Market." *To be presented at the 94th Annual Meeting of the Transportation Research Board.*(2015): 2.

90 Daniel J. Fagnant, Kara M. Kockelman. "Dynamic Ride-Sharing for a System of Autonomous Vehicles in Austin, Texas). *Under Review for Publication in Transportation* (2015): 8.

BARRIERS

There were a few varied responses to my question regarding top barriers to the implementation of AVs. One view is that the biggest barrier to implementation will be developing that last 1% of technological capability. Other oft-cited barriers were market acceptance, and the public sector's inability to coordinate and communicate with OEMs. Market acceptance refers to concerns that people will be hesitant to give up the control that is assumed when a vehicle is owned and operated by an individual. It is also somewhat questionable whether people will be willing to pay for the autonomous features, feel safe in an AV, or rely on a fleet of shared AVs to meet their transportation needs. There were also different positions about the timing for AV roll-out, where one interviewee said that he believed that most people will not recognize cars in five years – and another stating that he did not believe that he will see AVs hit the roads during the remaining 10-15 years of his career.

Many aspects of AV development are features that have already been explored and used in military applications. However, there are protocols that regulate how these applications are used which include tele-operation or manually observed autonomous features. The military is also able to accept more risk in the deployment of this technology and they have more latitude than the civilian sector. Most technologies developed for the military make their way into the civilian market within fifteen years. One big difference between the military applications of autonomy and what is being proposed for AVs is the environment. For civilian vehicles, the infrastructure is fairly predictable but also carries more risk because of the number of people on the streets. The military applications that were discussed during these interviews were being driven in areas that had difficult, often unpredictable terrain. On the topic of environment, this interviewee illustrated the fact that most of the AV testing that is taking place today is occurring on streets that are in places where the weather is favorable. Weather is a huge challenge in getting this technology safe enough for public use – snowy environments in the US are heavily populated. Snow and rain storms will create reflections which will make it difficult for sensors to operate accurately. Currently, we are not seeing AVs being tested in these environments.

If we develop models of dedicated AV lanes, it seems possible that we could see AVs being commercialized faster. But really, the general view is that if we don't get to a shared AV model, there is not as much of a societal benefit to bringing AV technology into the mainstream. The shared AV model, at this point, seems to be the most beneficial for the environment since these fleets could drastically reduce the number of vehicles that are needed to serve the same population. Fewer cars on the roads could alleviate the wear on infrastructure and slow down the need to expand infrastructure in some places. Shared AVs could eliminate the need for households to own cars and provide mobility for the underserved. These are the optimistic long-term benefits that are being discussed amongst professionals that are excited about these possibilities.

SOCIAL EQUITY

I received various responses to the question I asked about social equity – "do you think that there are segments of society that will benefit more than others?" One respondent was adamant about the fact that Google is focused on serving the underserved. There was general consensus about the idea that there will be an interim period where there will be a mixture of conventional vehicles with autonomous vehicles. During this time, the autonomous vehicles will have preferential treatment (perhaps faster speed limits, maybe designated lanes). From a planning perspective, there could be a shift in the amount of federal funding that is granted to local public transit systems. Many people depend on regional transit authorities to get to and from work – and transit services in America are heavily subsidized (the fares simply do not cover the actual cost of service). If federal funds are being shifted to research, development or infrastructure for AVs – those who depend on public transit will lose.

Other concerns about social equity will arise out of labor issues – this statement was made by all of my interviewees. There are certainly ramifications for the reduction of cars that will be driving on the roads in general. It's not just the car manufacturers that will suffer in profitability. All of the ancillary industries related to car ownership (repairs, mechanics, car washes, parking garages, detailers, etc.) will also a reduction in demand for services (assuming the shared AV model is the format that prevails).

Long-term, however, there are several societal benefits associated with AVs. One interviewee stated that there is an approximate 15 year turn-over for vehicles – imagine what could happen if there was a shift to safer, less accident prone AVs over the course of 15 years. According to reports reviewed in the literature section of this paper (Texas A&M Transportation Institute), the number of lives that could be saved is reason enough to pursue AVs as a transportation solution in this country. Additionally, most of the interviewees agreed that AVs would open transit options for segments of society that have previously been unable to obtain or maintain a driver's license (the disabled, young, and old). The shared AV model could also provide additional mobility options for those who have chosen to not own a vehicle and instead utilize public transit, walking, or cycling as alternative forms of transportation.

RECOMMENDATIONS

Throughout my conversations with these experts, I learned a lot about the commercialization of AVs, but some very interesting ideas were also floating around during these conversations. One interviewee suggested that states should consider requiring that companies that are developing this technology pay a facility fee for being granted access to test vehicles on public highways. It's possible that testing could eventually generate liability issues, at which point various transportation agencies could be involved in legal battles – which is a huge drain on public funds. Other uses for these funds could include research, education, and planning for infrastructure changes that may occur. Another policy that should be considered is whether or not a federal or state policy should exist where public agencies are granted access to data generated through AVs.

Finally, while there are numerous challenges that lay ahead for the AV industry, it is exciting to imagine a world where traffic fatalities are dramatically reduced. All of the practitioners I spoke with shared in this view – stating that this is the first time we have looked at pragmatic ways to prevent traffic accidents. Everything the auto industry has done in response to the dangers that vehicles pose has been related to protecting the driver during an accident, or immediately thereafter. AVs have the potential to pose a preventive solution. Isn't that worth a strong pursuit?

Glossary

AV	Autonomous Vehicle
CAV	Connected Autonomous Vehicle
DSRC	Dedicated Short Range Communications
FAR	Floor to Area Ratio
FCC	Federal Communications Commission
ICT	Information and Communications Technology
GPS	Global Positioning System
MCC	Microelectronics and Computer Technology Corporation
NEPA	National Environmental Policy Act
NHTSA	National Highway Traffic Safety Administration
OEM	Original Equipment Manufacturer
OECD	Organization for Economic Co-operation and Development
OS	Operating System
R&D	Research & Development
SAV	Shared Autonomous Vehicle
SoC	System on Chip
TDM	Traffic Demand Management
TRB	Transportation Research Board
TTI	Texas Transportation Institute
TxDOT	Texas Department of Transportation

V2I	Vehicle to Infrastructure
VMT	Vehicle Miles Traveled
VSL	Value of a Statistical Life
US DOT	U.S. Department of Transportation

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