Driving Toward Monopoly:
Regulating Autonomous Mobility Platforms as Public Utilities

By

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A. B. in Social Studies
Harvard College (2013)

Submitted to the Department of Urban Studies and Planning
in partial fulfillment of the requirements for the degree of

Master in City Planning

at the

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Abstract

Autonomous vehicles (AV) have captured the collective imagination of everyone from traditional auto manufacturers to computer software startups, from government administrators to urban planners. This thesis articulates a likely future for the deployment of AVs. Through stakeholder interviews and industry case studies, I show that there is general optimism about the progress of AV technology and its power to positively impact society. Stakeholders across sectors are expecting a future of autonomous electric fleets, but have divergent attitudes toward the regulation needed to facilitate its implementation. I demonstrate that, given the immense upfront capital investments and the nature of network effects intrinsic to data-intensive platforms, the autonomous mobility-as-a-service system is likely to tend toward a natural monopoly. This view is corroborated by key informants as well as recent industry trends. In order to better anticipate the characteristics of this emerging platform, I look back at the developmental trajectories of two classic public utilities – telecommunications and the electricity industry. I argue that the aspiring monopolists in autonomous mobility, like icons in these traditional industries, will succeed in supplanting a legacy technology with a new, transformative one, and use pricing and market consolidation tactics to gain regional dominance. The discussion on monopoly power is then adapted to the new business models of internet-enabled technology giants, and I examine two additional industry case studies in Google and Amazon. I argue that the autonomous mobility platform will first be designed to prioritize scale over everything else, including profits, and that firms are likely to pursue both horizontal and vertical integration strategies to achieve sustained market leadership. I conclude by recommending next steps for reining in platforms that may harm the public interest, and encourage planners to traverse disciplinary boundaries to better facilitate discussions between innovators and regulators.

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To my family, friends, and B26, for sustaining me through another thesis;

And finally, to Jason, for being a gift and an anchor in this transformative season. I hope you read this thesis one day.
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Chapter 1: Introduction

“If I had asked people what they wanted, they would have said faster horses.”
- Henry Ford (apocryphal)

The rise and acceleration of autonomous vehicle (AV) development have captured our collective imagination. In particular, as a student of urban planning embedded in the MIT ecosystem, I find myself in the epicenter of many AV discussions. Hardly a day goes by when I do not hear something about AVs, how they will save the world, how they will ruin the world, or even how we should actually be talking about self-flying, not self-driving, cars. From automobile manufacturers to software startups to government administrators, every stakeholder group has a different angle on AVs. We all love speculating, and know that we are speculating. The goal of this thesis is to draw on some of these theories to articulate a likely future for the deployment of autonomous vehicles.

My interest in this complex subject began last summer, when I worked at an early-stage startup in the autonomous vehicle data space in both a business development and policy research capacity. The daily interactions I had with private sector players in the AV space -- including traditional automakers or original equipment manufacturers (OEMs), emergent OEMs, suppliers, and startups -- provided a valuable basis for understanding how the industry sees itself. Then as I attended government-sponsored meetings about regulating this new industry, I sensed from the officials a significant (and not unacknowledged) gap in expertise of the very technology they are supposed to regulate, and a persistent attitude to learn more from an industry reluctant to help set the boundaries for this new game.

A Primer on Autonomous Vehicles

The recent progress in AV development has caused much concern for urban planners. The uncertainty surrounding not only the testing but ultimately the deployment of AVs includes everything from their impact on climate change and traffic congestion, to their implications for data privacy and mass mobility. While researchers have been diligently creating projections of AV adoption and writing policy guidelines on how to manage the roll-out of this new technology, practitioners, especially those with a government regulatory function, have found it
difficult to set up regulatory or legislative guardrails on this nascent industry that features very seasoned stakeholders as well as completely new players.

The nature of the problem being studied is twofold and involves bodies of literature on autonomous vehicle technology and its projected implications for urban form; as well as the theory of economic and social regulation. The relationship between them is discussed in the following section.

*Autonomous vehicle: definitions and technology*

Autonomy in driving is generally defined by stakeholders across sectors using six categories created by the Society of Automotive Engineers (SAE). The SAE’s six-level spectrum has been widely adopted, including by the U.S. Department of Transportation (DOT) in their recent AV-related industry guidelines. The spectrum begins at Level 0, “No Automation”, where the human driver performs all driving tasks with possible support from warning systems, to Level 3, “Conditional Automation”, where the Automated Driving System completes all the driving with the human driver responding when requested, up to Level 5, “Full Automation”, where the human driver does not intervene at all. Many older vehicles today are at Level 0, whereas newer models that have adaptive cruise control and automatic emergency braking systems would be at Level 1. The goal for AV developers is to attain Level 5 automation, in which the human is completely out of the loop with regards to completing driving tasks. (For more detailed information, see Fig. 1.1 below.)

*Fig. 1.1 SAE Levels of Vehicle Automation*

<table>
<thead>
<tr>
<th>Levels of Automation</th>
<th>Who Does What, When</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 0</td>
<td>The human driver does all the driving.</td>
</tr>
<tr>
<td>Level 1</td>
<td>An advanced driver assistance system (ADAS) on the vehicle can sometimes assist the human driver with either steering or braking/accelerating, but not both simultaneously.</td>
</tr>
<tr>
<td>Level 2</td>
<td>An advanced driver assistance system (ADAS) on the vehicle can itself actually control both steering and braking/accelerating simultaneously under some circumstances. The human driver must continue to pay full attention (“monitor the driving environment”) at all times and perform the rest of the driving task.</td>
</tr>
</tbody>
</table>
An Automated Driving System (ADS) on the vehicle can itself perform all aspects of the driving task under some circumstances. In those circumstances, the human driver must be ready to take back control at any time when the ADS requests the human driver to do so. In all other circumstances, the human driver performs the driving task.

Level 4

An Automated Driving System (ADS) on the vehicle can itself perform all driving tasks and monitor the driving environment – essentially, do all the driving – in certain circumstances. The human need not pay attention in those circumstances.

Level 5

An Automated Driving System (ADS) on the vehicle can do all the driving in all circumstances. The human occupants are just passengers and need never be involved in driving.

Source: NHTSA 2018

**Assisted and Autonomous Driving Technology: A History**

**Early Autonomous Technology**

While fully autonomous driving may appear to be a recent and fundamental shift in mobility, the underlying elements of driver assistance systems have been developing over the past century across a variety of transport modes. One of the earliest milestones in assisted navigation technology was the successful use of a gyroscope by the pilot Wiley Post to track his plane's orientation in an around-the-world flight in 1933 (WIRED 2016). Cruise control, an essential feature in cars today that automatically controls their speed as determined by the driver, was invented in 1945 and installed in new Chrysler vehicles by 1958 (Park et al 2013). Inspired by the space race in the 1960s and hoping to develop a Moon rover, researchers at Stanford outfitted a cart with stereo cameras and a radio control; the cart was able to follow a “high contrast white line” on the road at a speed of about 0.8 miles per hour (mph) (Nilsson 2010, 12.2). In 1977 the “first real automated vehicle” was built by Tsukuba Mechanical Engineering Lab in Japan. The car tracked white street markings and attained speeds of nearly 20 mph (Becker et al 2014). Ten years later, an automated vehicle built by German engineers achieved highway speeds of 60 mph with “a bank of cameras and 60 micro-processing modules to detect objects on the road” (WIRED 2016). Researchers at Carnegie Mellon University (CMU) in 1995 completed a “No Hands Across America” tour, in which their vehicle “steered autonomously 98 percent of the time while human operators controlled the throttle and brakes” (RAND 2016, 56). In addition, remote sensing methods such as RADAR (or Radio Detection and Ranging) and LIDAR (or Light Detection and Ranging), which use radio waves and pulsed lasers to measure distances.
respectively, have accelerated the development of perception technology in building an autonomous vehicle.

**DARPA Challenges**
The most important catalyst for autonomous driving as we know it today was a series of three “Grand Challenges” sponsored in the 2000s by the U.S. Defense Advanced Research Projects Agency (DARPA). The main objective of the Challenges was to “develop an autonomous robot capable of traversing unrehearsed off-road terrain” (Thrun et al 2006, 662). The first Challenge took place in 2004, and required research teams to navigate a 142-mile long course in the Mojave Desert in less than ten hours, for a prize of $1 million. Even though just over 100 teams registered for the race and 15 actually raced, “none of the participating robots navigated more than 5% of the entire course” (ibid). Eighteen months later, the same Challenge was hosted for a prize of $2 million. Nearly 200 teams registered, 23 participated, and this time, five were able to complete the course. In 2007, the third and final Challenge featured a 60-mile urban course. Three of the six teams that completed the race did so within the time limit (RAND 2016, 57).

The urban iteration of the DARPA challenge “spearheaded advancements in sensor system and computing algorithms to detect and react to behavior of other vehicles, to navigate marked roads, and to obey traffic rules and signals” (ibid). However, arguably the most important development to have resulted from these DARPA Challenges was one of human capital and collaboration: automobile manufacturers and universities began to establish partnerships with one another, and talent pipelines from academia to industry began to solidify. GM renewed funding for a research lab at Carnegie Mellon University, and Volkswagen (VW) launched an Automotive Innovation Lab at Stanford. Key leaders in the autonomous vehicle space also began to emerge, connecting research institutions to car companies as well as software companies. Sebastian Thrun, who led the Stanford team to win the second DARPA Grand Challenge in 2005, founded the aforementioned lab with VW at Stanford in 2008, then went on to lead Google’s self-driving car project alongside several other key players from the DARPA Challenges such as Chris Urmson from CMU and Anthony Levandowski from the University of California, Berkeley (Thrun 2010).
**Fig. 1.2 Timeline of AV Technology Development**

<table>
<thead>
<tr>
<th>1908</th>
<th>1977</th>
<th>1995</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ford’s Model T introduced</td>
<td>Tsukuba in Japan builds “first real AV”</td>
<td>CMU team completes “No Hands Across America” tour</td>
</tr>
<tr>
<td>1945</td>
<td>1987</td>
<td>2004-13</td>
</tr>
<tr>
<td>Cruise control invented</td>
<td>AV built by German engineers achieves 60mph</td>
<td>DARPA Challenges catalyzes the commercialization of AV technology</td>
</tr>
</tbody>
</table>

**Human Capital, Academia, and Industry**

Many of the engineers involved in the early stages of Google’s self-driving car project have in the past several years started their own ventures in the AV space, enabled by enthusiastic venture capital, auto manufacturers, and the next generation of top engineering talent. Urmson, technical team leader of the CMU team that won the 2007 Urban Challenge, left Google in 2016 and co-founded an AV startup called Aurora Innovation shortly thereafter (Bhuiyan 2017a). In early 2018, Aurora announced its collaborations with VW and Hyundai. Bryan Salesky, the senior software engineer on the same CMU team, left Google in the same year to found his own AV startup, Argo AI (Korosec 2017). Ford gave Argo AI $1 billion in 2017 to be the latter’s “sole customer, backer, and majority stakeholder” (ibid). Levandowski, who “built the world’s first autonomous motorcycle” (Thrun 2010), also left Google in 2016 to found his own self-driving truck startup called Otto, which was acquired by Uber within the year (Dillet 2016). A year later, Waymo, Google’s self-driving car group that had just spun off from its parent company, filed a lawsuit against Uber that accuses the ride-sharing company-turned-AV-developer of stealing company secrets through its acquisition of Otto (Isaac and Wakabayashi 2017). The lawsuit was settled in February 2018, after months of negotiations and testimonies (Isaac 2018).

Despite such intimate connections between cutting-edge research and venture capital in the autonomous vehicle industry, timelines to achieve higher levels of autonomous driving offered by automakers and other AV developers have varied greatly. Tesla CEO Elon Musk has said on numerous occasions that a Tesla car will complete the drive from Los Angeles to New York without having any human intervention by the end of 2017, a promise that has not been fulfilled as of May 2018. More conservative estimates have come from traditional players such as Honda and Toyota, who are predicting a roll-out in 2020 for automated driving on highways before their AVs can operate in urban areas (Faggella 2017). Meanwhile, some disruptive startups in the
AV space are working toward drive-by-wire technology for existing cars: as comma.ai asserted in June 2017, “Building a car is stupid. The current cars are perfectly good at what they do, they just need to, well, drive themselves.” Using hardware to communicate with the car through the on-board diagnostics (OBD) port and accompanying software to interpret road conditions, they claim that “most 2012+ cars can be made drive by wire with software (modifications) alone” (comma.ai 2017).

The Critical Role of Software

Therein lies the major differences between the vehicles that are to come and those that have been developed in the last century: the critical nature of software. While the conventional mechanics of how a car moves by steering, accelerating, and braking may remain in its driverless version, the fundamental task of replacing a human driver requires the creation of specialized sensors and machine learning algorithms to interpret the sensory inputs, as well as decision-making programming to translate the information that has been perceived and interpreted to the action of driving (e.g. the system perceives an object coming into its path, recognizes it as a person who is not going to stop, and applies the brakes). Hence the discussion about the development of AVs in the past few years has focused on the “race” between Detroit and Silicon Valley -- automakers may well know how to design and manufacture cars efficiently, but software engineers have the competitive advantage of building the “brains“ of the AV. OEMs have traditionally focused on building cars that operate within strict safety regulations, and have built relationships with regulators through their long history of working together. Software companies, on the other hand, are only beginning to realize their need for government relations and lobbying, as their products that are designed to be “disruptive“ to the status quo often prove to be exactly that. While Detroit is working hard to keep up with the innovation in this space, Silicon Valley is learning to reconcile its “move fast and break things” modus operandi with the reality that they have to work with the bureaucracy and process of government for their products to be accepted by the public. The two industries are now closely linked in their AV pursuit, and both are aiming to use the other as their supplier instead of customer in order to be higher up the value chain (Rothfeder 2017). Given the requirements of autonomous driving and the divergent competencies between the two industries, emergent players in the automotive space believe that “autonomous vehicles are not an incremental shift, (but) a very transformative shift, almost like moving from the horse and carriage to the car” (Carol Reiley, co-founder of Drive.ai, in Roose 2017b).
Autonomous vehicle: potential impacts on quality of life and urban form

While OEMs and computer software companies speculate on who will be designing and manufacturing AVs in the future, planners and other stakeholders are focusing on the projected benefits and drawbacks of these vehicles.

Safety: Advocates of AV technology are optimistic that taking humans out of the driving equation will reduce the number of road fatalities and incidents caused by human error. Incremental additions of safety features accumulated over the past decades are currently being eroded by an increase in distracted driving (Bloomberg Aspen 2017). A 2015 report from the National Highway Traffic Safety Administration (NHTSA) showed that of the two million crashes studied over two and a half years, the driver was assigned as the “critical reason” for the crash in over 90 percent of cases, and half of those cases were caused specifically by driver inattention (Singh 2015). AVs will not be exogenously distracted by an incoming text message or get tired, so are anticipated to improve safety in this regard. On the other hand, concerns about complacent drivers in partially automated vehicles, as well as uncertainty about how cars will react in critical situations, are well-founded and should be assuaged before widespread deployment.

Mobility: Enabled by vehicle-to-vehicle and vehicle-to-infrastructure communication technology, AVs are expected to achieve great travel time and resource efficiencies through platooning with other AVs (Bloomberg Aspen 2017). With the success of transportation network companies (TNCs) like Uber and Lyft (and these firms’ own development of AV technology), mobility-as-a-service (MaaS) is considered a highly viable deployment model for AVs. As autonomous vehicles go “from luxury to utility” (ibid, 62), more passengers will be able to take advantage of this improved mobility. Nevertheless, while these networks of AVs can provide first/last-mile solutions to transit nodes, they may also cannibalize modes of public transit.

Energy: AVs are expected to yield great gains in energy efficiency: platooning can translate into more efficient driving patterns; cars are projected to be lighter and last longer because of fewer crashes; less time will be spent looking for parking; and assumed higher occupancy per car from carpooling should mean fewer cars on the road. However, since vehicular travel will become relatively cheaper, vehicle miles traveled (VMT) may actually increase -- people may live further away from their regular destinations or simply travel more (Brown et al 2013). According to an
estimate by the National Renewable Energy Laboratory, if an AV model were deployed via private ownership fueled by non-renewable sources, energy use would actually increase more than twofold; if AVs were shared and electric, the energy savings would approach 90 percent compared to present day (ibid).

Typically, discussions among policymakers and planning academics posit that the critical junctions in the adoption of the new technology are the powertrain and the ownership model (Freemark and Zhao 2018). There is general consensus that the “FAVES” model, coined by Zipcar co-founder Robin Chase -- Fleets of Autonomous Vehicles that are Electric and Shared -- would capture great welfare for the public. Nonetheless, the common thread among all this speculation and advocacy is uncertainty, and projections of the aforementioned net impacts have tended toward qualitative (see Fig. 1.3).

Other consequences important for stakeholders to consider include impacts on the urban form, workforce, data sharing, and public finance: Would improved mobility encourage sprawl? What will permanent dislocation mean for professional drivers? To the extent that they remain private entities, how would MaaS providers be required to share data with public entities? Finally, as federal public works like infrastructure maintenance and municipal services have historically been at least in part funded through the gas tax and traffic violations, what would be the impact of AVs on government finances? These questions are out of scope for this thesis but remain import ones for planners and policymakers to consider.

**Regulating a System of Shared Autonomous Vehicles**

This section discusses regulation from outside the industry, i.e. external entities that compel and monitor the behavior of these systems in order to ensure public safety, but also to ensure that these providers of public services actually serve the public interest. We look at the current state of AV-related regulation, useful regulatory frameworks, and potential pitfalls.
Fig. 1.3 Directional impacts of AVs on various societal measures
Source: Freemark and Zhao 2018, 22
Current State of AV Regulation

Since autonomous vehicles are billed as a totally transformative shift, lobbyists representing AV developers from traditional automakers to technology companies argue that the phenomenon is unprecedented: we cannot look to how cars have been regulated in the past to inform the future, so let us innovate and take a wait-and-see approach before imposing overly restrictive regulations on the industry. The RAND Corporation, reprising its role from the Cold War Era as technical assistant to policymakers, has been publishing on this topic since as early as 2009; a full guide for policymakers was released in 2016, promoting the positive externalities of AVs and warning that “different states’ attempts to regulate AV technology could result in a crazy quilt of incompatible requirements and regulations that would make it impossible to operate a vehicle with this technology in multiple states” (RAND 2016, xxiv). RAND most recently published an even more strongly-worded report, cautioning policymakers of the significant cost in human lives lost to car accidents while “waiting for nearly perfect automated vehicles” (Kalra and Groves 2017). The uncertainty surrounding the technology, its implications, and potential deployment has indeed led to a smattering of regulation being proposed across states and at the federal level today without clear coordination about jurisdiction and scope while “Washington plays catch up” (Roose 2017a).

This thesis scopes out the safety concerns plaguing policymakers now about the testing of autonomous vehicles, and is mainly concerned with the state of AVs as they enter the large-scale operational phase. I investigate the hypothesis that the transportation services provided by the platform may eventually become so necessary and entrenched in society that it is declared a modern-day utility, like internet access or public transportation; in addition, I explore the question of whether this new service would be provided by a monopolistic entity. Following this, the investigation will focus on identifying analogies relevant to the AV MaaS case, not within the automobile industry, but in more systems-driven industries such as telecommunications and power utilities.

Large-scale industries that provide essential infrastructural services to a city usually require significant capital investments and thereby tend to become natural monopolies. A lengthy discussion on Richard Posner’s influential theory on the topic will be presented in Chapter 3, and an updated perspective on natural monopolies from contemporary antitrust scholars will follow in Chapter 5.
Safeguarding the Public Interest

In addition to theories of economic regulation with regards to natural monopolies, a concern that runs parallel to how this autonomous MaaS system would be regulated is that the regulations, whatever the mechanism, should protect public welfare against private interest. As discussed above, autonomous vehicles are projected to provide substantial public benefit in increasing mobility, reducing congestion, improving road safety, and so on. In order to ensure we are consuming the optimal amount of this service, regulation is not only needed but must be safeguarded against regulatory capture, defined as “the result or process by which regulation, in law or application, is consistently or repeatedly directed away from the public interest and toward the interests of the regulated industry, by the intent and action of the industry itself” (Carpenter and Moss 2014, 13). In their anthology on the subject, Daniel Carpenter and David Moss make clear that observers of government-industry relations often quickly accuse regulatory bodies of being “captured” by special interests, without a more nuanced understanding of the kind or degree of capture. They assert that capture is not absolute, and special interests can influence regulation in less direct ways, such as through cultural currents, corrosion of regulation, career concerns, and provision of expertise by industry. In a chapter on the last mechanism mentioned, Nolan McCarty argues that regulators in the highly complex financial sector often do not have the internal expertise to produce effective regulation, and “may be so extremely dependent on the industry for information, expertise, and talent that they are not able to exercise independent regulatory authority” (in Carpenter and Moss 2014, 100). This means that “unless the agency is willing and able to commit significant resources to building its own expertise, it can learn about the policy environment only through monitoring the firm” (ibid, 103). This kind of informational-based influence may be commonplace in autonomous vehicle regulation, based on my observations from in-person meetings with policymakers and the literature by planners on the subject. Since this is an emerging and technology-intensive industry, barring a public AV-related catastrophe, few regulators are likely to be comfortable with crafting agreements with service providers without advice from the latter, which may make them vulnerable to regulatory influence that would diminish public interest. While some policymakers have expressed that they “don’t want to get Uber’ed again” -- referring to the way the transportation network company had entered many urban markets without regulatory oversight and thus was able to dictate how they are regulated after attaining consumer support -- they do not currently have the capacity to preemptively regulate an autonomous MaaS system. This thesis aims to bridge these gaps between industry and
government in order to increase capacity on both sides and increase transparency in their interactions.

Research Questions and Methodology
I am broadly interested in the much-anticipated but not well-understood projection of widespread AV deployment that is expected to occur within the next few decades, and a potentially new corresponding regulatory framework. My research questions are as follows:

1. In what ways does autonomous driving technology represent incremental progress in automobile development, and in what ways is it a fundamental transformation of the industry?
2. What are the current industry sentiments about and projections of the future deployment models of autonomous vehicles? In particular, what are their expectations with regards to individual ownership vs. shared mobility, powertrain, and integration with the public transportation system? What do these stakeholders see as the visions or goals that AV technology will promote or enable?
3. If a mobility-as-a-service platform is the most likely model to develop, what will be its characteristics, business model, and the economic structure of its market? Critically, is there reason to believe that it will tend toward a natural monopoly or a transport utility?
4. What kinds of ownership, operating, and regulation models are relevant when considering this AV case? What can we learn from analogous case studies in comparable industries, including classically-conceived public utilities, as well as contemporary industry giants such as Amazon and Google?

These questions are critical for not just transportation planners but also anyone who cares about facilitating an equitable and sustainable future way of life. I hope that this thesis will contribute to a growing body of knowledge that planners and policymakers can use to inform decision-making when crafting regulation for a world where AVs will represent an undeniably important mode of transportation and will have enormous potential to reshape our cities.

My research relies on four case studies and fifteen key informant interviews. I selected two classic public utilities -- telecommunications and power utilities -- as well as two modern-day technology companies -- Google and Amazon -- to serve as analogues to the future autonomous mobility platform. These case studies were chosen because of a set of shared
characteristics as well as differences, which, when combined, “affords analytical leverage otherwise unattainable” if simply considering a single industry (Jacobson 2000, 4). Further explanations for choosing these case studies are presented in Chapters 4 and 5.

This paper also draws on information gained from a series of interviews. Because the nature of the interview questions pertains to different stakeholders’ visions of the future AV platform, some of which constituted trade secrets, I chose not to record the interviews to encourage candor from my informants. The interviewees were promised anonymity, and their affiliations spanned from lobbyists, planning professionals, and government administrators, to policy managers at AV startups and government relations professionals at OEMs and ridesharing companies. I identified most of the interviewees on LinkedIn, then contacted them via LinkedIn and cold-emailing. I conducted most of the interviews by phone or video conference, and a few in-person in the Boston area. The length of the interviews ranged from 30 to 60 minutes, averaging 45 minutes each. The demographics ranged from younger interviewees in their early 30s to senior professionals with more than 20 years of work experience. Most were very enthusiastic to talk about the topic at hand, and affirmed the significance of my research questions. The table in Fig. 1.3 explains why I chose each stakeholder group to interview. The schematic of priorities facing each stakeholder group is outlined in Fig. 1.4, in which I deliberately position planners (including myself as a researcher) to be at the center of these conversations.

**Fig. 1.4 Overview of Interviewees**

<table>
<thead>
<tr>
<th>Key Informant Group</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Public and Non-Profit Sector Stakeholders</td>
<td>Understand their view of and approach to AV regulation vis-a-vis the MaaS model, and their overall vision or expectations for the future of autonomous mobility</td>
</tr>
<tr>
<td>AV Developers</td>
<td>Understand their view of what regulations would be appropriate for their industry given their inexperience with the regulatory landscape and enthusiasm for technological innovation</td>
</tr>
<tr>
<td>OEMs</td>
<td>Understand their view of what regulations would be appropriate for their industry given their long-term experience with the regulatory landscape and concern about new market entrants</td>
</tr>
</tbody>
</table>
Overview of the Thesis

In this chapter, I introduced the research questions and provided an overview of the literature on autonomous vehicle development and economic regulation. In the next chapter, I summarize stakeholder predictions about the future state of AVs, namely that they will be deployed as autonomous electric fleets in dense urban areas. I also outline their sentiments toward regulation in the industry, which range from an emphasis on shared values with the public sector, to a request to just wait and see, to a strong sense that government intervention is needed to ensure social goals are met. In Chapter 3, I present literature on natural monopoly and its key characteristics, and argue alongside my interviewees that the autonomous mobility platform will tend toward monopoly as a result of the requisite high upfront investments and its network effects.

In Chapters 4 and 5 I present the aforementioned case studies to guide our understanding of the autonomous mobility-as-a-service platform. In Chapter 4, two classic public utilities -- telecommunications and power utilities -- are analyzed, with specific focus on the transformative nature of their respective technologies, the difficulty the industry leaders faced in overtaking the
inferior legacy technology, and the pricing as well as consolidation tactics taken by the aspiring monopolists to secure their market dominance. I apply each of these characteristics to the AV case, and find evidence of similar phenomena in this fledgling industry. Chapter 5 adds to the discussion of monopolistic utilities by examining two of today’s largest technology companies. I find that the laser focus exhibited by Google and Amazon to become market leaders, and the aggressive methods they use to entrench themselves as such, to be a likely path for a platform company looking to dominate the autonomous mobility service market. In the final chapter, I recapitulate my findings and discuss policy implications. I encourage urban planners and policymakers to step outside of their disciplines to appreciate both the technical insights offered by the innovators and the difficulties facing regulators in the AV space, in order to facilitate a sustainable and equitable autonomous future.
Chapter 2: The Inevitability of Autonomous Electric Fleets

“People are really bad drivers and they kill a lot of people. This isn’t some dark secret master plan… we’re not selling you one thing or another.”
-- Informant S, General Counsel for Prominent AV Startup

“I am not convinced by what the automobile industry is trying to tell us.”
-- Informant J, environmental advocate

In this chapter I first report on industry sentiments about the anticipated deployment model of autonomous vehicles based on interview data as well as recent industry reports -- namely that the first iteration, at least in dense urban areas, will be Autonomous Electric Vehicles (AEVs) in fleets (a term I use interchangeably with “MaaS system” and “mobility platform”). I will also briefly touch on the stakeholders’ opinions about this system’s integration with the public transportation network in cities. I then discuss the degree of certainty of this future among the interviewees and argue that their current sentiments toward regulating such a future correspond to this certainty. Those who are most skeptical about this vision are generally most vocal about setting up appropriate guardrails and protections against negative externalities (discussed in Chapter 1), whereas those who are most certain about the AEV model tend to focus more on assuaging fears among the public and asking regulators to actively assist innovators in achieving this future.

The Future Will be Autonomous Electric Fleets

In this section I summarize the current industry sentiment about the future model of mass AV deployment as informed by interviews with employees of traditional OEMs as well as new players in the space such as technology companies; lobbyists representing AV companies; urban planning professionals; and government administrators.

Electric Powertrain

For the most part, the powertrain question was one that already appeared settled in the minds of the interviewees, whether they work for a traditional automaker, a technology-centric startup, or a government agency. A few OEMs have made public commitments or at least aspirational announcements about the mass production of exclusively electric vehicles in the near future.
Informant R, the director of policy at one such OEM, said that his company has made the deliberate decision to not invest in hybrid vehicles, as they believe that autonomous vehicles fit uniquely into their vision of not only fewer collisions and less congestion on the road, but especially into that of a zero-emission automotive future. Informant T, a policy manager at a top-tier AV company, reiterated this strategy, noting that the hybrid model is the wrong thing to do. Similarly, the general counsel for a prominent AV developer (Informant S) emphasized that “(their) cars will be electric, not only version one, but two and three”, suggesting that all foreseeable models will be AEVs as well. In addition to the desire to reduce emissions, there is also a safety component to the design process -- the general counsel for another well-funded AV company, Informant X, noted that part of the reason for going all-in for AEVs was that their engineers did not want to work with potentially explosive hydrogen fuel cell prototypes. Several representatives of a multinational ridesharing company identified a sustainable energy future as part of their company’s ethos from the outset, and that electrification is one of the key pillars for their projects in autonomous mobility. In the urban planning sector, leading organizations like the Metropolitan Area Planning Council (MAPC) in Massachusetts made clear in a document on legislative and policy considerations for AVs in May 2017 that “it is MAPC’s goal and expectation that the vast majority of autonomous vehicles will be ZEVs (zero emissions vehicles)” (MAPC 2017, 6).

Reports have shown that electric vehicles (EVs) “will have immediate cost advantages over traditional and hybrid vehicles in mobility services that will only grow” because of lower operating costs that offset higher capital costs and EV supply equipment infrastructure (Johnson and Walker 2017, 9). Improvements in autonomous driving technology will moreover accelerate the adoption of EVs: since autonomy is safer and may eventually “act as an effective substitute” for conventional heavy features in cars, automakers could produce vehicles higher on the automation spectrum at lower weights, meaning AVs that are fully or partially electric can travel the same distances using smaller and thus cheaper batteries. Level 4 AVs in particular can charge more frequently in between passenger rides. Overall, EVs -- charged by clean energy -- “have the potential to dramatically lower transportation GHG emissions, oil use, and conventional air pollutants... (and AVs) can hasten this transition” (Anderson et al 2016, 35). The key here is how the electric power to charge cars will be produced, and while the current administration is trying to protect the use of non-renewable sources by power utilities, renewable sources are becoming more economically viable. In early 2018, federal regulators
appointed by the current administration sided with critics within the electric power industry to oppose a proposal by Energy Secretary Rick Perry to subsidize “uncompetitive coal and nuclear units” (Plumer 2018). Industry experts project that the operating costs of shared, electric, autonomous vehicles can be so low that they could even be entirely covered by funding from advertisers (Arbib and Seba 2017).

Drivers around the world have already begun to embrace EVs, as new registration of EVs reached record levels in 2016. Electric vehicles make up almost 30% of the car market in Norway, while China was by far the largest EV market and accounted for more than 40% of electric cars sold in the world (IEA 2017, 5). According to the International Energy Agency, research, development and deployment as well as mass production prospects will lead to lower battery costs and greater efficiency (IEA 2017, 6). Industry trends like the success of Tesla Motors and decisions like Volvo’s that all of their new cars starting in 2019 will either be hybrids or entirely electric are positive signs that the market share of EVs will continue to increase (Ewing 2017). General Motors and their AV development unit, Cruise Automation, announced that starting in 2019, they will be mass-producing an autonomous version of the Chevrolet Bolt EV (Etherington 2017a). That one of the first major milestones in consumer-facing AV technology involves an electric car is yet another confirmation of the important connection between autonomy and electrification.

Nonetheless, a handful of interviewees were more hesitant on calling a zero-emission future for autonomous car travel. Informant Q, a director of government affairs and policy for an established automaker, was far and away the most non-committal in her view among her peers at other OEMs. Q brought up time and again the uncertainty in the field today, and stressed that her company is focused on developing a safe car above all else, and that they are not yet in the discussion of what the right energy platform would be, even as they are alert to the global environmental issues. Q added that it is too soon to address the complex intersection of energy systems and the future of automation. This sentiment was only echoed by one other informant, F, a lobbyist for a diverse group of autonomous vehicle companies. There is no direction that there will only be AEVs, said F, citing that some OEMs will have different answers and may choose to pursue the hybrid model as they wait and see how the market economics will play out. Ford is the most famous player with this position, placing its first bets on a new hybrid Fusion model that with autonomous features (Etherington 2017b).
Mobility-as-a-Service Fleet Model

The other largest variable in the widespread adoption of AVs other than the powertrain is the likelihood of managed fleets versus that of individual ownership. Industry sentiment is that the shared model is economically more attractive: autonomous taxis in the year 2020 (or a MaaS system) are projected to cost $0.35 per mile traveled, half of that of a personal car ($0.70), and much lower than current TNC ($2.86 for Uber in San Francisco) and traditional tax service ($3.50 for an average U.S. taxi) (Keeney 2017, 2). Shared AVs also are projected to have ten times the utilization rates of individually owned cars (Arbib and Seba 2017, 7). Moreover, the growing usage of shared mobility services across modes (cars and bicycles) and preliminary evidence that TNCs may contribute to reduced car ownership (e.g. Hampshire et al 2017) suggest that consumers are adopting the new model.

Given the favorable economics, that the mobility-as-a-service (MaaS) model is the more likely incarnation of autonomous car technology -- at least at first -- was also confirmed by my informants. Informants at transportation network companies (TNCs) -- whose core business currently already is MaaS platforms -- are most obviously supportive of this version of future mobility, given that they see fleet management as their competitive advantage. Nevertheless, almost everyone outside the TNC world also agreed that AVs will first have to be deployed and managed as fleets, primarily because of the expense. Informant T of a well-known AV developer expressed certainty that fleets will be the entrance point because of the capital expenditure needed to finance the development of such a system, which would prove to be inordinately expensive for the average consumer. T explained that if AVs are deployed as fleets, his company will be able to not only gain but also monetize consumer information and preferences. In the same vein, Informant R of a traditional OEM said that owning and maintaining their own fleet will help them glean important lessons to further refine their technology along the way. This virtuous cycle unique to data-intensive platforms will be highlighted again in Chapter 5.

Other AV companies conveyed that the vision of autonomous MaaS systems is intrinsic to their mission. According to the general counsel for a technology company, Informant X, his company is designing and planning to deliver vehicles intended for shared use in dense areas: they are very maneuverable and travel at a maximum of about 25 miles per hour for safety considerations. As AVs are reliant on high-resolution maps that have to be constantly updated, areas with higher use should be prioritized in data collection exercises. Cities would moreover
make the most sense for their product because shorter trips between destinations mean that range anxiety for their batteries will not become a problem.

Some interviewees took issue with their competitors making public pledges to the fleet model, perceiving these efforts -- the most famous of which is the “Shared Mobility Principles for Livable Cities” spearheaded by Zipcar co-founder Robin Chase -- to be at best no more than a self-serving public relations campaign for the signatories, and at worse, anti-competitive behavior. Informant Q, director of government affairs for an OEM, noted with some frustration that Chase has been effective in making her case, but Q’s company is thinking of staking out a counter position in response because they are unlikely to find a profitable way to operate under those commitments. Other informants at AV developers were of the milder opinion that these guidelines would ultimately limit consumer choice. The potential and the obstacles facing the autonomous MaaS system in supplanting this old system of car ownership is a theme to which we will return in Chapter 4.

Before moving to the next section on the anticipated connections with the public transportation system, I would like to address a major caveat to the fleet model, which is that very few of the interviewees made a distinction between a “shared” model in which riders are served by the same vehicle but all parties would take trips separately from one another (the typical form of “ride-hailing”) and one in which each AV trip would serve multiple riders with different destinations (a true “ridesharing” model like UberPOOL or Lyft Line today). The impacts on congestion and VMT will look very different in these two scenarios, and I do not make any assumptions in this paper on which scenario is more likely.

Integration with the public transit system
Another popular question about AV deployment, especially in the rest of the transportation world, is the effect of private on-demand transit on public transportation services in cities. Even before autonomy arrives, this issue has vexed cities and planning agencies, pitting transportation network companies who insist that their services are reducing car ownership against planning agencies who accuse TNCs of worsening urban congestion. The Metropolitan Area Planning Council (MAPC) published a research report in February 2018 that spoke to the worst fears of public transportation advocates. TNC-provided trips around the study area of Boston were overwhelmingly (80%) servicing one party at a time. A significant portion of the
TNC trips suggested some manifestation of transit substitution, particularly during rush hour when congestion is worst. The report concluded that “15% of ride-hailing trips are adding cars to the region’s roadways during rush hour” (Gehrke et al 2018, 14).

On the subject of autonomous MaaS systems cannibalizing or even usurping public transportation, most informants said they foresee some sizeable degree of complementary integration between the two. All were familiar with the “first-mile, last-mile” model frequently invoked in the discourse today, which refers to AVs providing connective services between a rider’s origin or destination and transit stops. Z, an engineering lead at a TNC, said they have been “absolutely transparent” about their approach to this model, i.e. trips can be multimodal, and MaaS can be used only for a portion of the trip.

Several interviewees across sectors identified the potential benefit for public transportation systems to adapt the flexibility that comes with on-demand services instead of fixed routes for their bus lines. Fare box recovery for bus services, especially those in sparsely populated areas, tends to be quite low but transit services still have to be offered to meet the needs of those residents. Dynamically scheduled autonomous transit options in the form of passenger cars or small vans can theoretically produce efficiency gains compared to a closed loop bus system. Informant K at the regional planning agency went further to suggest that the integration of an autonomous MaaS system and the local public transportation system can be extended to implement a single payment system across the modes. The most assertive interpretation of this question was provided by Informant L, the chief policy officer for a major technology company. L is confident that AVs will not be able to replace high throughput transit systems, but that a well-coordinated and well-developed autonomous MaaS system will enable public transportation agencies to rationalize their operations -- they can stop operating subway systems overnight and prune the bus network (barring labor union objections), handing off those services to the aforementioned on-demand system that will be much more efficient in matching supply and demand of mobility services. Lastly, public sector planners and private sector representatives across the board agreed that governments cannot simply restrict services provided by TNCs in order to bolster the financial prospects of the transit authorities; the latter are also responsible for ensuring operational viability and improving their offerings to remain relevant to consumers.
Three Categories of “Believers”

The stakeholders I interviewed for my research can be broadly categorized into three groups based on their overall posture toward articulating the future deployment of AVs as autonomous electric fleets: those who almost certain or at least highly optimistic that this vision will be proven correct; those who are most skeptical, almost cynical, about the possibility; and, invariably, those in between.

Those who are most confident that AVs will be EVs deployed in fleets tend to be informants from technology companies and AV developers outside of the traditional OEM world. They are younger and work in dense coastal cities, where the prevailing lifestyles and political positions would suggest downward trends in individual car ownership and reduced use of internal combustion engines in automotive technology. Informants who are more resistant to signing on wholeheartedly and exclusively to the fleet deployment model do not share this kind of urban bias. They represent traditional automobile manufacturers who have long-standing relationships with customers across the country in all geographic regions. It is too soon for this vision of an autonomous MaaS system to confine the technology, said Informant Q of a leading automaker, and thus we should instead be prepared for an array of alternative possible future scenarios and how we can identify which future we are headed toward as the technology matures. Several public sector informants shared similar views, maintaining that these futures are impossible to anticipate and we will likely end up somewhere in the middle vis-a-vis the “100% of AV travel will be satisfied by MaaS versus 100% will be individual ownership” debate.

By far the most skeptical informant was J, who represents an environmental advocacy organization. J has been attending public and private meetings at a state legislature as well as various transportation departments for the past few years. He noticed that AV developers are focusing most of their resources and attention to doing the difficult task, i.e. making AV technology a reality. At meetings with public sector stakeholders, they usually only present the rosy future that they think government administrators and elected officials want to hear, which J said will not come true unless certain regulations are put in place. He remains “unconvinced by what automobile industry is trying to tell us, that everything will be shared and electric”. As a result, J has been very active in communicating with policymakers on how to create a better transportation system with the aid of autonomy.
The three broad categories of “believers” as I call them map fairly consistently on to three corresponding attitudes toward regulation. In the following section, I detail these approaches and explain how they help us understand the opportunities and challenges facing policymakers of today and tomorrow.

The degree of certainty people feel about the future of an autonomous MaaS system informs the way they manage government regulation in this space. Generally, stakeholders who are more certain about the fleet model as described above commonly interact with regulators and policymakers with the goal of educating the latter on the technology and (in many cases) its inevitability. Those who are less certain are advocates of the “wait and see” approach. Those who are most skeptical about the fleet model are consistently pushing for more rules and more precautions. These sentiments were apparent both in my informant interviews and at the roughly bimonthly public meetings held by the Massachusetts Department of Transportation’s Autonomous Vehicles Working Group throughout 2017 and 2018.

**Approach 1: “We want the same thing”: Policymakers should understand and enable**

Policy liaisons and government relations managers at AV startups, technology companies, and TNCs reported that their overall strategy is to educate government administrators and legislators so that the public sector can accelerate the development and deployment of autonomous fleets. Informant S of a prominent AV startup noted that his message to government officials is to give them a better idea of what his company is working on, and to provide ideas for regulations. As general counsel for his company, S insisted that they “respond with earnestness” to these officials and work toward establishing common ground by telling them that “I care about the same things you do”. “A lot of the times, we are not pushing for something,” S added, somewhat defensively. “We’re not selling you one thing or another, and there isn’t some dark secret master plan.” He has encountered a “fear” among government officials that they want to get ahead of the technology before dominant players force them into enacting reactionary regulation, as in the TNC case; yet these officials almost always say yes if S pressed them about whether TNC services have been net positive for their constituents. S believes he can make the same case about AVs today. Public servants have come a long way since even 18 months ago in terms of their baseline understanding of the technology and impacts of AVs, said T, policy manager for another AV startup. Moreover, according to X,
general counsel for another well-regarded AV startup, there remains a substantial educational
deficit, but he has found that city and state governments have largely been very reasonable.

All of the interviewees in this group are younger and earlier in their regulatory careers than
those in the other two groups below. Because of how new the industry is and how recently they
started with these companies, there are no entrenched dynamics between these policy liaisons
and their target audience in government. Not enough interactions have occurred between the
two parties to produce any potential antagonism. In fact, most of these informants are
personally sympathetic to the general policy directions pertaining to on-demand mobility,
reduced emissions and individual car ownership, and thus are well-aligned to help advance the
goals of the regulators.

Approach 2: “Do nothing”: Policymakers should wait and see
The second group consists of informants at traditional OEMs, who are much more hesitant
about committing to a fleet-only future, given their obvious financial interests in manufacturing
and selling cars. These individuals are therefore taking a different tack than their younger
colleagues, focusing instead on reiterating to regulators that doing too much now will result in
government “picking winners and losers” in the industry.

Unlike the first group, these interviewees have a dimmer view of regulation, informed by their
previous experience in the automotive industry, other industries, and even government itself.
Informant Q recently became a director of government affairs for an OEM after spending over a
decade at a relevant federal department. Q expressed frustration at her former colleagues for
“not getting it” when it comes to setting rules for AVs, citing as a prime example their blanket
requests for data from AV developers that are proprietary, or too voluminous for public entities
to handle in any case. Innovators should not be prematurely constrained by regulatory
frameworks that are “technologically ill-informed and overly fearful”. R, director of policy at an
OEM, emphasized that the difficulty in communicating with policymakers is to convey that the
technology is indeed developing very rapidly, but at this nascent stage, there must also be
enough room in the regulatory framework for innovative solutions to be worked out. Once the
technology becomes more established, market players and governments can determine what
the “right” regulatory approach can be. R advocates for keeping the playing field as open as
possible.
Lobbyists representing OEMs are also similarly reluctant to recommend policy changes other than those that obviously constrain the development of AVs, such as New York State’s requirement that all licensed drivers must have one hand on the wheel (Davies 2015). One such informant, F, said that his practice has engaged fairly vigorously with regulators on the point that the reason AV developers are working so hard is the outsized value proposition of this new technology, and that is powerful enough of an incentive to keep them in check on issues of public concern. Another lobbyist, G, commented that if policymakers really want to speed up the deployment of AVs, in many instances no change in statutes is needed. Waiting to see how the technology unfolds is preferable to retroactively paring back “bad” regulation. At a Massachusetts Joint Committee on Transportation hearing in April 2017, Damon Porter, a spokesperson of the Association of Global Automakers, a trade association representing over 15 international OEMs and automotive suppliers, read a statement expressing concerns for a patchwork regulatory system. This “inconsistent” and “burdensome” system can prove to be anticompetitive; Porter even remarked that overly restrictive regulation can cause his clients to stop investing in their operations in Massachusetts.

This approach has been mostly employed by OEMs to critique proposed rules on safety concerns surrounding AV testing, but it has also been picked up by lobbyists who see issues with governments beginning to think about longer-term operational models. At the hearing in 2017, a representative from Toyota explicitly included in her feedback to the committee that there should be no new taxes and no zero-emissions requirements put in place for AVs. A representative of Audi likewise spoke against “overly burdensome regulations”, stating that her company also wants to develop shared AVs, but “to mandate it isn’t going to expedite it”.

These OEMs are understandably entering these discussions with more trepidation as they see entirely new entrants into their market that may threaten to render them obsolete in this transformative turn in their own industry (per the Detroit vs. Silicon Valley discussion in Chapter 1). Nevertheless, this “wait and see” approach is not particularly popular with its audience. “We are not used to people telling us to do nothing” was a representative response from regulators, given by the Chair of the Joint Committee on Transportation at the April 2017 hearing. It remains to be seen how effective this approach will prove for the OEMs, as elected officials and their staff begin to get more anxious about managing the AV file.
Approach 3: “Set ground rules”: Policymakers to put in place adaptive guidelines

The final group of informants are generally planners and advocates in the public or non-profit sector who are worried that the widespread deployment of autonomous vehicles may wreak havoc on urban infrastructure, air quality, congestion, and other public goods. As a result, they tend to be quite vocal in requesting that governments become more proactive in their governance of a future of AVs.

Informant J of the environmental advocacy organization was the most skeptical that a fleet model of AVs will prevail, and thus has been diligent in advising government contacts accordingly. J perceives the discussion on safety testing that dominate working group meetings to be a red herring, and prefers to focus on advancing policies and legislation to mitigate the fiscal and economic impacts of AV travel, hoping to guide technology developers toward truly shared on-demand mobility and away from solo AV trips and individual car ownership. Policies and laws will have to be in place for the technology to succeed, and they can be adjusted as needed. J would agree with Informant F, the lobbyist, that the value proposition of AVs is immense; in fact, so much so that J thinks if regulators put operational restrictions on AV developers, “they will work around it -- it’s such a game-changer that it will still happen.”

Other planners are similarly concerned about the recommendations by industry to keep the AV space unregulated. Informant K of a regional planning agency agreed with the first group of stakeholders that the public sector needs to be more informed about the technology, but she added that the AV developers themselves also need to be educated, specifically about issues such as operating in the public right of way, identifying jurisdiction, and understanding why they must abide by certain guidelines that are in the public interest. K thinks that AV developers as well as TNCs need to be brought back into the fold to engage in productive dialogue, instead of simply being on the receiving end of information from the technologists or taking a totally hands-off approach altogether.

Summary

In this chapter I provided a cross-section of what stakeholders across industries understand to be the future state of AVs, i.e. that autonomous electric vehicles will first be deployed as fleets in dense urban areas, with some degree of integration with the local public transit system. I then presented three distinct groups of stakeholders with varying degrees of certainty toward this
future, and described their corresponding views on the usefulness of regulation today (see summary table in Fig. 2.1). Appreciating the diverse positions of the interviewees helps us set the stage for their engagement with the rest of this thesis, and contextualize my approach in the subsequent chapters, namely the assumption that the autonomous mobility-as-a-service system will likely operate as regional monopolies, and the implications of this insight on crafting AV-related regulation in the long-run.

Fig. 2.1 Summary of How Stakeholders Group See the Future of AVs and Attitude Toward Regulation

<table>
<thead>
<tr>
<th>Degree of Certainty</th>
<th>AV Startups</th>
<th>OEMs</th>
<th>Public Sector / Planners</th>
</tr>
</thead>
<tbody>
<tr>
<td>AVs will be mostly electric</td>
<td>✓ ✓</td>
<td>✓</td>
<td>×</td>
</tr>
<tr>
<td></td>
<td>Very certain</td>
<td>Mixed response</td>
<td>Skeptical</td>
</tr>
<tr>
<td>AVs will operate primarily in fleets</td>
<td>✓ ✓</td>
<td>✓</td>
<td>×</td>
</tr>
<tr>
<td>AVs will integrate well with transit</td>
<td>✓ ✓</td>
<td>✓</td>
<td>×</td>
</tr>
<tr>
<td>Corresponding attitude toward regulation</td>
<td>“We want the same thing”: Policymakers should understand and enable</td>
<td>“Do nothing”: Policymakers should wait and see</td>
<td>“Set ground rules”: Policymakers to put in place adaptive guidelines</td>
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Chapter 3: Why the Autonomous Mobility Platform Will Be A Natural Monopoly

“Regulation may be likened to the treatment of an ailment whose gravity is not known with a costly and dangerous drug whose efficacy is highly uncertain. It can be improved, but I do not see how we can realistically hope to transform it into a fruitful instrument for advancing the public welfare.”
-- Richard Posner, in “Natural Monopoly and Its Regulation” (1969)

In the preceding chapter I described the anticipated future model of deployment for autonomous vehicles as a fleet system, and the broad stakeholder sentiment regarding regulating this system. In this chapter I argue that the fleet management of autonomous vehicles is likely to centralize into a monopolistic model in which one provider dominates each service region. I formalize this discussion first by outlining the characteristics of natural monopolies, the rationale for regulating them, and the obstacles to regulating them well. I identify reasons to believe that the autonomous MaaS system will become a natural monopoly, namely that one firm will be most efficient in providing the service instead of two or more, and that there is a high sunk cost as well as high barrier to entry into the market. Finally, I introduce the concept of the “common carrier” as it relates to natural monopolies, why it exists and matters, and briefly discuss several examples that will serve as analogues later in this paper. I propose that the future autonomous MaaS system should be considered a common carrier, and what that status means for crafting a corresponding regulatory framework.

A Primer on Natural Monopoly

In the following section I draw heavily on Richard Posner’s foundational work (1969) on natural monopolies to explain what they are, why their regulation exists, and the drawbacks to government economic regulation. While Posner makes clear that he does not believe government regulation of natural monopolies to be efficient, I argue that the goal of regulating monopolies is not efficiency but universal accessibility to essential services.
What is a natural monopoly?
The basic definition of a monopoly is a seller of a good or service without close substitutes. The definition of a natural monopoly adds to this concept, and is summarized by Posner as follows: “If the entire demand within a relevant market can be satisfied at lowest cost by one firm rather than by two or more, the market is a natural monopoly, whatever the actual number of firms in it. If such a market contains more than one firm, either the firms will quickly shake down to one through mergers or failures, or production will continue to consume more resources than necessary. In the first case competition is short-lived and in the second it produces inefficient results” (1969, 548). This concept is known as sub-additivity, where one firm can produce a good or service more efficiently than multiple firms can, and in turn depends on the concept of economies of scale, where average costs decrease as quantity increases, and the marginal cost of serving an additional customer is small. However, in order to truly deter entrants, “economies of scale must be associated with sunk costs” (Mosca 2008, 319). The notion of sunk costs are closely associated with that of high startup costs for an industry, usually exemplified by capital-intensive infrastructure (physical or virtual) needed to kick-start the network effects of said monopoly. In sum, a natural monopoly has two major characteristics: one firm is more efficient in providing services than two or more (regardless of how many firms actually exist in the market); and there is a high sunk cost for entering the market. Lastly, Posner notes that a natural monopoly does not have to be nationwide, and the good or service can be provided by different firms in different regions, so long as consumers cannot buy from firms outside their region (ibid).

Why and how do we regulate monopolies?
The argument for government regulation of monopolies is generally that without competition to regulate the behavior of firms in non-monopolistic markets, “direct controls are necessary to ensure satisfactory performance” in areas such as affordability of rates, quality of service, changes in service levels and capacity, and so on (Posner 1969, 548). Posner notes that these kinds of controls are called “public utility regulation” when applied to water and electric power companies, and “common carrier regulation” when applied to transportation and telecommunications (ibid). These companies provide essential services for a city to operate and an economy to grow, and thus should be promoted and protected to some extent; however, their status as monopolies and potential maximizers of producer surplus also invite accusations of greed. Monopolies are criticized for transferring wealth from consumers who are presumably
less well-off to stockholders, thereby exacerbating income inequality. Because the services produced by these industries are so important, governments have an interest in ensuring that everyone can access them at a reasonable cost and standard, even if some are unable to afford to pay what is otherwise the market price.

The most common mechanism used by governments to regulate monopolies involves the pricing of services. A regulated firm submits its annual expenses to the regulatory commission, which reviews the validity of the expenses and computes an allowance for a fair return to stockholders. The calculation is designed to factor in “the estimated cost of attracting and holding the necessary equity capital” (ibid, 592). The rates for the firm’s services are adjusted accordingly. Regulatory commissions also oversee service standards and monitor service discrimination, as well as make decisions regarding mergers and acquisitions in the industry.

Some arguments against economic regulation of monopolies
As mentioned above, Richard Posner generally does not think that public utility regulation is that useful beyond the social (health, safety) or antitrust kind. First, Posner argues that regulation leads to “industrial politicization”, in which the monopolist firm, understanding that it is in its ultimate long-term interest to maintain monopoly status through public image management, misallocates resources to government and public relations campaigns instead of “pursuing a single-minded policy of profit maximizing in the short term” (1969, 576). This may cause operational inefficiencies and further reward rent-seeking.

Second, since utility rates are regulated and often capped, firms that experience increases in operational expenses are unable to offset them to the customers so instead reduces the quality of service. Posner asserts that poorer service quality such as longer waiting periods are difficult to prove. Third, monopolist firms may not be as incentivized to innovate as competitive ones. Rates are not reviewed that frequently because the process is labor-intensive, and whatever cost savings that firms can squeeze out in between rate changes are usually enjoyed as extra profits. This regulatory lag may not be enough to induce investments by firms to innovate, and given how important innovation is to economic growth and development, says Posner, this is a very strong point against profit controls of monopolies. Fourth, given the rate at which technology and industries are changing, regulating a market that currently appears to be a natural monopoly may stifle competition that could have unseated the designated monopolist.
“To embrace regulation because an industry is today a natural monopoly and seems likely to remain so is to gamble dangerously with the future. To impose regulation on the basis of a prophecy that the industry will remain monopolistic forever may be to make the prophecy self-fulfilling” (ibid, 636). By establishing dedicated relationships with some firms and not others (including those yet to enter the market), regulatory commissions are effectively determining who belongs and who does not, Posner argues.

Lastly, Posner discusses in some length the issues with cross-subsidies that result from regulators requiring monopolistic firms to provide universal services. Although “the essence of a public utility’s or common carrier’s duty, as traditionally conceived, is to serve all comers at fair rates”, Posner says, it “does not necessarily imply a duty to provide services at rates below cost” (ibid, 607). Because commissions pressure firms to commit to universal service, firms are compelled to use some of their profits to subsidize extending their services to those who cannot pay the remunerative rate (ibid). Internal subsidies are not only paternalistic, he argues, but actually helps to further “entrench the regulated monopolist” by legitimizing operations that would not have occurred without regulatory interference (608). Posner goes so far as to suggest that instead of, for example, extending telephone service to communities in rural Alabama, governments should consider giving those residents tax revenues obtained from utilities instead of presuming they would consume this service. This proposal is unrealistic and inequitable: one of the fundamental characteristics of a natural monopoly is the high startup cost of infrastructure -- residents, no matter how big their tax rebates, will not be able to finance telecommunications infrastructure on their own without government intervention. If we agree that telephone service is essential to a consistent standard of living for all, cash payouts would be a poor substitute. Posner concedes that the strongest case for subsidies is to induce the provision of services that are so essential that the government would have to step in as a producer if companies did not extend the services to all. This is an important concession by Posner, because it means that the debate is less about whether essential services should be regulated, but which services should be counted as essential.

In sum, natural monopolies tend to have two characteristics -- that one firm is most efficient in providing the service, and that the high barrier to entry involves sunk costs. Natural monopolies are regulated to ensure essential services are being provided to all and at reasonable prices. Regulation usually takes the form of controlled rates, and has been subject to criticism on the
basis of inefficiency, removing incentive for innovation, and its tendency to decide winners in the market. Contrary to Posner’s views on cross-subsidies, I believe that because essential services enable everyone to participate more fully in society and in the economy, the ultimate goal of regulation should be to ensure those who otherwise cannot access these services at the market rate are still able to do so for both equity and productivity reasons. An update and critique on Posner’s perspectives will be provided in Chapter 5 when we discuss the strategies pursued by modern-day internet-enabled companies.

In the following section I demonstrate that the future autonomous MaaS system, as described in Chapter 2 by the industry and stakeholder interviewees, is projected to exhibit the two key characteristics of a natural monopoly. I then discuss the application of the “common carrier” to this system, and its implication for designing regulatory frameworks for it.

**Why the Autonomous Mobility Platform Will be a Natural Monopoly**

*Characteristic 1: One firm is more efficient in providing service*

That one firm is most efficient in providing an autonomous on-demand personal transportation service was described by several informants as the importance of a centralized command center for the service. Representatives from TNCs were most comfortable with this idea, no doubt in part because their current operations rely heavily on such a very similar dispatch system.

Informant Y of a TNC said that his company was founded on a set of principles to improve the efficiency of the urban mobility system, so the deployment of AVs for them would make perfect sense in the form of a shared fleet managed by a centrally operated and owned system.

Informant Z, an engineer at the same TNC, also said that the scale of their future AV network will be one of their most powerful assets and will be most efficient in allocating rides as well as enabling massive data collection to constantly improve the technology through machine learning. Similarly, Informant X indicated that his AV company is currently conducting research in tele-operations to understand how to implement a centralized command center in each city. The autonomous ride-hailing model is a business case that coheres well together, said X, since it uses a fleet most efficiently.

Other informants, especially those working with traditional OEMs, are once again more reluctant that this will be the case. While newer software-based technology companies like Uber and Lyft have been battling for market domination since their inception, automakers have long
existed quite comfortably in an oligopoly. Unlike the ambitious proclamations of the newer entrants, Informant Q says her OEM does not see “the world as one winner and everyone else is dog food”. One of the lobbyists representing select OEMs, Informant F, also expressed skepticism since he believes there will be enough product and consumer segmentation to prevent a market power concentration of monopolistic significance.

It is true that even in the case of TNCs today, it remains to be seen whether a duopoly by Uber and Lyft will remain the stable equilibrium. However, this model still trends toward a natural monopoly because it is by definition inefficient to have duplicate ride-hailing networks in one regional market. It would be providing substitutive services to the same customer base while devoting twice the resources for two centralized command centers, two sets of maintenance processes and facilities, two support infrastructures for software platforms, and so on. This suggests that even if the duopoly enjoyed by current TNCs were to continue until the arrival of autonomous technology, it is inefficient and unlikely to remain indefinitely. In fact, even Informant F, who expressed doubt toward this level of market consolidation, conceded readily that all the players in the industry have the singular drive for maximum profitability and domination, and that they are “arm-wrestling” for territory. Even if the end state of the autonomous MaaS system is not serviced entirely by one firm, the economics would suggest the dominance of one firm over all others in the market.

**Characteristic 2: High sunk cost / barrier to entry**

The other major reason to believe that the autonomous mobility service will become a monopoly is its barrier to entry. First, from an infrastructure and R&D perspective, autonomous technology is incredibly expensive and multi-faceted, from software and hardware development to building the central command function and V2X communication infrastructure. In order to get to the deployment stage, the capital expenditure for the first fleets will be so high as to exclude all but the companies with most funding. Second, competitors are racing to absorb large amounts of venture capital worldwide, with Uber leading the charge at $20 billion in funding as of March 2018 (Crunchbase 2018d). Industry observers have noted that while Uber may in fact need that amount of money to finance its business operations and R&D, it is also financing “a war of attrition, a mad scramble to starve the competition of cash” (Sorkin 2016). The more money Uber is able to raise, the less willing venture capital investors may be to fund a rival to compete with the incumbent.
Third, in the same way that they plan to dominate through fundraising, firms are also fiercely hiring talent not only to accelerate their own work but -- more crucially -- to stymie that of their competitors. A large part of VC funding is spent on retaining talent, with AV engineers being paid salaries upwards of $300,000 (Ohnsman 2017). Even with this kind of compensation, Waymo, the AV spin-off from Google and the industry leader in technology, has been losing engineering talent through “major defections” to formidable peers like Uber but also to new startups founded by their own former employees (Bhuiyan and Molla 2017). General Motors has grown its AV-related personnel from 90 in 2016 to a projected 2,100 later this year (Wu 2018, 29). This incredible amount of resources being devoted to this arms race suggests that the industry not only recognizes the lucrative value proposition of AV technology, but also the zero-sum, winner-takes-all nature of the game.

Finally, many point to the network effect that helps ride-hailing companies to succeed today as another barrier to entry. For the ride-hailing market, the more riders and drivers use one app over the other, the more difficult it is for new entrants to compete without even greater capital reserves (see Fig. 3.1). Beyond the straightforward network effect of having customers on one’s platform, Informant T of a prominent AV company noted that his firm would monetize consumer information, use it to inform business decisions, and improve both the technology and the user experience to gain more customer loyalty. This was echoed by Informant Z, engineer at a TNC. Z indicated that they do not care to have the first AV out on the street because they “have already lost that race”, but that their ambition is to be “first at scale”, implying that the winner will dominate the market because of the positive feedback loop. It is not difficult to imagine that one marketplace can become so dominant that the firm that coordinates it can impose restrictions on producers to sell to other marketplaces, or that the firm becomes the most efficient way to serve customers that producers effectively use this firm exclusively. Industry observers have noted that elsewhere in Silicon Valley, firms tend toward monopoly, pointing to Airbnb for vacation rentals and Spotify for music streaming. As discussed above, these services exhibit network effects so powerful that “despite an array of options, users keep coming back to the market leaders” -- even if the winner does not take all, it usually takes most (Gelles and Isaac 2016). The importance of network effects on attaining a monopoly will be discussed in much greater detail in Chapter 5.
Partnerships and Consolidations
Aspiring monopolists use massive amounts of funding to accelerate R&D, aggressively deprive competitors of capital and talent, and take advantage of the network effect to shut out potential rivals. In the following section I catalogue industry trends and recent events that have led many experts to believe that there will be mass consolidation in the autonomous vehicle supply chain or stack as we progress toward widespread deployment.

Fig. 3.1 Uber’s Network Effects

Because of the “outsized rewards of trillions of dollars of market opportunities and network effects”, AV developers realize that the “winners-take-all dynamics will force them to make large upfront investments to provide the highest possible level of service, ensuring supply
matches demand in each geographic market they enter” (Arbib and Seba, 7). In particular, given the critical importance of software in AV development, there is much chatter in the industry of whether traditional OEMs will “survive” this transformation in the mobility industry. Informant R, director of policy at one such OEM, said that they are aware of the dramatic development in the space led by industry outsiders like technology companies (e.g. Google, Uber), startups (e.g. Argo, nuTonomy), and even non-traditional OEMs (e.g. Zoox, Faraday Future). “Tech mounts pressure across auto value chain”, announces an industry update presentation by CBInsights, alongside a graphic of a large fish about to swallow a smaller one (Wu 2018, 9). Although “automakers have not been disrupted… yet” (ibid, 14), the trending down of licensed drivers and the growing volume of competition mean that OEMs will need to do more to stand a chance of becoming the eventual winner.

OEMs do not want to become Foxconn (a contract manufacturing company that supplies to Apple and Google), said Informant F, the lobbyist for a group of AV companies. They do not want to lose their brand identity and end up as mere suppliers to a technology company like Uber or Lyft that manages an autonomous MaaS platform. In order to bolster their AV credentials, they must partner up or bow out. There is no natural notion of collaboration, F explained, as companies will only band together for their own gain.

The case for partnership is also compelling on the AV startup side. For the most part, these software engineers simply do not know how to build a car, and need an OEM partner to provide them with a starting point to test their technology. Not only have the two sides have found eager dance partners in one another as a result, but they also bring along other suppliers in the AV stack. Uber has partnered with Toyota, Volvo, Otto (an autonomous truck startup), and NVIDIA (a market leader in graphics processing units, which are critical to increasing computing power for AV software). Informant X of a now-prominent AV company said that he suspects Volvo is partnering with Uber because it wants to learn how to design AV software. X himself said that when they first started out, it was difficult to get leverage with OEM sponsors because many of them had already established relationships with other startups, that is to say, many of their potential dance partners have already been taken. When they were able to find a partner outside the traditional North American market, the agreement with the foreign OEM involved getting vehicles for free in exchange for information on their technology. The AV startup Aurora Innovation, founded in 2017 by engineering leads at Google, Tesla, and Uber, announced in
early 2018 that it has inked deals with both Volkswagen and Hyundai, “automotive partners that had global scale”, to help them deliver their mobility-as-a-service platform (Davies 2018). Seen as lagging behind its more mature competitor, Lyft is implementing a “dual-pronged catchup strategy” (Wu 2018, 32): in addition to investing in its own AV development efforts, it has publicized partnerships with Waymo, GM, nuTonomy (an AV startup spun out of MIT), Drive.ai (another AV software startup), Ford, Jaguar Land Rover, and, most recently, Canadian auto parts supplier Magna. Finally, in early 2017, Ford made a $1 billion investment in Argo AI, an artificial intelligence startup led by an ex-Google engineer, to build the entire technology platform for its AV offering, with Ford as Argo's sole customer, funder, and majority shareholder (Korosec 2017) -- everything short of acquiring the startup.

Fig. 3.2 Overview of Select Partnerships in the AV Industry

Source: Silver 2017
As “partnerships are fickle” and complicated (Wu 2018, 33), partners also come and go. The most famously acrimonious of these may be the fallout between Waymo and Uber, brought to bear when the former filed a lawsuit against the latter for stealing trade secrets. The two giants settled in February 2018, with Uber giving Waymo a 0.34 percent stake in its business (representing roughly $245 million) and promising to not use Waymo’s technology in its AVs (Marshall and Davies 2018). Reilly Brennan, a venture capitalist in the AV space, commented that “Waymo needed to do what market leaders need to do: maintain their leadership by going after all enemies foreign and domestic. The only way Waymo was going to lose was by doing nothing at all” (Brennan 2018). Despite the sparring in the industry, the lobbyist Informant F is confident that among the combinations and tie-ups between car makers and technology innovators today, the right OEM pairing with the right Silicon Valley company can be a real force multiplier in the industry.

There has also been signals for eventual industry consolidation given the handful of significant acquisitions that have occurred even over the past two years. GM bought the AV startup Cruise Automation for more than $1 billion in 2016 when the latter was only three years old; a year later, the OEM bought another three-year-old company, Strobe, for its LIDAR sensor technology for an undisclosed amount (Vlasic 2017). The MIT spin-off nuTonomy was acquired last year for $450 million by the Tier 1 auto supplier Delphi (renamed Aptiv in December 2017) (Burns 2017). Informant F, the lobbyist, noted that in the future Americans will theoretically need a lot fewer cars than the 250 million they have on the road today, and that can lead to industry consolidation in which only two or three providers of AVs will eventually remain. When that happens, he concedes, there may be market failures that would suggest a need for at least some regulation.

Many informants, when discussing potential consolidation moves by industry, brought up the possibility of a monopoly or having one dominant firm provide and manage the future autonomous MaaS platform. Once they arrive at this premise, all agreed that the firm will have be regulated like a public utility. Informant M, a municipal government administrator, said that the reasons for such regulation would be to ensure that the eventual winner in this arms race will provide access to everyone (universal service), disavow price gouging, and attain policy objectives on safety and service reliability -- similar reasons for TNCs in Massachusetts to be regulated by the Department of Public Utilities today. Joseph Coughlin of the MIT Age Lab,
which has been researching both the technological and sociological implications of AVs, predicted in a class lecture about AVs that consumers of the autonomous MaaS system will likely use a monthly subscription fee, much like the way utility bills are paid for today (Coughlin 2018). Both Informant M and Coughlin mentioned that in order to regulate this MaaS provider like a utility, the government would to some extent have to choose who the monopoly provider will be. And for the sake of important policy outcomes, said Coughlin, the government may have to pick winners -- to the chagrin of Posner -- and, of course, the losers of the race.

Natural Monopolies as “Common Carriers”

Why would governments want to pick winners and losers in any market? On the market side, as will be demonstrated in greater detail in Chapter 4, firms that are chosen as regulated monopolies enjoy considerable and consistent profits, insulated from competition. In the view of government, as discussed earlier in this chapter, some services are considered so essential to the public that the government should view as its duty to ensure they are accessible to everyone, regardless of ability to pay.

The concept of “common carriers” is useful in the case of these services. In his book The Master Switch on information empires, Tim Wu explains that the phrase originated in fifteenth-century England when private firms were operating public functions such as roads and ferries: “at the heart of common carriage is the idea that certain businesses are either so intimately connected, even essential, to the public good, or so inherently powerful... that they must be compelled to conduct their affairs in a nondiscriminatory way” (2010, 58). Four basic industries are deemed common carriers: telecommunications, banking, energy, and transportation; “each plays a certain essential role in the workings of the nation and the economy, and thus these are the industries that have attracted regulation as common carriers, or infrastructure” (ibid).

In the following chapter, I examine two classic common carriers, the telecommunications and power utility industries, and identify four key characteristics within the industries that gave rise to their market domination by monopolistic firms. By applying these lessons to the future autonomous MaaS system, I aim to alert policymakers to historical patterns in common carrier development to be considered when drafting AV regulation.
Chapter 4: What Classic Common Carriers Teach Us About the Future AV Platform

“We recognize a ‘responsibility’ and ‘accountability’ to the public on our part, which is something different from and something more than the obligation of other public service companies not so closely interwoven with the daily life of the whole community.”
-- Theodore Vail, President of AT&T (1885-9, 1907-19)

Telecom and power utilities are two classic public utilities often studied for the intricacies of their regulatory development. In this chapter I compare elements of these case studies to the future autonomous mobility-as-a-service platform to identify lessons we can borrow about the process of natural monopoly development, what classic monopolists thought of regulation, and benefits and drawbacks of being regulated. I mainly draw on the following sources: for the telecommunications case, Tim Wu’s *The Master Switch* (2010), which traces the history of information empires through the last 150 years; for the power utilities case, Richard Hirsh’s *Power Loss* (1999), which outlines the relationship between industry and regulation in the nineteenth and twentieth century; Jeremiah Lambert’s *Power Brokers* (2015), which focuses on major players in the history of power utilities; David Nye’s *Electrifying America* (1990), which expounds the social impact of electric power; and Charles Jacobson’s *Ties That Bind* (2000), which compares the regulatory experiences of water, power, and cable TV from 1800 to 1990.

These two case studies were selected for several reasons. The first and most obvious is that they are both natural monopolies, as defined in the previous chapter. Because of the capital-intensive nature of these industries, one firm is more efficient in providing the essential services than two or more, and there is a very high sunk cost for entering the market. In both cases, I pay greater attention to the inception of the key technologies around the turn of the twentieth century, as the nascent stages of development are more relevant to the emerging technology that is autonomous mobility. The characteristics common across the industries -- as well as the future autonomous MaaS platform -- that I will discuss are:

1. the transformative and therefore essential nature of the technology;
2. the obstacles in supplanting a legacy system;
3. the rationale for regulated pricing and price discrimination in service provision; and
There are natural differences between the telecommunications and power utility industries. For instance, the former provides two-way communication between consumers, and the latter provides a one-way service terminating at the consumer. Between the two classic examples of public utilities and the autonomous MaaS case, the most commonly identified difference is that of fixed assets. The barrier to entry for telecommunications and power utilities is tied up in the high sunk cost of transmission lines and cables, generation stations, and so on, whereas the autonomous mobility platform, at least on its face, does not have that material constraint. This is true, and in the next chapter I will discuss contemporary versions of natural monopolies in the technology sector that use network effects and brand identity to achieve highly effective barriers to entry by potential competitors. Relatedly, Charles Jacobson mentions in Ties That Bind (2000) that “unlike the owner of a fleet of garbage trucks, for example, a private waterworks, electric utility, or cable television firm cannot easily ‘pick up’ its network and install it elsewhere” (11). While it would appear that the same logic may be applied to a fleet of AVs, the perception component of AV technology is geography-specific, i.e. an AV that has been trained to recognize weather conditions and pedestrian behavior in Boston cannot perform the same functions in San Francisco without additional training. Moreover, the fundamental barrier to entry for the platform is its network effects, which would be rendered useless if the platform were forced to move across regions or markets. In response to the methodological questions about comparing different industries, Jacobson writes, “it is the combination of both similarities and differences in technology, patterns of industry development, historical contexts, and public policy that affords analytical leverage otherwise unattainable” (4). In the following pages I employ a similar analytical leverage to illuminate the likely development of the autonomous MaaS platform of the future, first by outlining the brief history of regulating utilities, then detailing how each of the case study industries exhibit the four characteristics above.

**Brief History and Rationale of Regulating Utilities**

The core ideas of why and how we regulate natural monopolies were introduced in Chapter 3, mostly through a theoretical discussion of Richard Posner’s work. Here I augment that discussion with examples from history of regulating utilities, in order to provide context for the more detailed discussions of specific industries below. Essential services have been regulated in some way for a long time, from the concept of “just prices” in the time of the Roman emperor
Diocletian to the practices of innkeepers in sixteenth century England (Hirsh 1999, 16). The rationale given by England’s Lord Chief Justice Matthew Hale in 1670 for the regulation of “common callings” was that they were “affected with a public interest and they cease to be juris privati only” (ibid). In 1887, the United States Supreme Court decided in the case of Munn v. Illinois, in which grain elevator owners in the Midwest were accused of price gouging, that because the services provided “constituted a necessity for society”, the business “therefore resembled a government-chartered toll road that could only charge fees approved by a regulatory body” (ibid, 17). The government had the power to regulate private industries. As the idea continued to mature, observers of industry and industrialists themselves began to see the benefits of government regulation: that monopolies enjoyed economies of scale, and are able to acquire companies without much scrutiny. This assuaged investors’ fears of losing market leadership, and thus lowered the cost of borrowing. “In short, utility managers came to view regulation as a positive innovation” (ibid, 24). On the other hand, governments see benefits to society through regulating these industries, as the public tends to under-consume utility services because they produce positive externalities, and private user fees alone may not incentivize producers to provide these services at the optimal level. The basic role of public utility commissions as regulatory entities is to mediate between monopolistic firms that provide services at certain levels, and the customers that pay rates high enough to maintain these firms.

Both telecommunication and power utility services transformed the way people lived in the late nineteenth and early twentieth centuries. However, purveyors of these new technologies still had to work to overcome the stranglehold that legacy systems such as telegraphy and gas lamps had on the populace. This was generally achieved through aggressive pricing strategies and discrimination to undercut competitors and attain regional dominance. I now examine each of these in turn.

Transformative Nature of the Technology

Public utilities provide services that are transformative to society, which is why governments generally want to encourage their use for the public good. In his book The Master Switch, Tim Wu explains the difference between “sustaining” and “disruptive” innovation -- the former makes existing products better, the latter “threatens to displace a product altogether” (2010, 10). For example, an electric typewriter is a sustaining innovation by improving upon the
mechanical typewriter, and the word processor is a disruptive innovation that replaces both. Both telephony and electrification are examples of disruptive technologies.

Telecom
The Bell Company in the 1880s began as a primarily local connecting service for affluent customers; through Theodore Vail's work on its “long lines” at a Bell subsidiary called American Telephone and Telegraph Company (AT&T), the telephone later on becoming a service offered to the masses. Before Vail was able to achieve an effective monopoly, however, other producers were catching on to the potential of telecommunications to improve their lives. Farmers and other interest groups were wiring their own telephone networks instead of waiting for urban utilities to reach them, forming companies and calling themselves “the Independents”. Against Bell’s original vision of local networks serving the rich in cities, these Independents “saw a different world, in which the telephone was made cheaper and more common, a tool of mass communications, and an aid in daily life” (47) Crucially, they recognized the telephone not as a sustaining innovation but a disruptive one. It is the “first social technology”: as a farmer put it in the most glowing of terms in 1904, “with a telephone in the house comes a new companionship, new life, new possibilities, new relationships, and attachments for the old farm by both old and young” (ibid). Farmers were using their own open network to not only gossip with one another but facilitate other communal activities like news reporting and musical performances. Bell and Vail’s AT&T eventually moved to acquire the companies of these Independents and actualized his blatantly monopolistic vision of “one system, one policy, universal service”. In his discussion of Bell’s subsequent submission to serve as a common carrier, Wu wrote that it “was a promise to serve any customer willing to pay, charge fixed rates, and carry his or her traffic without discrimination. It made Bell’s telephone service offer rather what a taxi service is meant to provide in most cities -- a meaningful similarity, since the concept has its origins in transport” (57). We will, naturally, return to this comparison between communications and transportation later in the chapter.

Power Utilities
The ways in which people talked about electricity at the turn of the century were, perhaps unsurprisingly, very dramatic. Users of telecommunications cited the connective nature of that technology as its “paramount value” (Wu 2010, 47), whereas the impact of electrification was cast in a more socioeconomic light. Historian David Nye writes in Electrifying America (1990)
that because of its mystique and ability to literally and metaphorically illuminate, “electricity had a prestige attached to it as a vital force in human affairs” (156) and became “inextricably bound up with ideas of social progress and the transformation of human nature” (147). The possibilities for the use of electricity were endless, inspiring “visions of a better world amid the smoke, grit, and congestion of real life in late-nineteenth century and early-twentieth century American cities” (Jacobson 2000, 15). The transformational power of power to facilitate “the most intimate functions of our lives -- to communicate and cooperate with one another, to exercise authority over one another, to produce and distribute a wide range of goods and services -- constitutes one of the major ways in which our lives differ from those of our ancestors” (ibid, 1). The extension of electrification to more remote parts of the country “drew [rural communities] into the twentieth century and improved sanitation, sewerage, and communication” (Lambert 2015, 28). In the middle and late twentieth century, electrification was credited with productivity gains in the economy and demonstrating to the world the superiority of American industry and war preparedness (in particular to Communist countries during the Cold War). As the public continued to be enamored with electrification, engineers who enabled these processes enjoyed an elevated social status: “the engineer himself became the symbol of the rational man who had the skills to transform society.” (Nye 1990, 166). That technologists were celebrated as providing answer to social problems was a view embodied at the time by power company executives, who were typically trained as engineers, and it is relevant once again among today’s autonomous driving engineers.

**AVs**

The transformative nature of the autonomous mobility-as-a-service platform has been discussed for many years, as outlined in Chapter 1. As one of my informants dryly acknowledged, nobody is shocked to hear that autonomy is a new technology. Nevertheless, autonomy is explicitly discussed as a transformational, not incremental, shift in mobility technology (or disruptive, not sustaining, innovation, in Wu’s terminology). It has the potential to promote safety on the road, increased mobility for people who do not drive, and energy sustainability in transportation. Many stakeholders across sectors I interviewed shared this perspective. Informant H of a state transportation agency, like many others in the industry, likened the shift to AVs to that from the horse and buggy to the first automobile; similarly, Informant J of the environmental advocacy group stated that taking the driver out of the loop is the biggest change in the industry since the car was first invented. The policy manager at a TNC company, Informant Y, also made the
horse and buggy reference, adding the quote often (mis)attributed to Henry Ford that “if I had asked people what they wanted, they would have said faster horses” (according to Patrick Vlaskovits (2011), the quote does not appear until the early 2000s and the Henry Ford Museum confirmed it was unsubstantiated). Y used this to not only illustrate the dramatic change between horses and cars in transportation technology history, but the limited imagination of customers who conformed to certain behaviors and ways of thinking.

Not everyone believes that a major shift in technology necessarily means a fundamental change in how we live. In The Master Switch, Tim Wu expressed that the impetus for the book was his perception that time and again, people are very excited about the prospects of new technologies in ushering in some utopia, and yet sense that in many ways we have been here before. We always think that an emerging technology is a radical departure from the old way of life and the most unprecedented thing; “each of these inventions to end all inventions, in time, passed through a phase of revolutionary novelty and youthful utopianism; each would change our lives, to be sure, but not the nature of our existence” (2010, 6). Informant K at a regional planning agency agreed with Wu to some extent, citing an interesting example of the not-so-transformative impact of smartphone technology: when the Pope came to visit the United States in the 1980s, K remembers seeing an image of the crowds holding up cameras to photograph him. Fast forward to a few years ago to another papal tour, K saw the same image of crowds holding up smartphones to photograph the celebrity. The technology has changed but human behavior did not, K asserted. However, against Wu’s thesis, K believes that for those who have access, AVs will in fact radically change people’s lifestyles and their desires through changing their mobility.

**Supplanting an Old System**

Although the potential for such significant transformation in technology and, by implication, lifestyle is quite clear, the emerging technology itself does not predetermine how it will be deployed. The main driver behind deployment and adoption is human behavior, and “it is people who make choices and struggle with one another over how systems are to be designed, built, and used” (Jacobson 2000, 7). In this section we will look at the efforts by the producers of new technologies to replace incumbent technologies.
Telecom
As mentioned above, at its incipiency telephone technology was competing with telegraph services as the main tool for communications in dense urban areas as well as over longer distances. However, when Bell had first invented the telephone, the technology was not mature enough to mount any serious competition to Western Union’s telegrams -- so much so that in the late 1870s the president of Western Union turned down an offer from Bell’s president to sell him all of their patents for $100,000 (Wu 2010, 15). Even as Western Union realized its mistake and invested in its phone business, its strategy was to make it a complement to its core business of the telegraph, not a substitute for it (ibid, 26). Bell sued Western Union for patent infringement in 1878 and won, so Western Union gave up its telephony business and Bell promised to not enter the telegraph market (ibid, 31). Precisely because the technology was still emerging, historians believe the executives at Western Union assumed at the time that the telephone would remain both primitive and a luxury, instead of a legitimate successor to their own business. Liberated of its giant competitor, Bell went on to expand their network nationwide. By the time Bell-turned-AT&T acquired then divested of Western Union in response to antitrust lawsuits in 1913, customers have long been switching over to the telephone and the telegraph was already seen as an antiquated technology. The short history of the battle between Bell/AT&T and Western Union is representative of how telephony supplanted the telegraph: though in concept the former was technologically superior, it took over 30 years for it to effectively replace the latter.

Power Utilities
Like at the inception of telephony, power generation and transmission technology in its infancy did not quickly achieve economies of scale and market penetration against gas lighting or individual power generation. The technology relied on direct and not alternating current, meaning the voltage could not easily adjust to consumer requirements and generating stations had to be located near higher density of customers. Municipal governments would issue non-exclusive franchises to electric street lamp providers to encourage competition, which led to even more duplication of start-up infrastructure. By the mid-1880s, it was already evident that electric lights offered “a higher quality and more versatile source of illumination than gas” (Jacobson 2000, 79), but even large power utilities at the time faced financial pressures and fought for market share against “well-entrenched gas utility firms and with large customers who could economically generate their own electricity” (ibid). With the subsequent innovation of the
alternating current by Westinghouse in the late 1880s, generating stations could expand and move away from urban areas, and longer transmission lines can transmit more power to more people with more reliability. The output of electricity between 1907 and 1937 grew by twentyfold (ibid, 80), and the economies of scale achieved by monopolistic firms like Commonwealth Edison deterred new market entrants. Through multiple iterations of market consolidation, power utilities expanded their market share and reduced rates for customers while avoiding duplication of capital expenses. As a result, power utilities were able to induce customers away from both gas companies and producing power for themselves.

AVs
Through my interviews with stakeholders in both the public and private sectors, it is evident that a wide cross-section of people were skeptical that autonomous mobility services will manage one day to fully replace human-driven cars or individually owned AVs. There is first the reluctance by consumers to “give up” their cars out of uncertainty or fear of the technology. Informant G, a lobbyist for AV developers, stated plainly that the biggest hurdle to the mass adoption of autonomous vehicles is not technology or policy, but consumer acceptance. The public basically have to recognize that the notion of self-driving cars is scary in the abstract, but can be liberating in practice. The “legacy” market of individually owned cars will live on, said Informant F, another lobbyist, unless the autonomous MaaS platform achieves universal coverage. Since the industry attracts so much press attention, F added, everyone will pile on when the first crash occurs, and customer confidence may take another hit. (In fact, at the time of writing, one of Uber’s AVs killed a pedestrian while on a test drive in Tempe, AZ. This was the first recorded fatal incident involving a fully automated vehicle on a public road.)

Another source of reluctance to car-shedding by consumers is out of habit or preference. While in theory human driving can be banned, F insisted that there are people who will still want to drive themselves. And although AVs may be deployed as fleets in the beginning due to cost, once economies of scale are reached with AV production, even those with access to MaaS networks may revert back to car ownership. Informant J of the environmental advocacy group believes that just removing the human driver from the equation does not take away the “locker room effect” of the car, for example. People love owning cars, J said, and they will be willing to pay the premium to own an AV so they can leave their gym bags and outdoor equipment in it. Relatedly, many people who live outside dense urban areas may have to continue relying on
their own cars. These suburban or rural households may be able to share a jointly-owned car, but they would still be shut out of the MaaS network only accessible in dense urban areas. Informant M, an administrator in a municipal government, noted that individual car ownership would still make sense for these communities, and that giving up car ownership is generally a very big decision. The regional planner K went further to say that it would be unfair to discourage private car ownership for people without easy access to transit. While in both classic utility cases, the supplanting of old technology took a few decades, Informant J pointed to the adaptation of the smartphone in recent years as a sign that the autonomous MaaS platform may replace legacy car markets in a shorter time frame than we may expect.

As shown in both the telecommunications and the power utilities case, in order for a new technology to replace the incumbent, technological superiority is a necessity but not sufficient condition. It must be coupled with human behavior and shrewd business practices. In the following two sections, we examine the pricing and market consolidation strategies that eventually allowed these industries to thrive as monopolies.

**Regulated Pricing and Price Discrimination**

The third common characteristic of public utilities in developing monopolistic dominance is that of pricing strategies. Pricing is typically the most effective lever with which budding monopolists can undermine competitors and increase profits. It is also, as discussed in Chapter 3, the primary mechanism by which government regulators manage the activities of public utilities.

*Telecom*

When the independent service operators were beginning to threaten Bell’s monopoly in the early years of telephony, Bell employed predatory pricing strategies by using their profits in other markets to undercut the prices of local competitors. Later on, the president of AT&T Theodore Vail, with J. P. Morgan’s substantial financial backing, was able to finally destroy competitors by absorbing even more losses and further undercutting prices. Given his ambitious vision of one system and universal service, “where he disagreed with the Independents was simply over the fact of their existence” (Wu 2010, 52). His vision was realized through the Kingsbury Commitment in 1913: in response to accusations of antitrust behavior, Bell made “relatively painless concessions” like divesting of their telegraph operations in order
to become in essence a government-sanctioned monopoly. Its prices would be regulated by government, but the company would also be free from pesky competition.

In the early stages of telephony, Bell inflated rates for long-distance calls in order to subsidize phone service to rural communities, “making good on its pledge of universality without suffering a financial loss” (Wu 2010, 189). When the industry first came under scrutiny by state and federal governments in the 1920s, rates for local telephone service were kept low through state-imposed rules. As long line operations benefited from increasing economies of scale and technological improvements, rates for interstate calls began to drop more than that for intrastate ones. Local Bell operating companies argued that revenues from these long-distance calls to AT&T’s Long Line Department should be used to defray maintenance costs of local exchanges and lines, which long-distance callers were using without being charged accordingly. The Federal Communications Commission later made allowances for long-distance tariffs to cover local company costs. National business who can afford to pay more for their interstate calls, argued a senator at time, were being charged lower prices than the average household “who do not indulge in a great deal of long distance but are the lifeblood of the telephone business” (Gomez-Ibanez 2003, 73). In short, to enjoy the protected status of a common carrier, AT&T saw the only way of fulfilling the dual requirements of universal service and reasonable rates to be cross-subsidies.

Power Utilities
Samuel Insull and the predecessors of today’s investor-owned utilities likewise saw low prices as the most effective way to achieve market dominance in the early years of their industry. Before state regulations were established, power utilities were innovating on their services in order to gain more customers. In the case of Boston’s power utilities at the turn of the twentieth century, they were incentivized to provide high-quality services, cut prices, and expand to new markets. Even without the government-sanctioned monopoly status, Edison Electric was able to grow its customer base from 500 to 30,000 and its coverage from downtown Boston to about 500 square miles of the city and surrounding suburbs. As in Bell/AT&T’s case, once economies of scale were further reached through technological improvements in power generation and transmission, Insull was able to make General Electric’s services much cheaper than the alternatives of gas or generating power independently.
In the early era of government regulation, regulatory commissions had the authority to both set fixed rates by incumbent power companies, impose standards of service, and limit competition by other potential market entrants. As introduced in Chapter 3, the rates were generally calculated based on “cost plus a reasonable profit” (Lambert 2015, 15). Monopolists like Insull preferred this arrangement because it “meant protection from competitors, state sanction for his monopoly enterprise, and a reliable return on invested capital enabling him to finance more centralized generating plants and transmission lines” (ibid, ix). As operations expanded, power utilities turned to another way of profit maximization: improving their “load factor” -- the ratio of average daily or annual use to the maximum load sustained during same period. Because electricity cannot be stored in inventory like other goods but has to be delivered and consumed instantly, plants and stations were equipped to service the maximum load even though demand reaches it infrequently. With technological advancement of usage meters, Insull was able to price discriminate through charging for value of service instead of cost. By reducing prices to promote consumption at different times of day and investing heavily in marketing for new market segments, General Electric smoothed out demand throughout the day, and thus enlist even more customers. This tactic was employed by AT&T in its service provision, and has become standard business practice in mobility-as-a-service platforms today. Finally, despite what some may have thought about GE’s “century of hegemony” (ibid, 13), the public consensus was that the proof of the pudding was in the eating, and that consistently low electricity prices were enough to keep dissent to a minimum.

**AVs**

Compared to the two classic public utility cases, price discrimination and regulated pricing are much more contentious propositions in the case of the autonomous MaaS platform. The practice of price discrimination that was controversial in the classic public utility industries is more or less assumed of the new platform, given the legacy of pricing models among transportation network companies (TNCs) like Uber and Lyft. Tools used to gauge demand, like Insull’s usage meter in the electricity case, were once revolutionary; now in the age of smartphones, they are quotidian and extremely sophisticated. Armed with overwhelming volumes of data from both drivers and riders, TNCs are able to adjust prices generally on the supply side based on the number of available cars on the platform, and very precisely on the demand side based on each individual user’s willingness to pay based on a range of data points.
from their historical willingness to pay to the remaining battery level on their phone (Chowdhry 2016).

Given the ability of TNCs to price discriminate to such a high degree, many stakeholders I interviewed were quick to point out that not all people will be able to access the platform. Although both of my TNC company interviewees were consistent in saying that eventually rides will be quick and affordable -- even akin to the cost of bus rides today -- those in the public sector concerned with the social equity implications of this mobility platform believe that both economic and social regulations are needed to protect consumers from price gouging and other negative externalities such as increased congestion.

One of the primary concerns among observers of the autonomous MaaS platform that is born with the same foundational model as current TNCs is that nobody really knows the current true cost of each ride. Uber riders pay under 50 percent of the cost of their rides (Harris 2016), a practice of predatory pricing subsidized by incredible amounts of venture capital. That will not always be the case, said Informant J at the environmental advocacy organization, and it is unwise to pin our transportation hopes on this platform. In addition to mandated rules for undesirable practices like “zombie” cars, J cites the example of price discrimination depending on time of use and other conditions in the power utilities sector as how the public sector can incentivize both service providers and consumers toward public goals of sustainability. The regional planner Informant K agreed that this kind of price discrimination would be ideal, but conceding that the idea is still conceptual and would be very challenging to implement. K suggested that there may be a board -- similar to a public utility commission -- established to look not only at adjusting this kind of pricing, but also to ensure the private service provider compensates the government fully for use of public infrastructure. This board or commission would also determine the appropriate performance measures for ensuring social goals are met.

In response to these regulatory propositions, my private sector interviewees mostly focused on the potential impact on quality of service if the public sector regulators were to be heavy-handed on setting and monitoring prices. Informant R of an established automaker was the most diplomatic when asked about the social equity and environmental sustainability aspect of the potential model, saying that they would approach each city before deployment to understand the opportunities for their platform to serve unmet mobility needs and to determine
the right subsidy structure that makes sense for the public good. Informant S, general counsel for a well-funded AV company, expressed that the first priority of operating this autonomous mobility platform should not be low prices: “is mobility, period, the most important factor (of this platform), or is quality of service?” The implication is that depressing prices will affect other performance metrics such as response times and geographic coverage. Informant L, chief policy officer at a technology company, agreed that we as a society should be willing to price road consumption, but suggested that low-quality service for off-peak hours or neighborhoods with low demand would simply be an unfortunate result of an optimized system, not necessarily a constraint for which the platform would need to solve. L added that other services would emerge to fill the service gap in lower-income communities, like dollar vans in Queens, NY today.

As in the other cases and given the current landscape of TNC operations, it would appear that the autonomous MaaS platform market will emulate the beginning of both the telecommunications and the power utility markets vis-a-vis pricing structures. The firm that seeks to be the dominant player in the market will use predatory pricing to root out competitors; grow in market share through consolidation tactics; become subject to government regulation in exchange for monopolist status and protection; then employ cross subsidies in their portfolio of services to fulfill universal service requirements. If the quality of the service is good enough for a price that is low enough, consumers will not care about how the system operates or how incentive structures are created. I will continue to draw out these themes in the section below and in the following chapter on the contemporary analogue of Amazon.

**Regional Dominance**

The last common characteristic between the three industries is the seemingly inevitable road to regional dominance, mostly through consolidation of local markets. Alluded to several times above, the destruction and acquisition of competitors was the straightforward way for aspiring monopolists to achieve their dreams. In this final section we consider the tactics employed by the companies that became the hegemonic AT&T and General Electric to attain their peak market positions, and how the autonomous mobility-as-a-service platform may emulate their trajectories.
Telecom

In his account of the American information industries *The Master Switch*, Tim Wu explains the “Kronos Effect”, named after the Greek Titan who killed his own children to prevent them from overthrowing him as he had done to his father. In the context of public utility industries, this refers to the phenomenon of a dominant company consuming potential successors in their infancy to stymie competition. When Theodore Vail was made president of AT&T in 1907, he did not follow his predecessor’s practice of destroying independent telephone network operators through the previous policy of refusing to connect their networks to Bell’s. Instead, Vail already had consolidation in mind and moved to execute his vision through ostensible network integration: to use Bell’s network, the Independents were required to adopt their chief rival’s standards as well as equipment and pay Bell for connections. Wu characterized Vail’s message to these operators as “join the network and share the wealth, or face annihilation” (Wu 2010, 53). This message and model will be practised famously and effectively by Amazon in the twenty-first century, and a model that autonomous MaaS platform firms would be savvy to adopt in their race to market domination. The outcome of this veiled threat was that few Independents actually managed to connect their networks to Bell’s, and after the giving up Western Union in a concession to an antitrust lawsuit in the 1910s, Vail was able to “consolidate the industry unmolested” (ibid, 56).

During and after the consolidation phase, AT&T further solidified their market leadership thanks to the mounting barriers of entry. Before their demise, several independent operators tried to develop an alternative nationwide long distance system. Just as they were making plans to challenge the incumbent, all of their financial backers suddenly withdrew, after allegedly receiving pressure from AT&T’s financier J. P. Morgan to do so. Without access to massive amounts of capital, no rival network could get started. Today, starting a mobile phone service to take on AT&T would cost more than $10 billion (Wu 2010, 48).

Power Utilities

Samuel Insull achieved industry consolidation for his series of companies in a similar way, first through envisioning a central platform to control the power network, then executing the strategy through gradual but persistent moves to acquire rivals. Insull’s vision was to pursue a growth strategy based on “load building, diversification, territorial expansion, and rate reductions” (Lambert 2015, 5) but also the prevention of duplicative investment. At the time
utility executives rightly believed that the incredible amounts of capital needed to set up generation facilities and transmission equipment would become lost if there were more than one provider in each area or if the government decided to create its own network. When he first started out as Edison’s assistant, Insull went to many small cities to sell them licenses to use power generation equipment. It was through this stint that the future monopolist saw the dangers in relying on municipal contracts and being at the mercy of corrupt politicians who could “extract a quid pro quo for awarding utility operating rights” (ibid, 4).

In Jacobson’s study of Boston street lighting during this period, power utilities cemented their market power by colluding with one another when bidding on municipal concessionary contracts. The firms merged in 1887; the market consolidated again two years later when a suburban power company was bought out by Boston firms; three years after that in 1902, Edison Electric (which had mainly been servicing private consumers) took over Boston Electric to control the street lamp market in the greater Boston area. Power utility consolidation was happening concurrently across other metropolitan regions, including Milwaukee in 1896, Detroit in 1900, and Philadelphia in 1901 (Jacobson 2000, 109). Over in Chicago, Insull began to plot his eventual takeover of the utility sector first by acquiring small central stations in the city, then controlling the supply of patented equipment through exclusive partnerships with suppliers like General Electric. By 1907, Chicago Edison merged with its own wholly owned affiliate Commonwealth Electric; by 1925, Insull’s companies were serving “over 1,800 communities in 16 states, totals that would increase to over 5,000 communities in 32 states within the next five years and account for more than ten percent of the nation’s electric output” (Lambert 2015, 35). Indeed, by reducing the number of rivals through “horizontal combination”, companies are able to rationalize production facilities, focus on fulfilling consumer demand, and invest in innovation (Nye 1990, 171); economies of scale are reached and they can either consistently undersell any rivals, or secure arrangements with the government to be regulated. And the virtuous, profitable cycle of a natural monopoly continues.

**AVs**

Because autonomous mobility-as-a-service platforms are projected to be transformative to human connectivity and accessibility; to supplant the old system of legacy human-driven and potentially individually-owned cars; and to have lucrative and dynamic profits for their operators, there are plenty of players in the AV space today vying to become the winner who
takes it all in the end. As mentioned before, the most significant new market entrants are the companies on the software side of the technology. Many of my interviewees brought up this phenomenon and added that as representatives of the industry themselves, they are experiencing this change in real time. Informant R, director of policy at an established OEM, pointed to Waymo (Google’s self-driving car company), nuTonomy (a 5-year-old MIT AV spin-off), and Zoox (a new OEM based in Silicon Valley) as examples of previously unexpected players in the automotive industry. Given the different areas of expertise by hardware OEMs and software companies, in Chapter 3 I outlined the recent trends and current events that hint at the potential upcoming consolidation the autonomous vehicle market. In this section I discuss the interviewee’s perspectives on the regional and geography-specific nature of this technology, and their feelings about the appropriate level of government to oversee its operations.

Most of my interviewees assumed that the roll-out of the autonomous mobility-as-a-service platform will be done city-by-city, and with the heavy involvement from municipal governments. Because autonomous vehicle perception algorithms cannot (yet) process information that it has not been trained on, massive visual and navigational datasets are required to bring this technology to each new city based on anything from changes in climate conditions or local driving culture. Informant G, lobbyist for AV developers, raised the famous example of the “Pittsburgh left”, a practice unique to the city whereby the first left-turning vehicle is allowed to proceed before those going straight through an intersection; the AV must be trained to recognize this otherwise unusual behavior in order to co-exist with human drivers there. This is one of the reasons many AV developers are approaching each city as a new partner in terms of both testing and deployment. Informant R at an OEM described a geographic expansion model with similar elements to Samuel Insull’s early stint as a traveling salesman to different cities on behalf of Edison. R insisted that they want to tailor make their mobility solution to each city’s needs in terms of public transit gaps, transportation planning priorities, and socioeconomic concerns. Informant S, general counsel for a prominent AV company, has also taken the tack of working out individualized pilot projects with cities to “see if we want to partner with them”. The technology as of now is still very geo-specific, said Informant X, general counsel for another AV company. Municipalities also tend to be the most excited about autonomous vehicles than their state or federal counterparts, so X believes that they make the most sensible partners. TNCs and AV developers with current TNC connections are furthermore working closely with
municipal officials as a continuation of work they have already been doing for years in the local regulatory environment. Somewhat surprisingly, Informant Z, engineer at a large TNC, conceded that the primary reason their relationship with cities is “interesting and complicated” is that while TNCs provide a valuable service for city dwellers, “most cities don’t want to be at the mercy of private companies for this essential service”. Nevertheless, because municipal governments so far are unable to mount any technologically or financial feasible challenges to building up their own AV network, they must engage with the private sector to shape the deployment of autonomous mobility services.

While few stakeholders believe that the federal government should oversee operational regulations of autonomous mobility platforms, other stakeholders expressed that regulation should be created at the state level to address the regional nature of market dominance in this industry. As with power utility executives at the turn of the twentieth century, these interviewees believe that regulation should be administered by the state and not municipal governments, which are too numerous and would lead to patchwork regulation across a metropolitan area. The lobbyist Informant G said that his practice barely has bandwidth to manage current regulatory discussions in the fifty states, let alone every municipality within them. G said the only city-level conversation he has had was in Chicago, where a city alderman was proposing to ban AVs. Informant H at a state transportation agency added that multiple state agencies have been involved in crafting an AV strategy, and since TNCs are currently regulated at the state level in Massachusetts, it would be only natural for the same to apply to the new autonomous ride-hailing platform, even as municipalities would be consulted on the matter. For this reason, Informant J at the environmental advocacy organization has been active in drafting legislation for the Commonwealth’s state house instead of focusing on city-level bylaws. Discussion have also begun across municipalities in the greater Boston area by regional planning agencies, said Informant K, the transportation planner. The aim is that instead of approaching each city individually before testing or deployment, AV developers can arrange with a group of coordinated cities in Massachusetts all at once.

Summary

In this chapter I discussed in turn the four similar characteristics between two classic examples of public utilities, telecommunications and power utilities, and the future autonomous mobility platform: the transformative nature of a new technology; the efforts to supplant the old
incumbent technology; the use of pricing to secure market leadership; and the regional nature of market dominance. In the next chapter I compare this emerging platform with two of the most powerful platforms in the world today, Google and Amazon. As Tim Wu points out in *The Master Switch* and as we will see in the following pages, the ambitions for monopoly since the era of Theodore Vail and Samuel Insull have not waned but have returned with a vengeance. The business moguls of yesterday had very little market information to guide their strategies, and they recognized their accountability to public interest and their responsibility in improving the quality of life for its diverse consumer base. The new titans of industry not only have all the data they need at their fingertips, they also appear to be driven toward monopoly not out of efficiency or public good, but purely for enduring profits.

Fig. 4.1 Summary Table of Characteristics Across Classical Case Studies

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Telecommunications</th>
<th>Power Utilities</th>
<th>Autonomous Mobility Platform</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transformative nature of technology</td>
<td>First social technology</td>
<td>Promotion of illumination and hygiene</td>
<td>Improves mobility, safety, sustainability, etc.</td>
</tr>
<tr>
<td>Supplanting inferior legacy system</td>
<td>Took 30 years to supplant the telegraph as Western Union slowly lost control of the legacy market</td>
<td>Further innovation helped to make electrification more attractive than gas lamping and in-house power generation</td>
<td>Common sentiment that people will still want to drive their cars, or at least own their AV</td>
</tr>
<tr>
<td>Pricing strategies</td>
<td>Implemented cross-subsidies to achieve universal service</td>
<td>Price discrimination to maximize load factor</td>
<td>Likely will continue in aggressive, individualized price discrimination for services and cross-subsidize for less profitable services</td>
</tr>
<tr>
<td>Regional dominance</td>
<td>Expanded network rendered independents obsolete and set up high barrier to entry</td>
<td>Cities succumbed to power utility monopolies one by one</td>
<td>Given the geography-specific nature of AV technology, stakeholders expect to work with each city to explore potential regional partnerships and consolidation</td>
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Chapter 5: What Today’s Technology Giants Teach Us About the Future AV Platform

“Tolstoy opens Anna Karenina by observing: ‘All happy families are alike; each unhappy family is unhappy in its own way.’ Business is the opposite. All happy companies are different: each one earns a monopoly by solving a unique problem. All failed companies are the same: they failed to escape competition.”

-- Peter Thiel, in Zero to One (2014)

Public utilities provide transformative essential services that replace legacy systems through lower prices and gain eventual regional dominance. In this chapter I show that modern internet-enabled companies share some of these characteristics with classic public utilities, and exhibit unique qualities of new platforms that distinguish them from old understandings of monopoly, namely the crucial roles of scale, service integration, and data. New generations of monopolies follow similar patterns as the old guard of utilities in terms of predatory pricing and consolidation activity. However, unlike their predecessors who use capital-intensive physical infrastructure like transmission cables and generating stations as barriers to entry, technology companies heavily rely on network effects and massive volumes of customer data to prevent potential competitors from flourishing. The old rules governing monopoly are not adapting to these new realities, and regulators have little control over the businesses of technology companies.

Using Google and Amazon as case studies, I argue that the new autonomous mobility platform will likely follow the trajectory of these technology giants. For the following analysis I mostly rely on Zero to One (2014) by Peter Thiel; for material on Google: The Master Switch by Tim Wu; How Google Works by Eric Schmidt and Jonathan Rosenberg with Alan Eagle (2014); and Throwing Rocks at the Google Bus (2016) by Douglas Rushkoff, professor of media theory at CUNY; for material on Amazon, Amazon’s Antitrust Paradox (2017) by Lina Khan in the Yale Law Journal.
Adapting to New Monopolies

There exists a critical debate in the contemporary literature on the nature of antitrust laws in the age of technology giants. While most scholars have the same point of departure that these twentieth-century laws are not keeping up with the times, they have divergent conceptions of the root of the problem and thus how to improve them. Some like Richard McKenzie, economics professor at UC Irvine, take the view that antitrust laws are too restrictive, and penalize super-competitive behavior as anticompetitive; others like Lina Khan of Yale Law School believe the opposite, i.e. that the laws are too loose and toothless, and mistaken anticompetitive for procompetitive behavior. These views are summarized in Fig. 5.1.

View: Regulators see procompetitive as anticompetitive

In his book Trust on Trial (2000), Richard McKenzie discusses the Department of Justice (DOJ)'s antitrust lawsuit against Microsoft in the late 1990s, whereby the company was accused of using predatory pricing and restrictive contracts with buyers to destroy its rivals. McKenzie, who repeats throughout the book that he was not in any way affiliated with Microsoft and has no conflict of interest in the matter, is an assertive defender of the company. He posits that Microsoft is not a monopoly in the operating systems or the internet browser market, but is in fact ultra-competitive. Rivals such as Sun Microsystems, Oracle, and Netscape had been conspiring to take down their chief competitor by tying up its hands when Microsoft simply had superior products. “Is success being punished?” he asks rhetorically at the outset of his book (McKenzie 2000, 1).

McKenzie’s first major argument is that Microsoft does not fit the mold of monopoly as we know it, citing the traditional combination of monopolistic characteristics: restricted production to raise prices and profits, lack of competitors, and high barrier to entry. None of these criteria applied to Microsoft, as it sold to whomever wanted to buy its products; there are plenty of competitors such as Apple’s OS and Linux; and the low barrier of entry that would allow any software engineers to challenge its market position. McKenzie believes that Microsoft has “market power” in the sense that customers voluntarily choose them over rivals without coercion because Microsoft products are better and often cheaper. The so-called monopolist Bill Gates emulated John D. Rockefeller of Standard Oil in gaining market dominance because of the superiority of offerings and low prices, “not increasing its prices as practising monopolies are expected to do” (ibid, 57). One central question in the antitrust literature is how to identify
predatory pricing and whether extremely low prices was illegal or just good business, and it is one to which we will return in the Amazon case study later.

Even if Microsoft were a monopoly, McKenzie argues further, that status in and of itself would not be illegal. The DOJ had to show that its monopoly power was attained through anticompetitive behavior at the expense of consumers. The other central question in the literature is the definition of consumer welfare and how to recognize when it will be harmed. McKenzie and other scholars in the Chicago School assume that price is the ultimate measure of consumer welfare, and longer-term or less tangible measures such as product quality and diversity are irrelevant. This seems like an overly narrow conception of the complex phenomenon that is consumer welfare, and in general, McKenzie tends to use a conveniently absolutist, strawman definition of “monopoly” (a firm owns almost 100 percent of the market, raising prices on inferior goods to prevent superior goods from entering the market). Microsoft may be offering an innovative, transformative service that consumers demand, but what do we lose when we let these technology companies scale up and dominate their respective markets?

**View: Regulators see anticompetitive as procompetitive**

Lina Khan answers these questions in her Yale Law journal article, *Amazon’s Antitrust Paradox*, which is an important influence on the analysis I present in this chapter. One of the crucial points Khan makes in the article is that the current antitrust regulatory regime is ill-suited to police technology giants:

> “Specifically, current doctrine underappreciates the risk of predatory pricing and how integration across distinct business lines may prove anticompetitive. These concerns are heightened in the context of online platforms for two reasons. First, the economics of platform markets create incentives for a company to pursue growth over profits, a strategy that investors have rewarded. Under these conditions, predatory pricing becomes highly rational—even as existing doctrine treats it as irrational and therefore implausible. Second, because online platforms serve as critical intermediaries, integrating across business lines positions these platforms to control the essential infrastructure on which their rivals depend. This dual role also enables a platform to exploit information collected on companies using its services to undermine them as competitors.” (emphasis added) (Khan 2017, 710)
Critics of companies like Amazon find it difficult to clearly articulate their antitrust concerns, in particular with regards to pricing, because everything Amazon is doing seems to be good for customers.

Prior to the 1970s, the view that the structure of a market can influence the incentives of the players was more popular, and scholars were wary of the attempts by firms to coordinate prices and market segmentation, block new entrants, and -- crucially -- enjoy greater bargaining power not only against consumers, but also suppliers and workers. The subsequent ascendancy of the Chicago School perspective ushered in a shift in jurisprudence from economic structuralism to price theory. The implications are twofold: first, “consumer prices became the dominant metric for assessing competition” (ibid, 720); and second, economies of scale enjoyed by incumbents are not considered barriers to entry because they are merely “objective technical demands of production and distribution” (ibid). Prominent voices of the Chicago School such as Robert Bork were skeptical that predatory pricing existed at all, since below-cost pricing is irrational, even if it is to undercut competitors -- the firm cannot know if the strategy will work, and will have to recoup the initial losses to survive in the long run. Regulators convinced by Bork’s position are naturally unable to police something that they do not think exists. In addition, economies of scale achieved by any means, including vertical integration, are seen to promote efficiency instead of unfair advantage. If a firm is able to use its dominance in one product market to achieve dominance in another, e.g. a clothing manufacturer enters into the adjacent retail market by subsidizing low retail prices with profits from up the supply chain, Bork would commend the firm for passing on efficiency savings to the consumer.

Khan details two main reasons the Chicago School is wrong, namely that consumer welfare is more than low prices, and that antitrust laws were designed to protect more than just consumers. Consumer welfare is a broad concept that should be extended to include product quality, offering variety, and degree of innovation. In the long run, monopolistic firms rest on their laurels and are not incentivized to improve products or create new ones. Moreover, Khan reminds us that antitrust laws promote competition in order to protect people not only as consumers, but also “our interests as workers, producers, entrepreneurs, and citizens” (ibid, 737). Concentrating economic power in the hands of a few firms means concentrating political power. It also enables not only the reduction of consumer wealth as a result of increased
monopoly profits; but more controversially, the transfer of wealth from both consumers and suppliers to the intermediate monopolist.

In sum, because predatory pricing and vertical integration often lead to lower prices for consumers, scholars of the Chicago School would rarely say that these strategies impair consumer welfare. Critics of the Chicago School generally believe that their conceptions of what constitutes monopoly and consumer welfare are too narrow. The former seeks to monitor pricing, whereas the latter seeks to monitor market structure independent of pricing. However, as I demonstrate later in this chapter, the fundamental challenge at hand is that new technologies and business models make it difficult to identify anticompetitive behavior and distinguish between “competitive advantages drawn from superior skill and production, and those drawn from the brute power of size and capital” (ibid, 725). Nevertheless, there are enough similarities across contemporary monopolies for us to delineate some of their key characteristics, and compare them to a future autonomous mobility platform model.

Fig. 5.1 Updating the Chicago School on Natural Monopoly

<table>
<thead>
<tr>
<th>Regulators see procompetitive as anticompetitive</th>
<th>Regulators see anticompetitive as procompetitive</th>
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<td>New internet companies like Microsoft are NOT monopolies because:</td>
<td>New internet companies like Amazon are new forms of monopolies because:</td>
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<tr>
<td>- They sell products at low prices</td>
<td>- They achieve low price points through predatory pricing</td>
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<td>- They have plenty of competitors</td>
<td>- Competitors are aggregated across business lines to make them look more competitive</td>
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<td>- As software companies, they have low barriers to entry</td>
<td>- Network effects present very high barriers to entry</td>
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How is This New Monopoly Different?

Almost all technology giants today -- Microsoft (operating system), Facebook (social network) Amazon (online retail), Google (search engine), Uber (ride-hailing service), Airbnb (accommodations), Spotify (music streaming), YouTube (video sharing), and so on -- are primarily platforms, not discrete products. A platform is, “fundamentally, a set of products and services that bring together groups of users and providers to form multisided markets”
Because platforms act as intermediaries that bring together consumers and producers, the platforms operate in a virtuous cycle of more users begetting more users; the popularity of a platform is directly tied to its effectiveness. In his book *Zero to One*, venture capitalist Peter Thiel discusses the unique economics of platforms that induce monopolies, including proprietary technology, the aforementioned network effects, economies of scale, and branding. Unlike McKenzie’s pejorative use of the monopolist label, Thiel embraces and advises his readers to strategize for it. Thiel argues that monopolists can afford to focus on things other than money, since they are not concerned about narrow margins squeezed by competitors. Monopoly profits provides firms with the luxury to innovate, incentivized by the potential to maintain these profits for years or even decades to come (Thiel and Masters 2014, 33). A firm believer in the power of innovation to transform society, Thiel insists that monopolists add value to the world by growing a dynamic market instead of simply collecting rent in a static one. For the old guard of public utility monopolists, this age-old desire to insulate themselves against competitors was manifested through fondness for favorable government regulation; for contemporary technology companies, it is secured through the obsession with scaling quickly and leveraging user data to further entrench their market position.

In the following section I detail the key characteristics of technology companies today and why older conceptions of monopoly can fall short in detecting anticompetitive behavior, using Google and Amazon as case studies. I discuss the critical concept of platforms and the role of scale and data, then marshal evidence from my interviews to apply these trends to the anticipated autonomous mobility-as-a-service platform.

**Scale Over Everything**

Scale over everything: this is the motto of the new guard of aspiring monopolists. Technology companies do not have capital-intensive startup costs in the same category as in telecommunications or power generation and transmission. However, the upfront investment is equally important as that needed to build physical infrastructure for public utilities. To get a technology company started, massive capital is needed to hone in on a proprietary technology that separates a firm from existing competitors, then offering the product to as many people as possible. According to Thiel, the strength of one’s product should be at least ten times better than its closest substitute, which can be achieved by inventing something completely novel like a new drug; dramatically improving an existing product like his company PayPal did to online
payments; or offer ten times as many products than incumbents like Amazon did to traditional retailers. Once the investments have been used to hire engineers and product managers to build the product, firms rely on economies of scale to offer the product to anyone who would want it, taking advantage of the essentially zero marginal cost of producing an additional copy of a software or app. Firms offer services for free or an extremely low cost with the hopes of getting user buy-in then lock-in, at which time they have a captive user base from which they can extract monopoly profits. In order to arrive at this point, technology companies are content to lose money at the beginning of their venture, setting their sights on the ability to not only grow but endure into a future when they will become incredibly valuable.

**Google**

The search engine giant Google wears this motto on its sleeve. Founded by Larry Page and Sergey Brin through their PhD thesis work at Stanford in the late 1990s, Google is a platform that matches users with the webpages they seek. Google is not an absolute monopoly because there are plenty of other search engines available to users, who can theoretically switch products anytime. And in this sense, this platform is very much unlike telecommunications utilities, which are very unlikely to be replaced at any time given the capital investment needed to start a rival network. Nevertheless, Google had over 90 percent of the search engine market share worldwide as of March 2018; the next most popular alternative was Bing at three percent, then Yahoo! at two percent (StatCounter 2018a).

The quest for scale over everything was designed at the outset of the company. In their book *How Google Works* (2014), Eric Schmidt (Google’s CEO from 2001 to 2011) and Jonathan Rosenberg (a senior vice president at Google until 2011) wrote that the company’s founders were obsessed with scale because they recognized it as the key to longevity. When Google went public in 2004, Page and Brin issued a “letter from the founders” alongside the requisite investment prospectus to the Securities and Exchange Commission, in which they communicated that they “didn’t care about maximizing the short-term value and marketability of their stock” (Schmidt et al 2014, 33-34), but prioritized a long-term focus. According to Schmidt and Rosenberg, the general principle for Google, as can be applied to any other “Internet Century success story”, was plainly to “bet on technical insights that help solve a big problem in a novel way, **optimize for scale, not for revenue**, and let great products grow the market for everyone” (emphasis added; ibid, 69). For Google Search, the technical insight that
separated this monopoly from its competitors was known as the PageRank algorithm, in which a webpage’s relevance to a user’s query is determined by how many other pages link to it. This promotes pages with higher-quality content, and keeps the users satisfied. This strategy was chosen specifically in lieu of a more profitable one in the short-term, in which the search engine results privilege webpages that were paying more to be featured over those that are more relevant to the user. Rosenberg was adamant that this was the best way to attract and retain customers, and even told his counterparts at the rival AOL that they would get less user traffic by hurting their user experience (ibid, 80).

At least in the beginning of its existence, Google eschewed vertical integration, instead specializing on the central mission of perfecting Search. They were able to accomplish that because the founders understood that unlike AT&T or GE in the past, they did not have to build the entire supply chain; they could provide solely the infrastructure for search, and not generate any of the contents (Wu 2010, 283). This model of “infrastructure not assets” is distinct from older conceptions of public utilities that owned both elements, and is the common operating model for platforms today. By having a laser focus on making Search the best in five essential categories: speed, accuracy, ease of use, comprehensiveness, and freshness (Schmidt et al 2014, 84), Google was able to scale. Finally, the founders were well-aware that once the platform scales, the money will follow, and a virtuous cycle is established: “There’s another important benefit of platforms: As they grow and get more valuable, they attract more investment, which helps to improve the products and services the platform supports. This is why, in the technology industry, companies always think ‘platforms, not products’” (ibid, 81). Google’s parent company, Alphabet, currently has a market capitalization of over $770 billion (Yahoo! Finance 2018b).

**Amazon**

Amazon is another success story of the “scale over everything” mentality. It has confounded industry observers and regulators because its market dominance is not reflected in its profits. The statistics for Amazon’s size are staggering: “as of 2013, it sold more than its next twelve online competitors combined”; in 2015, it took in $107 billion in revenue; it represents 46% of online shopping market; and “close to half of all online buyers go directly to Amazon first search for products” (Khan 2017, 712, 714). Its flagship offering, Amazon Prime, in which subscribers pay a fee to access an array of products such as free shipping and video streaming,
has reached 100 million subscribers worldwide, with 80 million in the United States alone (Frommer 2018). It is estimated that half of U.S. household may be enrolled by 2020 (Khan 2017, 751). Nevertheless, Amazon is still regularly losing money. “The company reported losses in two of the last five years, for example, and its highest yearly net income was still less than 1% of its net sales” (ibid, 713). Investor interest has remained immense; even executives at Google acknowledge that “while financial analysts anguish over its profitability, Amazon always focuses on growth” (Schmidt et al 2014, 79).

Like Google’s Page and Brin did with Google Search, Amazon’s founder Jeff Bezos picked a single beachhead market from which to expand his retail empire. While the origins of Amazon as an online bookseller may not be familiar to every one of its 100 million subscribers, the initial steps that Bezos took were critical in arriving at its current market capitalization of $740 billion (Yahoo! Finance 2018a). Whereas Page and Brin may have been less explicit about their mission to dominate the market, Bezos displayed similar monopolistic ambitions as Samuel Insull and Theodore Vail. Even in his very first letter to shareholders in 1998, Bezos laid bare his position:

“We believe that a fundamental measure of our success will be the shareholder value we create over the long term. This value will be a direct result of our ability to extend and solidify our current market leadership position. The stronger our market leadership, the more powerful our economic model. Market leadership can translate directly to higher revenue, higher profitability, greater capital velocity, and correspondingly stronger returns on invested capital.” (Bezos 1998)

Bezos went on to cite the metrics that mattered to Amazon the most: customer and revenue growth, repeat customers, and strength of its brand (ibid). Profits were not on the list, and he implied that profits was not indicative of “market leadership”, a term that appeared six times in a ten-page document. The strategy for market leadership was not lost on industry observers; from admirers like Peter Thiel, who noted that “Jeff Bezos’s founding vision was to dominate all of online retail, but he very deliberately started with books” (2014, 54); to critics like Douglas Rushkoff, professor of media studies at CUNY, who recognized that “the books are just a loss leader for this bigger prize: ownership of the marketplace itself” (2016, 89). The specific tactics by which he achieved market dominance in the bookselling market, namely lowering prices to undercut traditional book retailers, will be detailed in the following section, but suffice it to say that Amazon’s singular and unabashed focus on scaling up is notable when we consider emerging platforms such as the autonomous mobility-as-a-service one currently in the works.
The Quest to Become Infrastructure

Scale may be the most important thing for the beginning stages of a company, but it is after all a means to an end, which is enduring market dominance and monopoly profits. In this section we discuss the tactics used by technology giants to ensure their market position through integration across services and consolidation. Like demonstrated in Chapter 4, these companies must combine technical superiority with shrewd business practices in order to achieve outsized success. Through the case studies of Google and Amazon, we learn that whereas classic public utilities like telecommunications and power utilities build infrastructure to provide essential services, these new internet utilities provide services to become the infrastructure through which we live much of our lives.

Google

The company that began with a singular focus on perfecting a search engine has now expanded its offerings to include internet browsers, internet services, myriad applications, smartphones, and beyond. By building up its brand equity and reputation through the excellently executed (and free) service that is Search, Google is able to capture an enormous audience for its other products. The roll-out of these products remains meticulous. Like Search, each product relies on strong technical insights to create new solutions to problems: for Google News, which aggregates headlines from various media outlets, it was that users wanted to see stories by topic and not source. For Chrome, the internet browser with over 55 percent market share (StatCounter 2018b), it was that browsers must be re-optimized for speed as websites became more complex. This mentality is similar to Peter Thiel’s philosophy of growing the economic pie rather than fighting over scraps in a stable commodity market, as well as Richard McKenzie’s argument that Microsoft’s operating system is dominant because it is simply the best in the market.

In addition to building its own products, Google has also acquired more than 200 companies since 2001, most notably the smartphone operating system Android in 2005, the video streaming site YouTube in 2006, Motorola’s mobile phone division in 2011, and the smartphone navigation app Waze in 2013 (Reynolds 2017; Crunchbase 2018a). These purchases kill two birds with one stone: they augment Google’s internally created suite of offerings, and they nip potential competitors in the bud. As a result, Google is increasingly vertically integrated. You can now check your Gmail, browse with Google Chrome, use the Google Search bar, plan travel...
on Google Trips, scroll through pictures on Google Photos, all on your Google Pixel phone or Google Chromebook, using the Google Fiber mobile network. This extensive integration across content, operating system, device, and network (Jamison 2015) allows the company to monetize all these services used by a single user, and generate enormous amounts of data about each user. In 2011, Google was accused by the Federal Trade Commission of using “its dominance as a search engine to cement its advantages and exclude rivals in other lines of business” (Khan 2017, 785).

This model of developing a platform dedicated to a single, well-defined service and then bundling additional products once scale has been reached has been emulated by almost all large internet companies. Netflix, which started out as an online movie streaming service, is now one of the most respected producers of original media content. The same goes for Amazon’s video department. YouTube (owned by Google) did not generate any of the videos on its platform when it started and remained that way for a long time, but in recent years began creating its own content to capture more value up the supply chain. Spotify has also been releasing exclusive content in addition to what partnering musicians provide to the platform.

Despite the immense degree of vertical integration in its product offerings, Google insists that they “make it easy for customers to leave… we want to compete on a level playing field and win users’ loyalty based on merit. When customers have low barriers to exist, you have to work to keep them” (Schmidt et al 2014, 88). While this claim may be true for someone who is only interacting with one or a few Google products, a user who has adopted the fully integrated chain of products would have to leave every one of them, e.g. switch to another mobile network, buy another mobile device, transfer all their emails to another service, re-learn how to navigate using another app, and so forth. An “alternative” to Google is not just one service but ten or twenty. The barrier to exit for customers has in fact accumulated to become quite high.

Tim Wu named his book *The Master Switch* in reference to Google, which he calls the new “telephone girl” (2010, 279). Google has become the ultimate platform for internet users and the essential infrastructure for much of our online activities. In the following sections we look at how Amazon is fast becoming the infrastructure for online retail, then how a future autonomous mobility platform that follows the operating models of these internet giants may develop.
Amazon

Like Google, Amazon has evolved beyond its original mission. The online bookseller has become “the titan of twenty-first century commerce. In addition to being a retailer, it is now a marketing platform, a delivery and logistics network, a payment service, a credit lender, an auction house, a major book publisher, a producer of television and films, a fashion designer, a hardware manufacturer, and a leading host of cloud server space” (Khan 2016, 710). While our analysis of Google has focused primarily on the impact on the end user and difficulty in separating out business lines when considering leaving the service, our analysis of Amazon is focused on the impact it has on not only the end users but other businesses. According to early Amazon employees, Jeff Bezos’s original vision included the strategy to target other businesses, and develop as not an online retailer but “rather a ‘utility’ that would become essential to commerce” (ibid, 755). The invocation of a utility here is of course critical to this study, and it is rare to have an intrinsically monopolistic firm admit this somewhat freely.

The genius of Amazon Prime was to lose money in order to hold customers captive. The end game was to change people’s mentality, such that they would not even think of shopping anywhere else. Launched in 2005, Amazon Prime removes arguably the largest hurdle to online retail -- shipping -- and sets an annual subscription fee to encourage frequent usage. “As a result, Amazon Prime users are both more likely to buy on its platform and less likely to shop elsewhere” (ibid, 752). That the subscription fee of $79 went up to $99 in 2014, then to $119 in 2018, to little drama is a powerful testament to its customer lock-in.

How did Amazon achieve this incredible sense of customer loyalty? According to antitrust scholar Lina Khan, Amazon employed four strategies to establish structural dominance in the online retail market. First, echoing the tactics used by Insull and Vail in Chapter 4, Amazon used low prices to undercut its rivals in the beachhead market of online bookselling. Unlike his predecessors, however, Bezos practised aggressive methods of below-cost predatory pricing to root out competitors. Pricing all bestselling e-books below cost while absorbing the losses helped Amazon gain 90 percent of the e-book retail market through 2009 (ibid, 757). When the DOJ investigated claims of predatory pricing against Amazon in 2012, they found that its e-book distribution business remained profitable. Khan argues that the DOJ should not have aggregated all books into its investigation, but just the bestsellers. Amazon’s practices were not “loss leading” but predatory pricing, since the former is intended to generate more sales from
customers but the latter is designed to drive out competitors. The distinction is more meaningful for physical retail stores because each visit is discrete, but online platforms like Amazon are able to glean additional information about each visitor’s preferences and habits. It would also be difficult to identify recoupment across products, since the personalized nature of the platform means that prices for the same product can change without warning and vary between customers.

The second method used by Amazon after undercutting some competitors on price was to acquire them. Khan cites the example of the company’s 2010 purchasing of Quidsi, a collection of online marketplaces such as Diapers.com and Soap.com. To undermine Quidsi, Amazon launched a separate product line called Amazon Mom, tracking product prices on Diapers.com and then deliberately pricing below them. After Quidsi was no longer able to compete, Amazon bought it, discontinued Amazon Mom, and increased prices on the same products. Amazon has also recently bought Whole Foods to enter into the produce market, and is rumored to have considered buying the beleaguered Toys ‘R’ Us to expand further into the toy and warehousing market (Townsend et al 2018).

Amazon also leverages its dominance as an online retailer to increase its footprint in the logistics industry. Because of their market position, they are able to hold enormous bargaining power with delivery services, which have been reported to raise prices on smaller retailers in order to afford the 70 percent discount given to Amazon (Khan 2017, 775). As a result of this arrangement, Amazon created its Fulfillment-by-Amazon business line, which helps smaller retailers take care of packing, shipping, and customer service for their products. It is cheaper for these vendors to go through Amazon than to manage the process on their own. Khan sounds the alarm that “Amazon achieved those cross-sector advantages in part due to its bargaining power” (ibid, 778). Amazon brilliantly uses its retail market dominance to secure extraordinarily low prices for delivery, then turns around to leverage delivery discounts to support the retailing side of its business through learning about the operations of its business customers.

The final tactic employed by Amazon is one that separates this aspiring utility with its predecessors. Amazon is armed with effectively endless amounts of data on each of its users, including “how long you hover your mouse on a particular item, how many days an item sits in your shopping basket before you purchase it, or the fashion blogs you visit before looking for
those same items through a search engine” (ibid, 764). They use the data collected to, unsurprisingly, bolster their market leadership. This is manifested in several ways. Amazon is able to intelligently site warehouses, sorting centers, and delivery stations because it has all the data points needed to optimize for distance between vendors and customers. “Analysts estimate that the locations of Amazon’s fulfillment centers bring it within twenty miles of 31% of the population and within twenty miles of 60% of its core same-day base” (ibid, 777). In addition, Amazon’s Marketplace business line, where third-party retailers sell products to consumers through Amazon’s platform, enables Amazon to see every transaction that has occurred for consumer preference and willingness to pay, then use the data to adjust the operations for their house brands. Not only are they able to identify aggregate trends in consumer behavior, they can privilege their own products on the platform simply because they own the platform. Both the scale of its operations and the reach of its big data capabilities are so crucial to Amazon’s success since it renders the advantages enjoyed by the monopolist self-reinforcing. This is different from the non-internet utilities, where price discrimination may be practised but the extent to which the firms can leverage the granular levels of data across sectors is unprecedented.

The combination of these methods has given Amazon a highly unusual place in retail. It swallows up competitors then changes the rules of the game to prevent other entrants; it “retrieves the spirit of empire by colonizing not just verticals within its own category but horizontals in everyone else’s” (Rushkoff 2016, 89). Lastly, by selecting a subscription model, Amazon has managed to secure itself in each household’s annual budget, further entrenching itself as a utility that provides essential services through regular payments. These tactics have been proven to be so effective and lucrative that it seems almost inevitable for savvy firms looking to build a transportation services platform to emulate this set of practices.
Applications to the AV Case

The comparison between these two technology giants and the upcoming autonomous mobility-as-a-service platform is based on the common goal that these firms share in providing the underlying infrastructure that facilitates the lives of the end users. Google at its core connects users with information; Amazon connects users with material goods; the AV platform connects users with destinations. What follows is the most speculative part of this thesis, as I extract lessons learned from the previous case studies of modern-day internet monopolies and project them onto a monopoly that does not yet exist. I am not condoning the following as the best or most equitable way to roll out an AV mobility platform, but am proposing that it will be the most likely way in which this platform will be implemented, barring policy intervention. In this section I first present findings from my interviews that would suggest the AV industry’s preference for and tendency toward a centralized platform for autonomous personal travel services. I then outline actions by several industry players, i.e. Uber and Lyft, that indicate the scaling up and eventual operations of the AV platform will follow the trails blazed by Google and Amazon. I conclude the chapter by drawing attention to a few downsides to this particular implementation model, including the decline of service quality and concerns about the commitment to universal service.
The ambition for AV developers, as outlined in Chapter 3, is to become a centralized platform with contemporary monopolistic characteristics. Informant Y, policy manager of a transportation network company, explicitly said that he envisions a centrally-operated and -owned system. Y invoked the comparison to Google’s Android operating system when describing this future platform, saying that an AV developer would do well to open up its network to partners in order to scale up the customer base quickly, just as many smartphone makers have adopted the Android OS in their products. “With open, you trade control for scale and innovation,” confirmed Google’s own Schmidt and Rosenberg (Schmidt et al 2014, 86). Informant R, director of policy at a traditional automaker, expressed that his employer would like to own the fleet, maintain it, and use the data they glean to develop their offerings. This strategic usage of consumer data is similar to Amazon’s, whereby firms attempt to reinforce their market leadership through tailoring products to consumer preferences. R also mentioned that his OEM will be deploying in several business lines, including other fleet applications such as package delivery, AV rental or AV-sharing services, and so on. This would also allow the OEM to leverage data or market position from one business line to another, as Amazon has done.

**The Google/Uber Model**

The key learnings from Google’s experience as explained above are to rely on strong technical insights to launch a product, focus on scale over everything, execute one beachhead market really well, gain customers on the platform, and then move into adjacent markets through acquisitions to ultimately become a vertically integrated infrastructure service. This strategy has been emulated by Uber fairly closely.

By executing on the singular technical insight that people should be able to hail a ride from their smartphones instead of making a call or hailing on the street, Uber was already distancing itself from the incumbents in the taxi industry. As described in Chapter 3, Uber has collected $20 billion in funding for its efforts to build not physical infrastructure but “intangibles like brand recognition” (Khan 2017, 772). Just as Google wanted to be everyone’s search engine, Uber wanted to be everyone’s private driver. The funding has also gone to subsidizing trips such that they are competitive with other transport modes. By focusing initially on wealthier riders in San Francisco, Uber was able to dominate a small niche market before expanding to other cities as well as other services (Black Car, SUV, uberXL for larger parties, POOL for shared rides, uberWAV for those with accessibility needs, and so on). Uber has also launched services
for helicopters, boats, and a food delivery service in Uber Eats. While there is little public information about the profitability of each of these services, it is reasonable to assume that Uber is cross-subsidizing across business lines in order to use leverage from one market in which it is dominant to secure market position in an adjacent market.

Uber’s autonomous vehicle strategy has evolved in the past few years, and recent developments lead me to believe that they will be more aggressively pursuing a vertically integrated stack as Google has done (for a graphic representation, see Fig. 5.3). Initially, Uber’s AV strategy was internally focused, working with Volvo as their main supplier to develop in-house AV technology. Eager to expand its capacity, Uber began acquiring both horizontally and vertically. It first bought deCarta, a company that makes location-based software platforms, in 2015. In 2016, it acquired both Geometric Intelligence, an artificial intelligence startup, and Otto, a self-driving truck startup. In a somewhat surprising move, Uber then bought Swipe Labs in 2017, hoping to leverage the studio’s expertise in social media “to make its driver app more human” (Constine 2017). Finally, in April 2018, Uber announced its acquisition of JUMP Bikes, a dockless e-bike sharing service. CEO Dara Khosrowshahi confirmed that Uber is looking to expand beyond ride-hailing, and will use its platform to integrate across several transport modes from e-bikes to public transit (Bhuiyan 2018). Users will soon be able rent cars and buy public transit tickets via its app. This move signaled a shift in direction for a company known for ruthless competition in the ride-hailing and AV technology space, and is the most concrete indication that it is pursuing a vertical integration strategy in which Uber will “own a piece of every trip that happens in cities… even if it’s not an Uber-operated service” (ibid). The change in direction may validate rumors that Uber’s AV technology is lagging behind competitors, a claim that has come to light after an Uber-operated Volvo killed a pedestrian while in self-driving mode earlier in 2018 (Wakabayashi 2018). Uber may be setting its sights on a broader set of transportation offerings since putting all of its eggs into the AV basket has proven to be unsuccessful.

It may be too cynical to believe that once we begin to pay for public transit tickets on Uber’s app, the fight for mass urban transportation will be over. However, without guidelines and regulations in place, it would be difficult to ascertain how much Uber is charging for each part of a trip, and it may essentially absorb any brand equity that public transit systems have in any city, resulting in lower political visibility and thus influence (Freemark and Zhao 2018). Douglas
Rushkoff was prescient in noting that Uber has to first own ride-sharing completely before it can become “the default app for every other transportation-related function” (2016, 87). This will include autonomous travel once the technology is mature, and Uber could become the underlying transportation infrastructure in our cities.

Fig. 5.3 Uber’s Vertical Integration Model

The Amazon/Lyft Model

Lyft takes after Amazon’s playbook. The takeaways from Amazon’s market domination tactics were to undercut rivals on price, acquire horizontally in the same market, become an essential service for not only end users but other businesses, and use data throughout to inform business decisions. Although it has only one-fifth of Uber’s war chest ($4 billion compared to $20 billion), Lyft has also sustained huge losses in order to gain riders through subsidies (Crunchbase 2018c; Bhuiyan 2017b). Like Uber, Lyft has been acquiring companies to prevent the development that may threaten its business, as well as to augment their own offerings. This includes Rover, an app that provides routing information; a ride-sharing app that is the predecessor to Lyft Line called Hitch also in 2014; two social media platforms; and predictive analytics and referral platforms to boost user growth (Crunchbase 2018b). These two first steps overlap significantly with Uber’s strategy, so we will focus on the latter two strategies in this section.
Lyft’s AV strategy from the beginning has been focused on partnerships instead of building its own technology. Like other internet giants at their outset, Lyft has focused in the last few years on building a platform that would bring together consumers and producers. As mentioned in Chapter 3, Lyft has announced partnerships across industries, from OEMs to AV startups, including Google’s Waymo, GM, Ford, Jaguar Land Rover, nuTonomy, Drive.ai, and, most recently, the auto parts supplier Magna. On its website, Lyft touts the “open era of autonomous” and that it is a “first-of-its-kind open platform (that) introduces the world’s leading autonomous partners to millions of weekly miles. Together, we can accelerate the growth of self-driving technology and improve the safety and quality of life in our cities” (Lyft 2018). It claims to be “the most efficient way to bring your autonomous technology to market”, and that partners would benefit from its expansive network, seamless integration through a robust API (application programming interface, which allows external entities to obtain information from Lyft), and many other features (ibid).

This approach is very reminiscent of Amazon Marketplace as well as Fulfillment-by-Amazon, whereby the platform gets to mediate heavily between producers and consumers. By providing the API to partners to access data like customers and routes, Lyft would be able to emulate Amazon in turning its competitors into customers. Lyft could use the data produced by its partners on the rides they provide to reinforce its leadership in the AV mobility market to site parking lots for its fleets and better optimize for routes across the system. This advantage would enable them to get to riders and complete trips more quickly. Since Lyft launched its own self-driving division (Buhr 2017), the company will moreover be able to use the data gleaned from its partners’ operations on its platform to privilege its own AV service. Finally, just as Amazon is able to gauge which startups are gaining traction by monitoring their increased usage of Amazon Web Services and thus invest in them (Khan 2017, 783), Lyft would also be able to monitor how its partners use its platform to neutralize competition or pursue acquisitions.

Unlike Uber, who wants to take a bite out of every transport mode across the full supply chain of trips, Lyft appears to be prioritizing horizontal integration and the full intermediation between riders looking to hail an AV and partners who can provide the service (for a graphic representation, see Fig. 5.4). Lyft’s ambition to become the singular marketplace for personal AV travel may very well coexist with Uber’s ambition to become the arbiter of every trip taken in its deployment cities. While there is still much uncertainty in how the AV industry will
consolidate and how the platform will be implemented, the two preceding models serve as meaningful estimates of two strategically divergent but concurrently valid trajectories.

Fig. 5.4 Lyft’s Horizontal Integration Model

W
AWAYMO
GM
drive.ai
nuTonomy

Riders

Downsides and Cautions

What are the potential downsides to the aforementioned operation models for aspiring monopolist firms like Uber and Lyft? In the case of Amazon (and Lyft, by extension), Lina Khan calls out the lack of protections for suppliers who partner with the online retail platform. Just as the demise of booksellers can be attributed to Amazon and certain vendors have seen their products replicated by Amazon’s in-house brands, OEMs may be relegated to mere suppliers that can eventually be replaced by Lyft’s own AVs. Even as the OEMs do not want to become a contract manufacturer or commodity supplier like Foxconn, as an interviewee memorably said, there may well be a decline in brand equity for these partners, just as online shoppers are identifying more and more with Amazon at the expense of individual vendors on its platform.

In terms of consumer protections, Khan is keen on re-asserting the definition of consumer welfare to include more than just low prices. In addition to our uncertainty about the "true", unsubsidized prices of ride-sharing services, we should be wary of the potential decrease in service quality and variety. Moreover, since "everyone passes through the same digital
turnstiles” in these highly centralized platforms (Rushkoff 2016, 29), there may be a decrease in product diversity in the transportation stack as riders simply follow whatever modes their Uber app may recommend for their optimal trip.

Finally, there is the central question of consumer choice and universal service. For a platform like Google which has historically operated over an infrastructure it does not own, it has been vulnerable to net neutrality concerns, meaning that internet service providers may be able to privilege certain content on the web while blocking others. This would greatly inhibit Google’s platform. Google has in recent years begun to build its own internet network, and itself also has the power to control the traffic between users and websites. Tying everything back to our Chapter 3 discussion, “if one allows that the Internet is our key means of conveyance, the ‘common medium’ of our national life and economy, net neutrality is the twenty-first century’s version of common carriage” (Wu 2010, 286). Just as twentieth-century critics of monopoly were cautious about concentrating economic and therefore political power in the hands of a few, critics of modern-day monopolies are rightfully concerned that when essential services like transport are controlled by a single entity, some neighborhoods may get redlined or see lower levels of service.

Summary

In this chapter I outlined the characteristics that make contemporary technology monopolies distinct from their classic public utility predecessors, namely its obsession with scale over everything, including profits, and its ability to leverage data to reinforce its market leadership over its competitors. I offered two possible and complementary operating frameworks for future autonomous mobility platforms as indicated by recent activities by Uber and Lyft, and briefly explained potential drawbacks for these models. In the next chapter, I conclude my thesis with thoughts on how we may rein in the aspiring monopolists in the autonomous mobility platform space, given what we know about other case studies in public utilities and internet infrastructure providers.
### Fig. 5.5 Summary Table of Characteristics Across Contemporary Case Studies

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Google</th>
<th>Amazon</th>
<th>Autonomous Mobility Platform</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scale over everything</td>
<td>In letter to shareholders, founders made clear that their goal is to create long-term value.</td>
<td>In letter to shareholders, Jeff Bezos emphasized the quest for market leadership over short-term profits.</td>
<td>TNCs like Uber and Lyft already reflect this mentality in their non-autonomous business.</td>
</tr>
<tr>
<td>Integration and Data</td>
<td>Acquire vertically (e.g. smartphone makers like Motorola and app/content creators like Waze) to consolidate into vertically-integrated service stack.</td>
<td>Acquire horizontally (e.g. other marketplaces like Whole Foods); partner with as many vendors as possible; use the data gleaned from both sides to solidify dominance.</td>
<td>Both strategies are likely, and are likely to coexist.</td>
</tr>
<tr>
<td>Current Market Position</td>
<td>90% of search engine market</td>
<td>100 million subscribers worldwide (estimated 80 million in U.S.)</td>
<td>N/A</td>
</tr>
</tbody>
</table>


Chapter 6: Moving Forward

(SEN. LINDSEY) GRAHAM: Who’s your biggest competitor?
ZUCKERBERG: Senator, we have a lot of competitors.
GRAHAM: Who’s your biggest?
ZUCKERBERG: I think the categories of — did you want just one? I’m not sure I can give one, but can I give a bunch? There are three categories that I would focus on. One are the other tech platforms — so Google, Apple, Amazon, Microsoft — we overlap with them in different ways...
GRAHAM: Let me put it this way. If I buy a Ford, and it doesn’t work well, and I don’t like it, I can buy a Chevy. If I’m upset with Facebook, what’s the equivalent product that I can go sign up for?
ZUCKERBERG: Well, there — the second category that I was going to talk about are...
GRAHAM: I’m not talking about categories. I’m talking about, is there real competition you face? Because car companies face a lot of competition. If they make a defective car, it gets out in the world, people stop buying that car; they buy another one. Is there an alternative to Facebook in the private sector?
ZUCKERBERG: Yes, Senator. The average American uses eight different apps to communicate with their friends and stay in touch with people, ranging from texting apps, to email, to...
GRAHAM: Okay. Which is the same service you provide?
ZUCKERBERG: Well, we provide a number of different services...
GRAHAM: You don’t think you have a monopoly?
ZUCKERBERG: It certainly doesn’t feel like that to me.
-- Transcript of Facebook CEO Mark Zuckerberg’s Congressional Hearing, April 2018

Studying an emerging technology means that the subject will invariably evolve throughout the course of the investigation. Since I began my research in the summer of 2017, a few major milestones in the autonomous vehicle development space have been reached.

Waymo, Google’s AV spin-off, began testing its self-driving cars on public roads in Arizona without a safety driver in late 2017. Said a writer for TechCrunch, “It’s hard to understate (sic) the importance of this milestone: Waymo is operating at full Level 4 autonomy, sharing public roads with human-driven cars and pedestrians, with no one at the wheel able to take over in case things don’t go as planned. That shows confidence” (Etherington 2017c). As the
technology advances, automakers are also making strides in preparing for the production of these vehicles. GM announced that it is spending $100 million to upgrade factories for the production of its self-driving Chevy Bolt EV, the car that Cruise (a startup acquired by GM) has been using for testing (Lambert 2018). Finally, there was the first AV-caused death in March 2018, in which an Uber-operated Volvo killed a pedestrian while in self-driving mode. In addition to showing that important players in the AV development market still have an incredible amount of work to do before mass deployment, the incident illuminates some movement in the realm of consumer acceptance. There was a somewhat surprisingly blasé public response both inside and outside the AV industry. Many believed that the collision was inevitable or simply a matter of time (e.g. Bonnington 2018), and the police chief of Tempe, AZ, where the crash occurred, was quick to publicly speculate that it was not Uber’s fault (Hyatt 2018). These milestones indicate that self-driving technology and the conversation on social impact around it continue to progress, and that many people have come to view the ascent of AVs as a matter of course.

**Reflection and Summary**

This thesis articulated a likely future for AVs, namely that they will be first deployed on autonomous mobility platforms that demonstrate key characteristics of natural monopolies, like public utilities in some ways, and modern-day technological platforms in other, more salient ways. The topics examined in this thesis will vary in relevance as the AV industry grows and the discussion about the potential deployment and operating models matures. Nevertheless, precisely because we are not yet certain of what is to come in autonomous mobility, it is important to consider current stakeholder sentiments and analogous case studies to inform our understanding of the transformative technology. More specifically, my other key findings include:

*There is general optimism about the progress of AV technology and the power of AVs to positively impact society.*

The concept of autonomous vehicles is in fact not as novel as we think, and complementary components of AV technology date back to the mid-twentieth century. The Department of Defense catalyzed the development in earnest in the 2000s through a series of engineering challenges, which were instrumental in drawing the leaders of the technology in the United
States. The critical nature of software in self-driving cars separates them from legacy vehicles, and have attracted hundreds of non-traditional players into the automotive market.

The widespread use of AVs is projected to improve safety and mobility, as well as reduce emissions. While most people speculate that AVs will first and foremost be deployed as shared electric fleets in urban areas, many have reservations about the coverage of these mobility services in suburban and rural areas, and hold that private ownership of cars, autonomous or otherwise, will remain significant.

**Stakeholders across sectors are expecting a future of autonomous electric fleets.**

My interviewees across the private and public sectors largely affirmed the prediction that the future of AVs will be autonomous electric fleets, at least in cities. Several major players in the AV market have committed to electric powertrains, and most informants agreed that a fleet model would be the most sensible given both the upfront capital expenses and the positive social impacts. Most were skeptical that the rise of AV services will substantially undermine regional public transit systems, as they remain efficient modes to move large volumes of people.

The stakeholders can broadly be placed in three categories based on how certain they feel about the future of AVs, and these categories correspond fairly accurately to their attitudes toward possible regulation of the industry. The first group includes representatives of AV startups, technology companies, and transportation network companies, who tend to be more confident in their vision of autonomous electric fleets. They are likely to emphasize the values they share with the public sector, and work to project themselves as allies and educators to policymakers. The second group includes the older guard of the industry, those who work for traditional OEMs. These stakeholders are more familiar and comfortable with the “wait and see” approach for regulation, since they are less certain that the future of AVs will rely heavily on shared mobility models. The third group includes public and non-profit sector stakeholders who are most cynical about the promise of AVs to solve social problems. They tend to favor a heavier-handed approach than the first two groups, even as they are sympathetic to concerns about stifling innovation.
Given the immense upfront capital investments and the nature of network effects, the autonomous mobility platform is likely to tend toward monopoly.

A natural monopoly occurs in a market when the entire demand for a good or service can be satisfied at lowest cost by one producer rather than two or more, and if there is a high sunk cost and barrier to entry. Monopolies are regulated by government in order to ensure that essential services are provided at an adequate level and at reasonable rates. Industry reports and interview data indicate that the future autonomous mobility-as-a-service platform will be most efficient if there were one centralized command center and network. Moreover, the barrier to entry will only increase as the industry develops, considering the cost of R&D and network effects of a platform. Announcements in the AV space about acquisitions and partnerships at varying degrees of exclusivity suggest that there are strong undercurrents for the industry to consolidate, especially given the perception that this will be a winner-takes-all market. The concept of the “common carrier” is important here when discussing natural monopolies that provide services that are essential and generates positive externalities, such as telecommunications, electrification, and accessible personal transport.

The autonomous mobility platform is anticipated to reflect the development trajectory of classic public utilities, namely supplanting a legacy technology with a new, transformative one, and using pricing and market consolidation tactics to achieve regional market dominance.

The autonomous mobility platform is projected to share similar characteristics as two classic public utilities in their development into monopolistic industries. First, we considered the transformative nature of new technologies in telecommunications and in electrification, the former promoting social connectivity and the latter providing illumination and hygiene. The same breathless rhetoric has been applied to AVs, which are supposed to expand mobility and accessibility. Second, even as the new technologies were lauded, the public was initially hesitant to adopt them and clung onto legacy technologies like the telegraph and gas lighting. Experts in the automotive industry were convinced that the public will not be easily swayed in shedding their human-driven, privately-owned cars in favor of autonomous mobility services. Third, in order to gain market traction, both AT&T and the Edison companies took to undercutting the incumbents and tweaking with their respective business models to ensure that services are
almost universally provided at reasonable rates. The discussion about pricing is more sensitive in the AV case, as software platforms allow price discrimination to be practised at an unprecedentedly granular level, i.e. for each individual. Concerns were traded between those who wonder about the social equity implications of a singular AV platform and those who worry about the impact on service quality if strict universal service mandates were imposed. Lastly, executives in both telecommunications and power utility industries pursued consolidation to entrench themselves as monopolists, a strategy that will be attempted by aspiring monopolists in the AV industry as well from city to city.

The autonomous mobility platform will first be designed to prioritize scale over everything else, and firms are likely to pursue both horizontal and vertical integration strategies to achieve market leadership.

Conceptions of utilities, infrastructure, and monopoly have changed over the past 50 years, and scholars are increasingly calling into question the relevance of antitrust regulations typically used to protect consumers as well as producers. While the future autonomous mobility-as-a-service platform may follow some patterns of classic public utilities, they are also likely to incorporate elements of modern-day internet-enabled companies like Google and Amazon. Whichever firm aspiring to win the AV platform market may follow the mentality of “scale over everything, including profits” in the outset, as they focus solely on reaching customers and attaining lock-in to the platform. The firm may also pursue aggressively competitive (or anticompetitive, depending on which literature one consults) tactics to undercut their rivals on cost then acquire them. It may set itself up as the essential infrastructure through which other businesses can serve their consumers, convert competitors into customers, then leverage data collected on their platform against these competitors. Recent actions by Uber signal that the company is looking to emulate Google in its vertical integration approach, such that Uber would own a small portion of each trip a rider takes in a city, regardless of mode. Lyft, on the other hand, seems to be committed to a horizontal integration approach, choosing instead to serve as a multi-sided platform for both consumers as well as all AV-related service providers. Considering the two divergent tacks taken by these technology giants, there can be a future in which Uber and Lyft can divide and conquer their way into a stable coexistence in the future transportation market.
Policy Implications

While the fight for market leadership may benefit riders in dense urban areas in the short term through artificially low fares, no one can be certain what will happen when the subsidies are eliminated and the “true” cost of the autonomous mobility platform is revealed. Consumers may also suffer from a lack of product variety in monopolistic personal transportation market, and be limited to the offerings of whoever owns the market. While Peter Thiel believes that the promise of monopoly profits frees companies up to think about longevity over short-term gain, it is unclear whether that is incentive enough to offset the lack of competition in diminishing innovation.

What are some steps regulators can take in reining in potential monopolistic abuses? Several of my interviewees expressed pessimism at the ability and willingness of political actors to regulate the autonomous vehicle industry to mitigate negative outcomes before they occur. The political tipping point will not arrive until it is too late, said a lobbyist for AV developers, and until the products hit the road on a massive scale, people will not be confident enough to make rules around it. Even those working in the public sector alongside regulators expressed doubt that they will be able to step in and tame this Wild West; regulations may only be put in place after some birthing pains in deployment, or in the unlikely scenario that there is bold leadership in municipal or state governments on this issue.

In her article *Amazon’s Antitrust Paradox*, legal scholar Lina Khan suggested two high-level approaches to regaining public control over runaway monopolists: first, to govern online platform markets through greater competition, and second, to govern them as monopolies through regulation. The first option requires regulators to expand their understanding of market dominance. In his book *Zero to One*, Peter Thiel, a vocal promoter of monopolies, states that savvy companies disguise their monopoly through the union of markets, i.e. couching a market in which they are in fact dominant in a larger market to downplay their position. Regulators therefore need to learn to disaggregate a company’s lines of business when evaluating its monopoly status. They should also scrutinize mergers and acquisitions if there will be significant consolidation not only of market share but also of data, which can be used to further decimate competition.
The second proposal is to accept these companies as monopolies, eliminate competition altogether, and explicitly regulate them. Khan argues that in the case of Amazon, which has become the infrastructure by which many businesses operate, “applying elements of public utility regulations to its business is worth considering” (2017, 798). This would mean mandating universal service and nondiscrimination, regulated prices, and imposing capitalization requirements to ensure proper maintenance and investment in the platform.

Furthermore, if we accept that autonomous mobility platforms will be providing essential services with positive externalities that the government would want to encourage, we may even invoke the question of ownership. In his book Regulating Infrastructure, Jose Gomez-Ibanez frames the problem of infrastructure monopoly as a “long-term contracting problem” (2006, 3). He assumes that “the primary goal of public policy toward monopoly is to encourage efficient markets” (20), but also other values like equity through universal access to basic service. Gomez-Ibanez then presents a continuum of broad strategies for how to regulating such monopolies, in ascending order of government involvement (see Fig. 6.1).

Fig. 6.1 Spectrum of Strategies for Regulating Monopoly

<table>
<thead>
<tr>
<th>How prices and service quality are determined</th>
<th>Strategy for regulating monopoly</th>
</tr>
</thead>
<tbody>
<tr>
<td>Markets</td>
<td>Private Contracts</td>
</tr>
<tr>
<td></td>
<td>Customers contract directly with private infrastructure supplier</td>
</tr>
<tr>
<td></td>
<td>Concession Contracts</td>
</tr>
<tr>
<td></td>
<td>Government contract with supplier on customers’ behalf</td>
</tr>
<tr>
<td></td>
<td>Discretionary Regulation</td>
</tr>
<tr>
<td></td>
<td>Government set prices and service standards</td>
</tr>
<tr>
<td>Politics</td>
<td>Public Enterprise</td>
</tr>
<tr>
<td></td>
<td>Government or nonprofit assumes primary responsibility for supplying service</td>
</tr>
</tbody>
</table>

Source: Gómez-Ibáñez 2006, 33

Khan’s first proposal is a modification of option 1 of private contracts, whereas her second proposal falls under option 3 of discretionary regulation. She acknowledges that the kind of
public utility commissions needed for the monopoly regulation are generally unpopular, though the recent debates around net neutrality have revived the intellectual tradition of common carrier literature. A few of my interviewees mentioned option 2, concession contracts, in which firms compete for monopoly status, as a compromise that may serve the public interest and incentivize innovation. There was also discussion of partnerships with governments, in which the platform would operate in a semi-public capacity, and that this would be an opportunity to bring TNCs back into the fold after an era of confrontation. Finally, while there was sympathy that the government would not want to rely entirely on the private sector to provide this essential service of personal mobility, none of my interviewees -- not even those who are public servants, tellingly -- favored the public enterprise option. Our public transit system has no interest in owning or maintaining more vehicles, said a municipal administrator, not least because they will not have the confidence of the public to do it well. Nevertheless, the public sector must endeavor to remain proactive in these discussions and to safeguard the public interest in all circumstances.

Further Questions
As the future of autonomous mobility is multi-faceted and yet to be written, this research can be taken in many other directions that I did not address in this project. These include: investigating further the equity implications of universal service for rural populations and the potential for redlining neighborhoods; drawing out more explicitly the implications of a vertically- or horizontally-integrated transportation system; considering the possibility that AV technology itself will be disrupted (e.g. by flying taxis); studying how patient venture capital truly is regarding these platforms; referencing antitrust cases pursued by the European Commission; and proposing specific actions for government actors at all levels. I look forward to remaining involved in these projects with researchers and practitioners in the AV space.

Moving Forward
As urban planners and policymakers, we should welcome the new era of autonomous mobility that will enable more people in our cities to access not only services and spaces, but also one another. The recent congressional hearing with Facebook’s Mark Zuckerberg should be sobering for young policymakers, as it revealed -- admittedly with good humor -- the knowledge gaps that our current regulators and elected officials have about technologies that have been ubiquitous for more than a decade. The intersection between the emerging business
models of online platforms and the traditional regulatory practices in the automobile industry will be difficult to navigate for stakeholders on all sides. Planners should work to bridge the communications and values gap between these disparate groups, and must train our intellectual curiosity to expand beyond disciplinary boundaries. By facilitating innovation and guiding it toward socially desirable goals, we hope to shape a future era of transportation that will not only be autonomous and efficient, but inclusive and sustainable.
Bibliography


Glossary of Frequently Used Acronyms

<table>
<thead>
<tr>
<th>Acronym</th>
<th>First Mention (Page Number)</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>AEV</td>
<td>22</td>
<td>Autonomous Electric Vehicle</td>
</tr>
<tr>
<td>API</td>
<td>82</td>
<td>Application Programming Interface</td>
</tr>
<tr>
<td>AT&amp;T</td>
<td>49</td>
<td>American Telephone and Telegraph Company</td>
</tr>
<tr>
<td>AV</td>
<td>3</td>
<td>Autonomous Vehicle</td>
</tr>
<tr>
<td>CMU</td>
<td>9</td>
<td>Carnegie Mellon University</td>
</tr>
<tr>
<td>DARPA</td>
<td>10</td>
<td>Defense Advanced Research Projects Agency (part of the United States Department of Defense)</td>
</tr>
<tr>
<td>DOJ</td>
<td>65</td>
<td>United States Department of Justice</td>
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<td>DOT</td>
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<td>United States Department of Transportation</td>
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<td>EV</td>
<td>23</td>
<td>Electric Vehicle</td>
</tr>
<tr>
<td>MaaS</td>
<td>13</td>
<td>Mobility-as-a-Service</td>
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<tr>
<td>MAPC</td>
<td>23</td>
<td>Metropolitan Area Planning Council</td>
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<td>National Highway Traffic Safety Administration</td>
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<tr>
<td>OEM</td>
<td>7</td>
<td>Original Equipment Manufacturer</td>
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<tr>
<td>SAE</td>
<td>8</td>
<td>Society of Automotive Engineers</td>
</tr>
<tr>
<td>TNC</td>
<td>13</td>
<td>Transportation Network Company</td>
</tr>
<tr>
<td>VMT</td>
<td>13</td>
<td>Vehicles Miles Traveled</td>
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