Planning for Proliferation of Autonomous Vehicles and its Impact on the Future of Urban Mobility

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TABLE OF CONTENTS 00

01 INTRODUCTION

When the ball dropped in Times Square to usher in the year 2007, few people were thinking about the brewing technology and ideas that would soon allow people to press a button on their phone to summon a stranger for a "taxi" ride much less the widespread use and phenomenon that it would generate. The first iPhone was released by Apple in June of 2007, the Apple App store launched in July of 2008 and the first Uber rides occurred in San Francisco in 2010. The speed of these significant 21st-century technological advances and their effects are incredibly novel and, in many ways, difficult to fathom. The manner in which we communicate, learn, socialize and shop has fundamentally changed in just the last 10 years. Conversely, mass production of the automobile began in 1913 yet many of the automobile's major impacts, such as interstate highways and suburban sprawl, did not occur until the 1950s.

In 2000, Futurist (and current Director of Engineering at Google) Ray Kurzweil developed a thesis coined "the Law of Accelerating Returns," explaining that technological change is exponential, as opposed to linear. The magnitude of exponential growth is often explained through a common grade school query which asks: If a boy is given a penny on the first day of the month and that amount is then doubled every day (i.e. two pennies on the second day and four pennies on the third) for a month, how much would the boy have at the end of the 31-day month? The answer is a staggering $10.7 million, a powerful example of the mind-boggling magnitude of exponential growth. Nearly equally surprising is that Day 15 of the hypothetical yields just $163.84. With huge gains generated in the final few stages, the impacts of exponential growth can be felt rather sudden, almost as though they were generated overnight.

Kurzweil asserts that people think in linear terms and therefore erroneously assume that the current rate of progress will continue for future periods. (Kurzweil, 2001) With the exponential growth of technology, Kurzweil predicted, in 2001, that we will experience 20,000 years of progress over the next 100 years. (Kurzweil, 2001) Along these lines, the advent and proliferation of autonomous vehicles will again fundamentally re-shape mobility as well as our development patterns and infrastructure but at a much faster, possibly exponential, rate. The AV industry is already progressing at lighting speed, with new announcements regarding technology, capital investment and regulation occurring daily. With the acceleration of AV technology and investment, we are perhaps on the precipice of a mobility metamorphosis.

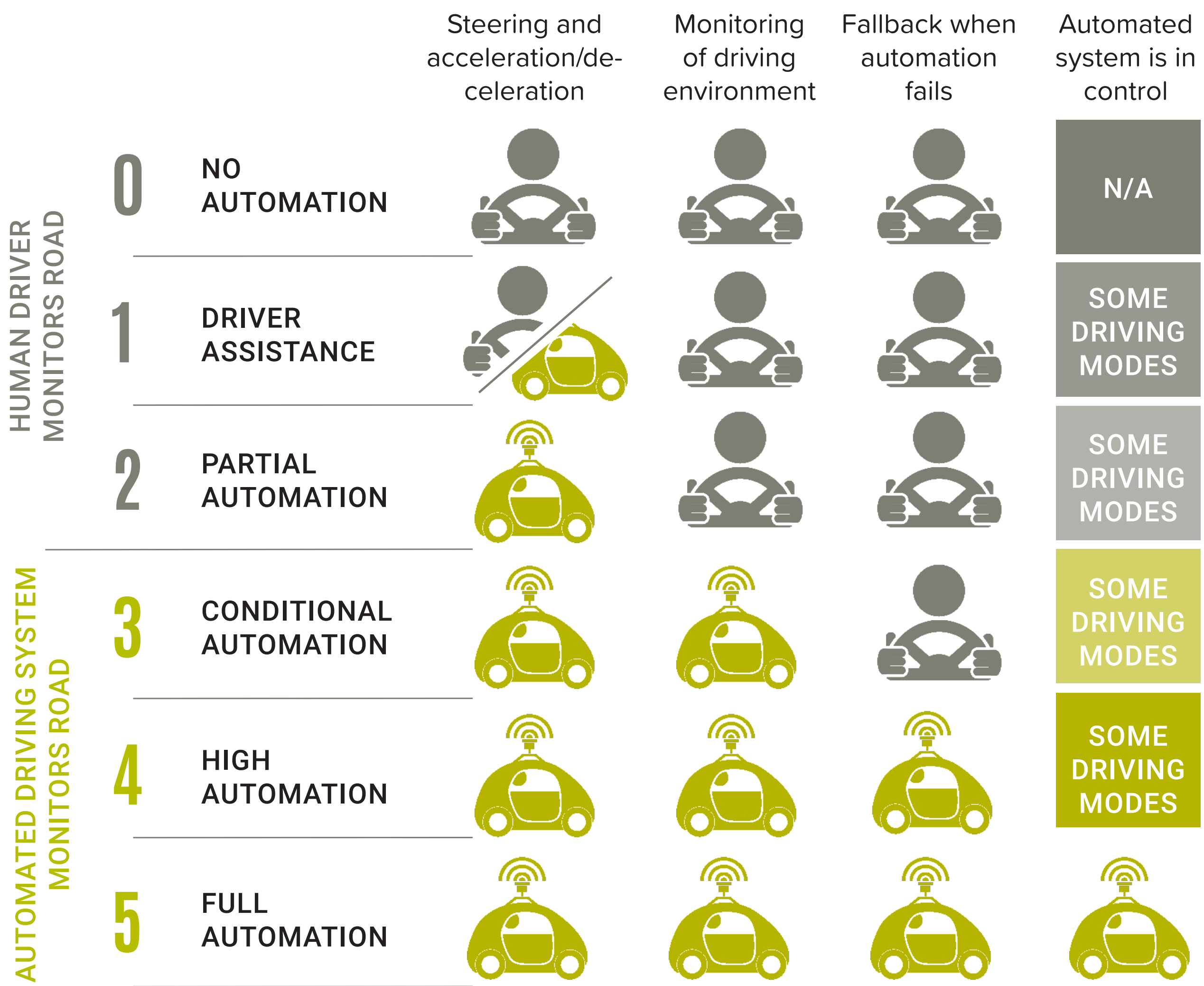
Based on this potential transformation of transportation, planning for the impact of AV proliferation is a prudent, if not imperative, pursuit for cities across the country. This paper seeks to provide a cursory overview of the six levels of vehicle autonomy, explore the timing and transition of the mode, and offer some preliminary planning considerations for cities that are designed to address both the needs of today and those of the anticipated near-future.

SAE International, a global association of engineers and technical experts, has developed a six level classification system, shown below, is widely regarded as the definitive taxonomy for autonomous vehicles.

Level 0, no automation, has of course existed since the days of the Ford Model T while the advent of cruise control brought about the first level of driver assistance.

Level 2 autonomy exists currently on the roadway through Tesla (Autopilot features), Mercedes (Drive Pilot features) and Volvo (Pilot Assist II). The transition from Level 2 to 3 is significant, as reflected in the SAE chart which demarks Level 3 as the initial stage of the automated driving system runs through Level 5/Full Automation.

The Five Levels of Driving Automation



03 TIMING AND TRANSITION

A general consensus seems to exist that AVs will be a transportation mode in the future, although there is significant debate as to the timing and transition of Level 3 and 4 (conditional and high) automation as well as the more theoretical Level 5, a fully automated system. Interestingly, the metrics of progress seem to vary by industry. Announcements from Technology firms seem to be more focused on new innovations in machinery and equipment while traditional automobile manufacturers speak in terms of production and product launches. Despite the diversity in message, both sectors, and their corresponding capital investments, demonstrate increased momentum for AVs. This section will identify recent news regarding capital investment, corporate announcements, the status of federal regulation and the potential application/transition of advanced vehicle automation.

Capital investment in AVs and related technologies is already significant. Goldman Sachs, in 2016, projected the market for advanced driver assistance systems and autonomous vehicles to grow from about $3 billion in 2015 to $96 billion in 2025 and $290 billion in 2035. (Taylor, 2017) In February, 2017, Ford Motor Company announced a $1 billion investment in Pittsburgh-based tech startup Argo AI with the stated goal of producing a self-driving vehicle for commercial ride sharing fleets by 2021. (Sage, 2017) On March 13, 2017 Intel, the world's largest computer chipmaker, acquired Mobileye and its expertise in cameras, sensor chips, in-car networking, roadway mapping and machine learning for $15.3 billion. (Cohen, Rabinovitch, & Lienert, 2017).

In 2016, Waymo, the car unit of Google parent company Alphabet, logged 635,000 miles in autonomous mode on California public streets; during this effort a human driver only had to take over controls (disengagement) on average every 5,127 miles. (Novet, 2017) On July 11, 2017 Audi announced the launch of its 2019 A8, and self-promoted the automobile company as the first to sell a Level 3 self-driving car; with sales expected to commence US sales in the spring of 2018. (Campbell, 2017) On July 28, 2017 Elon Musk unveiled the Tesla Model 3, capable of an upgrade to Level 4 automation, utilizing the equipment from the Enhanced Autopilot system, with a starting price of $35,000. Furthermore, Musk has predicted that this high automation technology upgrade will be available through Tesla in 2018. These announcements, and multiple others occurring daily, shine a light on the crux of the autonomous vehicle proliferation issue, which is that technology is advancing much faster than regulation.

While the United States currently lacks adequate federal regulation on the issue; it is now garnering both attention and bipartisan consensus, as evidenced by a July 19, 2017 subcommittee approval of a bill that would establish a federal framework for the regulation of autonomous vehicles. (Roose, 2017) Germany passed a law in June, 2017 that will allow drivers, in cars with Level 3 or 4 capabilities, to cede full or partial control of vehicle operations. (Hetzner, 2017) The confluence of significant AV capital investment, multiple corporations seeking to marketing conditional and high automation, and initial bipartisan support of the need for enabling legislation suggests that a significant number of Level 3 and 4 automation could exist throughout the country within the next 3 years.

As with timing, there is also debate as to the initial applications of the emerging Levels 4 and 5 of automation. The current model of individual automobile use/ownership yields relatively low utilization as cars are more often parked than driven. AVs naturally lend themselves to different use/ ownership models as the ability to share and maximize the use of the machine is more easily achieved. Uber began a pilot program of its driverless cars, which includes a human driver as backup, in September of 2016. Uber rival Lyft announced on July 21, 2017 that they would launch self-driving cars this year; their focus will be to design a common software interface that varying automakers can utilize their cars for ridesharing. (Fung, 2017) Ola Kaellenius, the head of Mercedes-Benz Cars Development, said he thinks self-driving taxis will be the first application due to the costs of sensors and computing power and he expects that between 2020 and 2025 the company will be providing taxi service itself or with a partner. (Woodard, 2017) Ford Motor Company announced in 2016 that they were targeting 2021 "to deliver high-volume, fully autonomous vehicle for ride sharing".

Capital investment in AV continues to experience significant increases; across the spectrum of the automotive industry as well as many companies in the Technology sector. Corporate competition within the emerging AV market is intense with competing announcements occurring on a daily basis. Politicians have started to take notice of these trends and both political parties have supported establishing a federal regulatory framework to provide for the use of AVs. Ridesharing, which has the potential, to increase access to AV more quickly and broadly, is also at the forefront of the AV discussions. While there are no guarantees of widespread AV use over the next 3-5 years, legal, insurance and ethical dilemmas are often cited as potential barriers, the pervasiveness of money and technological advances indicate that AV proliferation in the near future should be address in the local planning efforts.

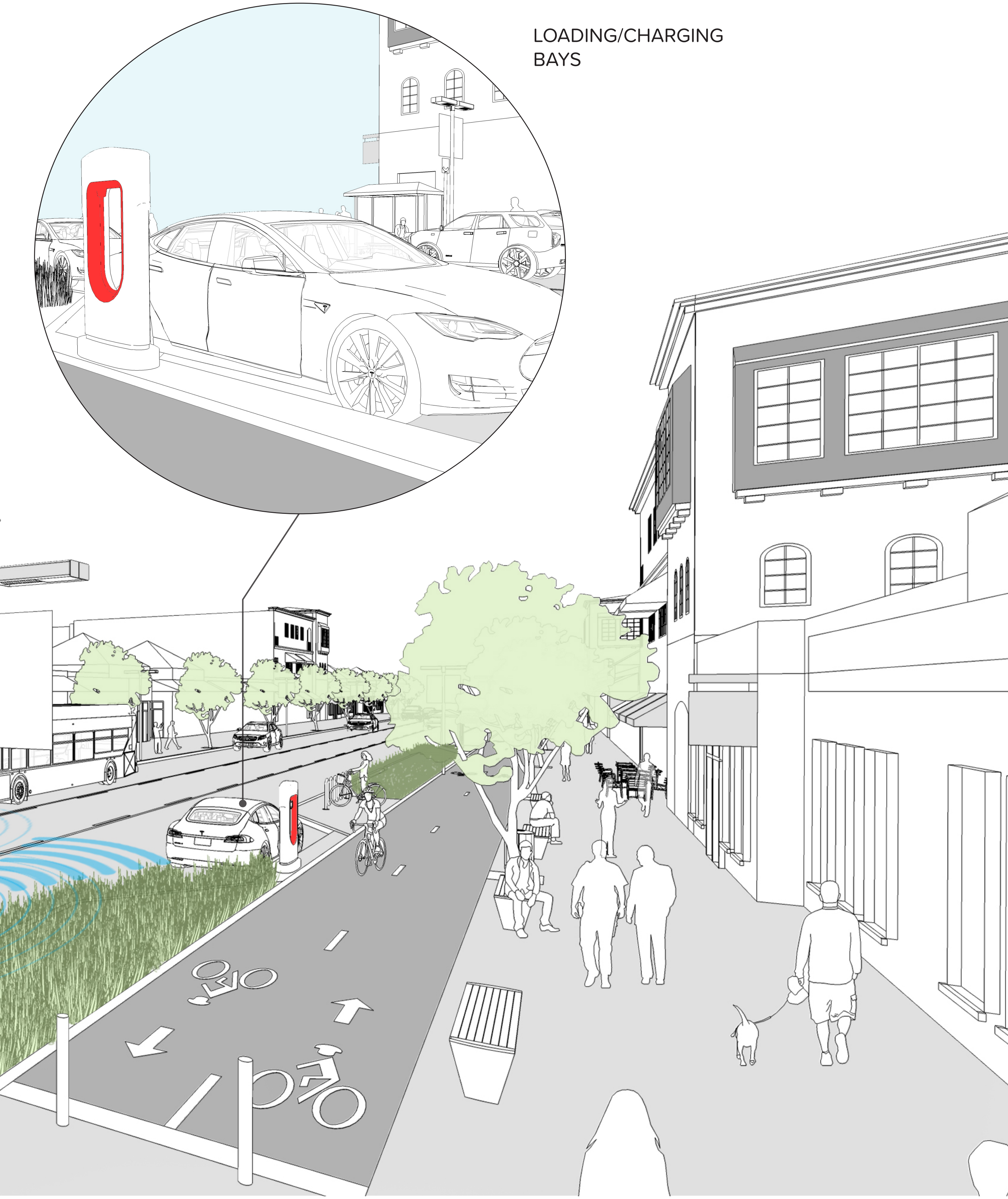
PLANNING CONSIDERATIONS

Much like the timing and application/ transition debates regarding AVs, there is not consensus on the future impacts or necessary planning considerations for this eminent change. Some have argued that the proliferation of AVs will lead to greater urban sprawl due to increased efficiencies in automobile traffic movement and reduced driver stress. However, if the initial applications are predominantly through ridesharing, the highest utilization looks to be in urban centers, where much of today's ridesharing occurs. Based on the premise that the initial impacts of AV will be seen in the proliferation of ridesharing; the focus of these planning considerations will be within the context of the urban core of cities. This focus is consistent with a 2017 report issued by INRIX, a global traffic analytics firm entitled: INRIX Highly Autonomous Vehicle City Evaluation. This report projects that highly autonomous vehicles will be utilized in shared-use fleets of electric and hybrid vehicles which would be most efficient as short-range urban trips to maximize occupancy remain closer to charging infrastructure. (Ash, Pishue, & Weiser, 2017)

The expansion of electric and hybrid automated vehicles, will increase demand for recharging station locations in and around the periphery of cities' urban cores, where many of the initial AV trips are anticipated. There are approximately 44,000 active charging stations throughout the United States, meeting the current demand of electric vehicles that represent approximately 1% of cars sold and 0.2% of the total automobiles in the United States. (Mims, 2017) ChargePoint, Inc., operates the largest Electric Vehicle (EV) charging network in the world and views the future of charging stations to be the driving component of a larger interconnected communication system. "Smart charging" for EVs is a comprehensive system that connects and communicates with vehicles, drivers, residents, parking/charging operators, electric utilities and municipal systems, data management platforms, payment platforms and enforcement systems and even other Internet of Things (IoT) sensors which ChargePoint asserts is critical to future urban mobility. (ChargePoint, Inc., 2017) Investment in smart charging is not unique to a single company. Ubitricity is a German firm seeking to reduced cost, low-power plugs that are part of freestanding city lampposts; the power sources can be accessed through an internet-connected "smart" power cable that also computes metering and billing. (Mims, 2017) As part of a proactive planning process, that helps position cities, and their urban districts to meet the demands of AVs, strategic charging locations should be identified. Furthermore, local governments should work with station vendors and utility providers in order to maximize the efficiency and effectiveness of potential site designs.

As AV ridesharing becomes more prevalent so does the need for safe and accessible, perhaps designated, pickup and drop-off locations. San Francisco is currently experiencing significant conflicts with Uber and Lyft drivers illegally utilizing bicycle lanes, for convenience, in certain areas of the City provoking safety concerns and outrage by cyclists. (Rodriguez, 2017) Valencia Street was designated as a primary bicycle corridor by the City in 1999. According to the San Francisco County Transportation Authority, the City experiences 6,000 ride-hails during daily peak periods in some San Francisco's most traffic congested neighborhoods; Valencia Street sees 2,190 daily pickups and drop-offs by ride-hails among the highest used ride-hail corridors in San Francisco. (Rodriguez, 2017) Existing on-street parking spaces could be easily restriped and converted to pick-up and drop-off zones. In areas where on-street parking does not existing, side street locations should be examined for improvements that would facilitate improved access for rideshare vehicles and patrons.

The initial impact on AVs/increased ridesharing services, with reduced prices and increased accessibility and availability, could be seen in a reduced number of personal cars per household. AAA estimates the average annual cost of car ownership to be approximately $8,558 (based on 15,000 miles driven in an average size sedan; includes estimates for Fuel, Maintenance Tires, Insurance License, Registration and Taxes, Finance Costs) (AAA, 2016) An annual average trip price of $7 would provide a consumer with more than 1,200 trips a year for the same price of owning or leasing a personal automobile. Reduced personal car ownership use, which may start as a return to one-car households, should also increase the use of alternate modes of transportation including transit, bicycles and walking. For example, on a crisp fall afternoon, a regular ride-share commuter might utilize bike-share to ride home via a path of protected bicycle lanes. Improved facilities, including wider sidewalks and protected bicycle lanes in urban areas of high activity, will help facilitate regular or semi-regular use of alternative modes.


LOADING/CHARGING
BAYS

05 CONCLUSION

As the technology, investment and requisite regulatory frameworks allowing for the widespread utilization of autonomous vehicles continues to advance, rapidly if not exponentially, planning for their impacts and the future of urban mobility is a prudent if not imperative endeavor. This paper was intended to, through the brief examination of the six levels of vehicle autonomy, potential timing and transition of AVs, and preliminary planning considerations, help increase awareness of these potential transformation changes to our transportation and mobility systems and provide some initial direction that will help guide the focus of future urban mobility planning efforts.

No City in the United States is currently prepared for the rapid proliferation of autonomous vehicles. While the exact timing and application/transition is not in plain view, existing trends and information do provide guidance for a planning framework. A thoughtful and comprehensive planning effort focused on the identification of needed infrastructure improvements, code revisions and policy initiatives will improve urban mobility, enhance quality of life and advance economic development through accelerated redevelopment.

The following is offered as an initial checklist of planning efforts components that may be included in a comprehensive AV-readiness assessment for Cities.

- A GIS-based analysis to include
    - Identification of residents who live and work within both 5 and 10-mile radii.
    - Identification of current trip origin and destination patterns
    - Mapping of existing and proposed EV charging stations
    - Mapping of existing and proposed drop-off locations
- Review of land development codes to assess existing minimum parking requirements and consider incorporation of new site development requirements that would provide for pick-up/drop-off locations and electric vehicle charging stations.
- Identification and prioritization of bicycle, pedestrian and transit improvements that would connect with AVs and help improve the system and overall urban mobility
- Identification of street network connectivity improvements and evaluation of one-way streets
- Identification of problematic corridors due to excessive curb cuts; evaluate incentive-based access management plans to incorporate pick-up/drop off infrastructure in exchange for the reduction of curb cuts

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