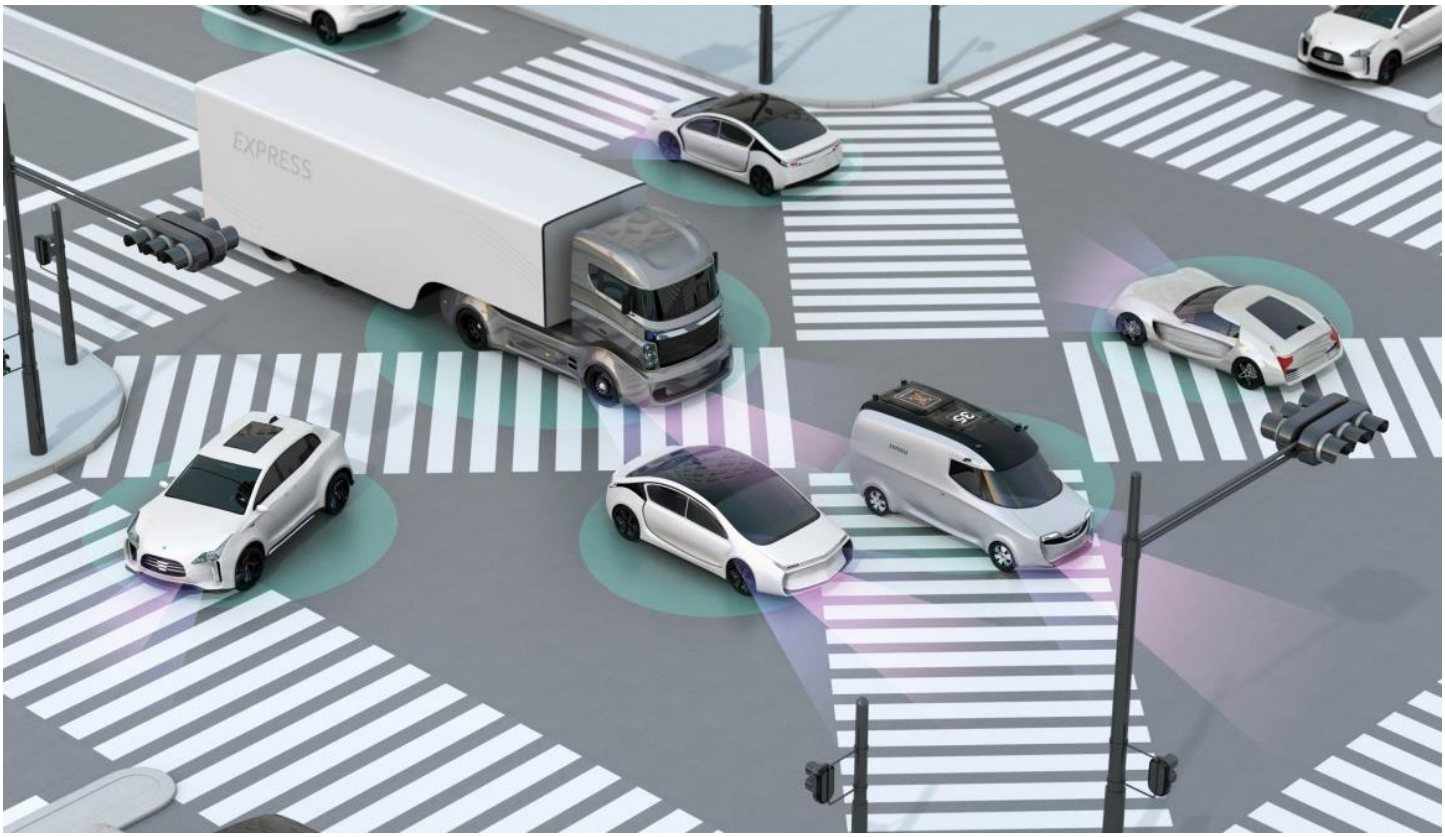

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ECONOMIC IMPACTS OF ADVANCING ARIZONA'S COMPETITIVE POSITION IN THE AUTONOMOUS VEHICLE INDUSTRY

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Executive Summary

Automated, also widely referenced as autonomous, vehicles (AV) are the future of transportation. The global AV market is currently estimated to be worth $54B and could grow to $557B by 2026[1]. In the U.S. alone, automotive and tech companies will have invested and allocated $61B in self-driving vehicle research and development through 2023[2].

AV technology is divided into six levels by the autonomy of the vehicle[3]. The technology in levels 0-2 is defined as Advanced Driver Assistance Systems (ADAS), or driver support systems. These systems alert the driver of unsafe conditions but do not intervene, and the operator remains in full control of the vehicle. The technology on vehicles in levels 3-5 are defined as Automated Driving Systems (ADS). These systems both warn the drivers of changing events and also intervene to avoid collisions or maneuver through traffic more efficiently. The driver is engaged intermittently, and when requested by the ADS, takes control of the vehicle.

The development of highly automated vehicles (HAV), those with ADS (level 3 or above), will significantly enhance the safety, efficiency and accessibility of transportation and provide additional economic opportunities. Arizona is in a position to benefit substantially from the transformative societal and economic impacts that the AV industry will provide.

The economic and fiscal impacts of these business activities are significant and will continue to grow as the state focuses on further advancing the AV industry. Because Arizona is already a leader in AV innovation, the state will be able to capture a disproportionate percentage of the long-term economic benefits. This will equate to higher wage job creation including the manufacturing of high-tech parts and the related research and development that accompany these efforts.

Summary of Economic and Fiscal Benefits

The AV industry is still in early development, but increased activity is expected to occur during the next decade. Since the industry is relatively new, reported estimates of economic activity have varied. For this reason, the following analysis utilizes multiple methods to calculate the extent Arizona can participate in this industry's promising economic activities. The review is also supported by the interviews of dozens of individuals representing the AV industry and local economic development groups. Scores of supporting reports and other materials were also carefully reviewed.

The first method of analysis utilized a respected estimate of overall U.S. AV activity including economic projections for the 2020s. By 2026, $6.1B[4] in estimated statewide R&D would create 39,000 direct jobs throughout the state and generate $4.3B in economic output. The spinoff (indirect and induced) effects would produce an additional 35,000 jobs and $4.9B in economic output. State and local governments would collect more than $350M in tax revenues from a conservative assumed capture rate of the national market arriving in Arizona.

[1] According to Allied Market Research
[2] According to AlixPartners
[3] Defined by the Society of Automotive Engineers and adopted by the U.S. Department of Transportation
[4] Estimated based on the AlixPartners national R&D of $61B

A second analysis included a review of opportunities within the semiconductor industry, which plays an important role in developing new AV technology. The total fiscal impact of this portion alone within the AV industry, estimated to be about one-third of total AV economic activity, leads to over $100M in tax revenues for both state and local government entities. Adjusted for full production, the impact increases to $300M. This validates the scale of activity produced in the initial analysis.

Still, a third analysis of the broader research and manufacturing process identified that a conservative capture rate by the state of less than 1% of global industry activities would yield a state and local fiscal impact of approximately $250M by 2026.

Overall, with supportive public policy, Arizona could increase its state and local tax collections by approximately $250M to $350M by 2026. This range is expected to increase to $400M to $500M by 2030. Despite these impressive numbers, the analytical approach used in this review can be considered conservative.

Additional Benefits of AV

The development of the AV industry will also lead to additional societal benefits. The U.S. has averaged nearly 40,000 fatalities from car accidents a year since 1994[5]. Nationwide in 2018, there were 6.7M car accidents resulting in 36,560 deaths. Approximately 94% of those accidents were the result of human error. It is estimated that HAVs with Level 4 automation react 10 times faster than a human being and that by 2030, vehicles with Level 4 ADS will prevent over 630,000 accidents[6]. In the U.S. commuters spent, on average, 97 hours in traffic in 2018, costing each commuter $1,348 in lost time and fuel[7]. HAVs will help alleviate traffic congestion, recouping a significant portion of that cost.

The favorable regulatory environment and business culture that emphasizes innovation have made Arizona an ideal location for AV companies to research, design, test, and later manufacture HAVs. The economic impacts of AV activity are already beginning to ripple through the Arizona economy. Arizona is the home to numerous companies representing various sectors of the AV industry ecosystem. Original Equipment Manufacturers (OEM), HAV fleet deployment firms, software developers, and hardware manufacturing firms all have a presence in Arizona.

AV Development in Arizona

The AV industry will develop rapidly during the next 10 years. Arizona is well positioned to participate in multiple categories of product development, many of which pay high wages. The fiscal impacts could accumulate to nearly $500M by 2030 or within a couple of years thereafter.

The decision to pursue the AV industry was a conscious policy choice and the economy is already realizing dividends. The benefits of hosting the industry will accelerate over time. Most importantly, Arizona has gained an important 'first-mover' advantage that will allow for the disproportionate attraction of high wage jobs during the next decade…and well after.

[5] According to the National Highway Traffic Safety Administration
[6] According to PTOLEMUS Consulting Group
[7] According to the INRIX Global Traffic Scorecard

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Introduction

Overview of Autonomous Vehicles

The self-driving or autonomous/automated vehicle (AV), once thought limited to science fiction, is now at the forefront of discussions surrounding the future of transportation. AVs are engineered with systems designed to make transportation safer, more efficient and more accessible.

The Society of Automotive Engineers (SAE) has defined six levels of vehicle autonomy. These definitions have been adopted by the U.S. Department of Transportation (USDOT) and have become the standard in defining automotive vehicle technology. The six levels of vehicle autonomy are generally separated into two groups – Advanced Driver Assistance Systems (ADAS) and Automated Driving Systems (ADS).

ADAS, or driver support features, are features that alert the driver to unsafe conditions but cannot intervene on the driver's behalf. For example, a blind spot monitor or proximity sensors alert the driver of objects that are nearing the vehicle, but the car will not engage brakes or steer to avoid those objects. ADS combine ADAS with systems that fully automate the major vehicle functions.

For example, a collision avoidance system will alert the driver of approaching objects and, if necessary, will apply the brakes or engage the steering to avoid hitting the object. The sophistication of ADS varies and ranges from requiring periodic driver engagement to not requiring a driver to be present at all. The following table depicts the various levels of automation in detail.

Levels of Driving Automation					
Advanced Driver Assistance Systems (ADAS)			**Automated Driving Systems (ADS)**		
Level 0	**Level 1**	**Level 2**	**Level 3**	**Level 4**	**Level 5**
No Automation	Driver Assistance	Partial Automation	Conditional Automation	High Automation	Full Automation
Driver maintains constant supervision of the environment. ADAS features are designed to alert driver as needed to maintain safety.			Vehicle monitors the environment and drives under specific conditions. Driver controls the vehicle after notice.		Vehicle monitors the environment and drives under all conditions
-Anti-lock brakes	-Blind spot warning **OR** -Adaptive cruise control	-Lane departure warning **AND** -Adaptive cruise control simultaneously	-Driver engagement required when driving conditions are not met	- Vehicle safely leaves the road autonomously if conditions are not met	-Driver never required -Steering wheel and pedals may not be installed

Source: Society of Automotive Engineers (SAE)

The large-scale adoption of highly automated vehicles (HAV), vehicles equipped with automated driving systems, onto public roads is expected to significantly disrupt the transportation and automotive industries. HAVs make transportation safer by reacting to changing events 10 times faster than human beings.

The increased reaction time is estimated to prevent 630,000 car accidents in the U.S. by 2030. HAVs are able to deliver groceries and packages without human assistance, reducing costs, and saving time and

expanding access to vulnerable populations. HAVs eliminate traffic bottlenecks by commuting more efficiently, recuperating time and fuel. Through V2X communication (the seamless integration between the vehicles with the surrounding environment), HAVs enhance multimodal transportation in cities and towns, reducing carbon emissions and traffic congestion. Large-scale adoption of HAVs impacts nearly every aspect of daily life. In anticipation of these impacts, Arizona has established an environment where the AV industry can operate and the development of HAVs can advance.

Industry experts predict the AV industry will continue to develop and be the focus of billions of dollars' worth of R&D. Continued investment in the AV industry will generate significant economic and fiscal returns. Additional opportunities to increase education, enhance workforce development programs, and create a high-skilled and high-wage workforce come as a byproduct of advancing the AV industry, making the Arizona economy more robust and resilient.

The Current State of the AV Industry

The results from the limited number of markets where HAVs are being tested show significant progress, and industry experts are encouraged for the future of the global AV market. Allied Market Research has estimated the market to be worth $54B in 2019 and is anticipated to grow to $557B by 2026. In the U.S. alone, AlixPartners found that $61B has been earmarked, or allocated, for self-driving vehicle capital investments and R&D through 2023 by auto manufacturers and technology companies.

Automakers, in response to early vehicle testing successes, have made significant efforts to collaborate with companies in the various sectors of the AV industry ecosystem. AlixPartners reports that over the last two years, nearly 55% of all mergers and acquisitions in the automotive industry were related to advancing AV technology. The efforts from automakers to advance the AV technology provide evidence that the industry outlook is optimistic.

Partnerships between HAV deployment firms and municipal and state governments to permit HAVs to be tested on public roads are growing. The amount of legislation related to the operation of HAVs proposed by state legislatures has also increased. The National League of Cities (NCL) reports that 46 bills related to the AV industry were proposed from 2011 to 2017 and 98 bills have been proposed in 2018 alone.

These public-private partnerships are a crucial component in advancing the industry. HAVs are currently being tested on public roads in as many as 24 cities around the country. Testing HAVs in real-world environments such as, differing road conditions, various infrastructure, and varying levels of traffic congestion is critical to improving the safety, consistency and reliability of AV technology and accelerates the advancement of the overall industry.

The faster the AV industry advances, the faster the benefits and economic impacts are realized. The Governors Highway Safety Association (GHSA) estimates that high-level ADS technology will not become standard on new vehicles until the year 2050 or later. Estimations of the effectiveness of HAVs to prevent collisions and data reported by the National Highway Traffic Safety Administration (NHTSA), show that in the U.S., approximately 5.6M accidents and 32,200 fatalities per year could be prevented if ADS technology were required to be equipped on every vehicle operating on public roads[8].

[8] Preventable accidents and fatalities were calculated using the ratio of fatalities per accident caused by human error from 2018 and applying the rate at which HAVs are estimated to be able to prevent those accidents

The future of the AV industry includes addressing various concerns surrounding large scale adaption of HAVs. In addressing concerns of HAV safety on public roads, regulators and industry leaders are establishing a framework to determine the reliability of ADS equipment to function properly before engaging in public road operations.

Arizona is proactively working to resolve these concerns without hindering innovation or stifling the advancement of the industry by fostering collaborative partnerships with private companies, public officials and academic researchers. Through its efforts, Arizona is positioned to become a national leader in the AV industry.

The AV Industry in Arizona

Overview of AV Activity in Arizona

In 2015, the Governor of Arizona signed an executive order establishing Arizona's support for the development, operation and testing of HAVs on the State's public roads. The order stated, in part,

> *"…the development of self-driving vehicles will promote economic growth, bring new jobs, provide research opportunities for the State's academic institutions…and allow the State to host the emergence of new technologies…the testing and operation of self-driving vehicles could produce transformative social benefits such as the elimination of traffic congestion, a dramatic increase in pedestrian and passenger safety,…and could beneficially contribute to other activities related to the State's transportation [industry]."*

The executive order established Arizona as a favorable regulatory and operational environment for companies involved in HAV development by ordering,

> *"…the Department of Transportation, Department of Public Safety, and all other agencies of the State of Arizona with pertinent regulatory jurisdiction [to] undertake any necessary steps to support the testing and operation of self-driving vehicles on public roads in Arizona."*

Since then, Intel acquired the software developer Mobileye, and established the Automated Driving Division in Arizona. Google's parent company, Alphabet, launched a self-driving program, Waymo in Chandler. TuSimple began building semi-trucks with ADS technology in Tucson. Nikola Motors is developing a manufacturing plant to engineer medium- and heavy-duty commercial trucks with ADS technology in Coolidge. Local Motors opened a manufacturing facility in Chandler to manufacture HAVs for the micromobility sector, as first-mile, last-mile shuttles.

Lucid Motors, an electric car maker whose vehicles support ADS, made plans with Casa Grande to construct a manufacturing facility. Imagry established a U.S. headquarters in Tempe. Udelv and Nuro partnered with Wal-Mart and Fry's to begin delivering groceries using HAVs in Scottsdale and Surprise. These companies, in turn, have partnered with various software and hardware component suppliers.

In response to the growth of the AV industry presence in Arizona, the Institute for Automated Mobility (IAM) was created in 2018 through an initial partnership with Intel, Arizona State university, and the Arizona Commerce Authority, and now includes State Farm. IAM is a consortium of private sector companies, public officials, and university research faculty that collaborate on furthering the AV industry in Arizona. The chart below shows the original equipment manufacturers (OEM), HAV deployment firms, and component suppliers that have operations in Arizona.

Sample of Arizona's Automated or High-Tech Vehicle Industry		
HAV Deployment Firms	**Original Equipment Manufacturer (OEM)**	**Software/Hardware Suppliers**
Waymo	Local Motors	Google
Lyft	Nikola Motors	Nvidia
Nuro	TuSimple	NXP
TuSimple	Lucid Motors	Mobileye (Intel)
Nikola Motors		Bosch
Embark		IBM
Udelv		Imagry

Source: Arizona Commerce Authority, Institute for Automated Mobility

There are several OEM firms with ongoing or planned manufacturing operations in Arizona including, Local Motors, Nikola Motors, TuSimple, and Lucid Motors. These companies are focused on manufacturing HAVs already equipped with ADS technology. HAV deployment firms, such as Waymo, Nuro, and Udelv have partnered with cities and towns to deploy HAVs on Arizona public roads for testing.

TuSimple and Nikola Motors, while manufacturing vehicles in Arizona, are also deploying them for testing on Arizona roads. There are various software and hardware suppliers with connections to the AV industry in Arizona. Mobileye, an Intel company, Imagry, and NXP have manufacturing facilities in Arizona that supply the AV industry. Google, Nvidia, Bosch and IBM all have partnerships with either OEMs or HAV deployment firms operating in Arizona.

Waymo has established Arizona as the headquarters for its operations and testing division and has been developing and testing HAVs in the valley since arriving in Chandler in 2016. Waymo now has over 600 vehicles in its fleet and is constructing an 85,000 square foot operations facility in Mesa. This facility doubles the size of the company's presence in Arizona and will serve as a second headquarters of the Waymo operations and rideshare divisions.

Waymo has also partnered with Fiat Chrysler Automobiles (FCA) to add 62,000 minivans, and with Jaguar Land Rover Automotive to add 20,000 SUVs to its fleet of HAVs. Many of these vehicles will be housed in the new facility in Mesa while being tested on public roads. The facility will also employ hundreds of support staff and technicians.

Waymo partnered with the rideshare company, Lyft, to test Level 4 HAVs in the rideshare sector. In 2019, Waymo launched driverless Level 4 HAVs as taxis and rideshare vehicles. Through the partnership with Lyft, these vehicles are now available to consumers in select areas of the metro Phoenix area. Waymo is the first company to offer this service and having successful results of this implementation will prove to be a significant advancement for the AV industry.

Local Motors and Nuro are focused on using HAVs to service the micromobility sector, shuttling people and goods short distances at low speeds. Local Motors owns and operates a manufacturing facility in Chandler. They are manufacturing Levels 4 and 5 HAVs to serve as shuttles for those traveling in dense urban areas, neighborhoods, and campuses.

Nuro, a firm that is developing Level 4 and 5 robotic delivery HAVs, has partnered with the grocery chain Fry's and is testing the HAVs' ability to deliver groceries in Scottsdale. Each company is successfully testing Level 4 HAVs and reporting positive results. Udelv also manufactures robotic delivery vehicles with Levels 4 and 5 ADS. Partnering with Wal-Mart, Udelv has begun a new pilot program to test these HAVs for grocery delivery in Surprise. Previous testing programs were successfully conducted in San Francisco and Oklahoma City.

HAVs are also being configured to enter the trucking industry. Nikola Motors has built a 200,000 square foot headquarters in Phoenix and has plans to construct a 1M square foot manufacturing facility in Coolidge. The plant will be the primary facility building the company's fleet of hydrogen-electric semi-trucks equipped with Levels 4 and 5 ADS.

At capacity, this facility will employ 2,000 people, and the activity of the facility is estimated to support an additional 20,000 jobs in the supply chain and other sectors. Nikola recently added 20 highly educated employees to their firm, 15 with Ph.Ds. and 5 with master's degrees. These employees will lead an effort to develop new battery technology that has the potential to make Nikola Motors the largest manufacturer of HAVs with a Gross Vehicle Weight Rating of 19,500 to over 33,000 pounds.

TuSimple, a second electric semi-truck manufacturer, also equips semi-trucks with Levels 4 and 5 ADS technology. The company has expanded from a 6,800 square foot warehouse to a 50,000 square foot manufacturing facility in Tucson as part of an expansion effort to increase the size of its fleet of HAVs operating in the U.S. from 50 to 200 trucks. The company estimates that the expansion will create 500 new jobs in Tucson and provide a total economic impact for the region of $1.1B through 2023.

Lucid Motors is an electric vehicle OEM that manufactures passenger vehicles equipped with ADS technology. Lucid Motors has begun constructing a manufacturing facility in Casa Grande. Upon completion, the facility will employ 2,000 people and produce 130,000 vehicles per year when operating at full capacity.

Intel has an established presence in Arizona and employs over 10,000 people. After acquiring Mobileye, a developer of Levels 4 and 5 ADS technology, Intel established the Automated Driving Division in Arizona. In 2017, Mobileye introduced the Responsibility, Sensibility, and Safety (RSS) Model. Intel is committed to providing solutions to the concerns facing the industry in addition to manufacturing technology that drives the vehicles.

Imagry, an Israeli software company, opened a U.S. headquarters in Tempe in early 2019. Imagry focuses on providing environment rendering solutions for HAVs without the need for HD mapping. Using advanced artificial intelligence, Imagry is developing a driving platform for HAVs that uses LIDAR (which stands for Light Detection and Ranging) sensors and machine learning to construct a digital rendering of its environment without relying on detailed maps.

The car is able to make real-time decisions based on current conditions instead of relying on a digital map to tell the HAV what the environment should look like. By eliminating the need for a strong and constant link to a GPS satellite, which is costly and requires constant updates, this technology allows the AV industry to scale efficiently and commercialize faster.

NXP Semiconductors operates a manufacturing facility in Chandler, making electrical components and capacitors for the hardware components in HAVs. The facility employs approximately 2,000 people, and nearly 50% of NXP's product sales are to the automotive industry.

The favorable regulatory environment, a business culture that supports innovation, and geographic location of Arizona will facilitate the expansion of operations of the AV industry in the state and create additional opportunities to add layers of resiliency to the state's economy.

Strengths of Arizona in AV Industry

Arizona is one of only 11 states that have issued executive orders authorizing full deployment and testing of driver occupied and driverless HAVs. Arizona has supported the activities of companies involved in the AV industry by creating a regulatory environment that maximizes both innovation and safety. The Institute for Automated Mobility (IAM) is also committed to implementing regulation that maintains the business culture and invites additional emerging industries to locate to Arizona while ensuring safety on public roads.

Arizona's moderate climate, and proximity to trade borders also make Arizona an ideal location for advancing the AV industry, particularly pertaining to freight transportation. HAVs will facilitate future trade, and with an established HAV foundation, an increased amount of commerce will flow through Arizona. Opportunities to expand trade partnerships with Mexico and others will further strengthen the Arizona economy. The reliable climate in Arizona creates stable and consistent road conditions, producing a physically predictable and stable environment in which HAV technology can develop.

The state's business culture is one that emphasizes innovation. Following the Governor's initiative to support the development of the AV industry, numerous cities began initiating partnerships with HAV deployment firms to facilitate testing and development, including Chandler and Phoenix. Additional cities and towns that recognize the potential impacts of HAVs have taken the initiative to start investing in large-scale HAV transportation. Scottsdale, Tucson, and Florence have begun researching and implementing "smart" infrastructure capable of V2X communication. V2X (vehicle-to-everything) communication is the seamless integration between the vehicles with the surrounding environment and is a crucial component in eliminating traffic congestion and enhancing inter-city multimodal transportation.

Chandler, where several AV firms are operating, has embraced the presence of firms researching and testing AV technology. The city has developed partnerships with the leaders of those companies to foster relationships and encourage transparency. Chandler has also taken the initiative in allowing for flexibly zoned developments that can be converted from one designation to another quickly as market demand changes. For example, a parking structure can be quickly zoned for the development of retail or residential units as demand for parking declines.

Phoenix has partnered with Waymo and Lyft to facilitate first-mile and last-mile mobility solutions. Waymo has recently deployed driverless Level 4 HAVs for testing within specific districts in Phoenix. The Phoenix metro area public transit agency, Valley Metro, has also initiated various programs aimed at increasing pedestrian safety and in providing access to mobility solutions. Valley Metro began implementing new technologies in crosswalks that more accurately detect pedestrians, especially those with disabilities. The Ridekick app was launched by Valley Metro with the goal of providing interactive trip planning. It provides users with all the information necessary to arrive at the destination, including bus routes, light rail schedules, and station locations.

Scottsdale has identified several major areas in which smart city initiatives should be focused. Plans to develop ultra-smart corridors in two of the most congested areas of the city are being finalized. Enhance paratransit and multimodal transit for the elderly and disadvantaged has become a priority. Initiatives to install smart traffic signals to favor transit and ride-share vans will help alleviate congestion and encourage carpooling.

In addition to these plans, the city has taken measures to improve multimodal transit using smart infrastructure. The city installed bike sensors at intersections to better detect the presence of a cyclist. These sensors enhance bicyclist safety and encourage bicycle use further reducing vehicle congestion. The city uses computer vision software and artificial intelligence to map potential collision points of vehicles and pedestrians. These maps help construct future infrastructure that maximizes safety.

Tucson has proposed several solutions to addressing traffic challenges. The city has begun installing smart infrastructure to connect buses, bus stops and emergency vehicles through V2X communication to enhance traffic flow. Developing smart corridors improves the flow of freight traffic and monitors road conditions throughout the region to make repairs and improvements more efficient and cost effective.

Florence has contracted with Milandr, Inc. of Denver, Colorado, to build and operate a commercial Smart City Network. Projects include developing advanced water metering infrastructure with auto-read technology. The communications network is also able to support emergency services and the town's departmental applications.

Cascade Investment LLC has invested $80 million to develop a smart city from the ground up in Arizona. Located outside of Phoenix and with a planned 80,000 residential units, the city will be of similar size and population to Tempe. The city will be the most connected in the nation, equipped with connected infrastructure, high-speed digital networks, data centers, HAVs, and improved manufacturing and distributing technologies.

The strengths of Arizona that attract the AV industry and other emerging technologies are the state's regulatory environment and business culture, each encourages and supports innovation. Municipalities have also planned future projects with these strengths in mind and support the state's policies. Arizona is in a position to benefit from the future impacts of the AV industry and the additional opportunities that are created as the industry advances.

The decision to pursue the AV industry was a conscious policy choice by the Governor's Office, and in the four years since the first Executive Order the state is already well positioned to be a global industry leader. The benefits of having this industry will only accelerate over time, much to the state's economic benefit.

Benefits of the AV Industry

Investments in the AV industry will yield significant economic returns, and the impacts of current HAV operations continue to ripple through the local economies. Advancing the AV industry in Arizona provides numerous opportunities for enhancing the safety of Arizona public roads, lowering insurance premiums and reducing injury liability, improving infrastructure and reducing traffic congestion, and advancing education and workforce development.

Safety

ADS technology on HAVs, at full deployment, is anticipated to make the passenger transportation industry significantly safer. According to the National Highway Traffic Safety Administration (NHTSA), there were a reported 6.7M car accidents and 36,560 car accident fatalities in the U.S. in 2018. The U.S. averages nearly 40,000 deaths a year from car accidents since 1994. Approximately 94% of accidents are the result of human error. PTOLEMUS Consulting Group (PCG) estimates that HAVs react 10 times faster than a human being. This reduces the number of fatal accidents caused by human error by up to 88%. Altogether, AVs are estimated to prevent over 630,000 accidents in the U.S. by 2030. After 2030, PCG estimates, vehicles with Level 4 ADS will represent 8% of new vehicle sales every year. The increase in Level 4 ADS will prevent over 750,000 accidents each year in the U.S.

Locally, the Arizona Department of Transportation (ADOT) reports there were 127,056 car accidents and 1,010 fatalities resulting from car accidents in 2018. HAVs, fully deployed in Arizona with ADS technology required on each vehicle operating on the road would prevent an estimated 105,000 accidents and nearly 889 fatalities each year.

Lower Insurance Costs

Although many vehicles with ADS are currently on the road, the insurance industry has not taken into account the increased safety ADS provide. In areas where ADS technology is required as standard, PCG estimates that insurance premiums will fall 40% due to the decreased risk offered by high-level ADS. The burden of liability may also shift. The emergence of ride-sharing companies and the willingness of OEMs and HAV deployment firms to engage in this market is likely to shift the ownership model for passenger vehicles. The companies, who are the owners of the car and “rent” it to passengers, are ultimately liable for the cost of any accidents, lowering the cost of liability insurance for consumers.

Infrastructure Improvements

An HAV is not required to remain stationary while the owner is occupied. Through ridesharing, HAVs can be constantly in use. Through V2X communication, HAVs are able to constantly monitor infrastructure conditions and will be able to report damage or needed repairs more efficiently. V2X communication also coordinates traffic patterns and makes commuting more efficient, saving both time and fuel. According to the INRIX Global Traffic Scorecard, the average commuter in the U.S. spent 97 hours in 2018 in traffic. At an estimated cost of $1,348 per driver, traffic congestion cost a total of $87B in wasted time and fuel. The freight industry lost another $74B in 2018 to traffic congestion. HAVs reduce commute times and traffic congestion and will recoup a significant portion of the costs.

Education and Workforce Development

A substantial portion of future R&D investment in the AV industry is anticipated to be for software development and engineering advancements. Improvements in software development include enhancements to artificial intelligence (AI), digital mapping, cybersecurity, and V2X communication. Advancements in engineering are related to the hardware and components used on HAVs. Continued investment to the software and hardware components is crucial to ensure that HAVs are safe, cost-effective, and viable for large-scale adoption. Focusing on advancing the engineering, software, and hardware development activities in the AV industry increases the magnitude of the economic impacts realized in Arizona and creates lasting economic resiliency by establishing a high-skilled and high-wage workforce.

The American Society of Mechanical Engineers (ASME) estimates there is a national shortage of approximately 5,000 engineers in the AV industry. Partnerships with Arizona universities and the AV firms in Arizona to increase the demand for software developers, as well as mechanical and software engineers graduating from Arizona universities ensures that a high percentage of those graduates are employed in the state, retaining the economic benefits those jobs produce.

HAVs process vast amounts of data. Intel estimates that an HAV processes over 4 terabytes of data every 90 minutes. Lack of uniform protocols surrounding data usage and storage raise concerns that HAVs may be vulnerable to cyberattacks, particularly ransomware. Advancing education related to cyber-security is something that can be done apart from the university level and is an additional opportunity for establishing a high-skilled and high-wage workforce. For example, Chandler Gilbert Community College has initiated a program that trains students to become proficient in the cyber-security industry and prepares them for entry into the AV industry from as early as the 9th grade.

The emergence of HAVs being used in the logistics and trucking industries has also created additional workforce opportunities. TuSimple's business model, for example, does not eliminate the need for a physical driver. The majority of their semi-trucks being developed will have a Level 4 ADS equipment but will need an operator. At full deployment, this single operator, through V2X communication, will be able to operate not only their vehicle but also up to 5 additional fully automated vehicles remotely. However, there is a disconnect between traditional truck drivers and the drivers TuSimple is exploring.

The expertise and qualifications needed for obtaining a standard commercial driver's license (CDL) are insufficient to qualify a person to safely operate and monitor multiple HAVs simultaneously. In order to bridge the gap in qualifications, Pima Community College has launched a certificate program that augments CDL holders' skills and qualifications to include operating trucks equipped with Levels 4 and 5 automated driving systems. The increased skills CDL holders have as a result of the certification further advances the high-skilled and high-wage workforce in Arizona.

The sophisticated ADS technology equipped on HAVs also presents opportunities in the automotive technician industry. Trade school certification programs focused on educating current or aspiring automotive mechanics in repairing and maintaining HAVs raise the level of skill, and therefore the wage, of an automotive technician. These and similar programs are preparing the Arizona workforce for the advancement of the AV industry. This educational advantage will need to be matched with AV industry development and support to maximize the benefits. High-skilled and high-wage jobs will be in demand as the AV industry grows and maintaining Arizona's position as a national leader in the AV industry is crucial to establishing a resilient and robust economy.

Economic Impacts of the AV Industry

The following section displays the potential economic impacts of the AV industry on the Arizona economy. The regulatory environment, geographical location and business culture emphasizing innovation are primary drivers for maintaining and advancing the AV industry in Arizona. Investments and partnerships that are focused on advancing software development and engineering activities of AV companies, in addition to the operations and testing activities, maximizes economic impacts.

Whereas continued investment and thoughtful policy in the AV industry has the ability to increase the modeled impacts, a lack of investment or shift in policy towards tighter regulation has the ability to decrease the impacts or expunge them altogether. Arizona must maintain a business and regulatory environment favorable to innovation in order for the modeled impacts to be realized.

Despite advancements in AV, the mainstream arrival and adoption of Level 5 self-driving cars remains uncertain. However, as the AV industry continues to expand and become more viable, the industry will make travel safer, reduce traffic congestion, dominate the automotive industry and generate significant economic impacts.

Because of the uncertainty as to when and at what scale the AV industry will impact the state, three scenarios were modeled to quantify possible economic consequences resulting from an expansion of current AV activities in Arizona. The modeled scenarios estimate the potential economic and fiscal impacts resulting from further AV advancements.

Economic and fiscal impact models are an effective way to demonstrate regional implications of a particular project, policy, business, development or other activities in a given area. The study area can range from a single neighborhood or city, to an entire state or country. The effects resulting from the activity are estimated in terms of *output*, *earnings*, *employment* and *tax revenues*.

Output captures a broader level of economic activity, or the total value of goods and services produced in the broader region, similar to how statistics like gross domestic product (GDP) capture economic volume in individual states and across the country. *Earnings* simply represents income to employees, and *employment* is the job count on an annualized basis. The economic activity is then converted into *tax revenues* in each of the relevant categories affected.

The levels of effects are further broken down as *primary* (direct) or *secondary* (multiplier or ripple) effects. Where *primary* impacts are the initial effects generated by the activity and *secondary* (indirect and induced) impacts are the subsequent effects resulting from the cycle of spending and re-spending within the regional economy.

Rounds Consulting Group (RCG) developed an economic and fiscal impact model to analyze the effects resulting from AV expansions and advancements in the AV industry in Arizona. The RCG model employs an input-output model enhancing a methodology commonly used by economists to determine impacts. This method was used to estimate the multiplier or ripple effects caused by the activities being analyzed. The detailed model methodology is found in the Appendix.

All estimates are largely speculative because of the uncertainty of the industry, but these estimates provide an effective way to measure the possible economic impacts. Estimates were based on currently available information compiled from a variety of sources and subject to uncertainty and variation. Therefore, actual impacts may vary, and some impacts may not materialize due to unanticipated events and changing circumstances.

Analysis #1 - Impact of Additional R&D in Arizona

An AlixPartners study found that $61B has been allocated for AV capital investments and R&D through 2023 nationwide. Arizona is one of only 11 states that have issued executive orders authorizing full deployment and testing of driver occupied and driverless HAVs. For perspective on the statewide economic impact of the planned investment, the following assumes the companies operating in Arizona spend just 10% of the $61B currently allocated.

The study did not account for a softening in economic investment in this new industry during the next economic downturn which is likely to occur around 2022. In this case, the estimated economic value of $61B would likely be spread over another two to three years. Therefore, for this analysis the assumption is the value will be reached by 2026.

By 2026, $6.1B in AV R&D would create 38,883 direct jobs throughout the state. The combined wages earned by those direct jobs equals $2.2B and generates $4.3B in economic output. The spinoff (indirect and induced) effects produce an additional 35,431 jobs, $1.7B in wages, and $4.9B in economic output. State and local governments stand to collect $391.0M in tax revenues from the estimated $6.1B in AV capital investment and R&D.

Economic & Fiscal Impacts – AZ Industry Capture

$9.2B Total Economic Output	74,314 Total Jobs	$3.9B Total Wages	$391.0M Total State & Local Taxes
$4.3B Primary $4.9B Secondary	38,883 Primary 35,431 Secondary	$2.2B Primary $1.7B Secondary	$272.4M Primary $118.6M Secondary

In 2019 dollars. May not sum to total due to rounding.
Sources: IMPLAN; AlixPartners; Rounds Consulting Group, Inc.

These impacts estimates are largely linear; meaning they can be scaled up or down to gauge the level of impact. For example, if one assumes Arizona could capture 20% of the $61B in AV R&D ($12.2B), the number of total jobs increases to 148,628, and the economic impact increases to $18.4B. State and local governments collect $782.0M from this level of AV activity.

Analysis #2 - Impact of Boosting Semiconductor Industry

Semiconductors are a key component of AV technology. With increasing integration of advanced systems such as collision warning in vehicles and robust growth in HAVs, the demand for semiconductor

manufacturing is forecasted to increase significantly. According to a report from McKinsey & Company, the semiconductor industry is expected to grow 3 to 4% a year over the next five years, but the automotive semiconductor industry will increase about 6% annually.

Arizona has been a leader in semiconductor manufacturing for decades. According to the U.S. Bureau of Labor Statistics, semiconductor manufacturing companies employed 18,162 people in 2018. As an example, the following assumes the semiconductor industry in Arizona grows by 3% over the next five years.

That growth translates to an increase of 5,241 semiconductor manufacturing jobs in Arizona and a direct economic impact of $3.1B. Once combined with the secondary (indirect and induced) impacts, the job number increases to 20,573 with $1.7B in wages and produces $5.5B in economic output. In total, state and local governments will collect $104.5M in tax revenues from the increased demand of semiconductor manufacturing as a result of growth in AV.

Economic & Fiscal Impacts – Semiconductor and Related Activities

$5.5B Total Economic Output	20,573 Total Jobs	$1.7B Total Wages	$104.5M Total State & Local Taxes
$3.1B Primary $2.4B Secondary	5,241 Primary 15,333 Secondary	$908.4M Primary $805.4MSecondary	$48.8M Primary $55.7M Secondary

In 2019 dollars. May not sum to total due to rounding.
Sources: IMPLAN; McKinsey & Company; U.S. Bureau of Labor Statistics; Rounds Consulting Group, Inc.

Analysis #3 - Impact of AV Component Manufacturing

According to Deloitte, AV and electronic systems represent 40% of the cost to manufacture vehicles today. By 2030 that estimate is projected to increase to 50% of a car's total cost. McKinsey & Company reports that global new-car sales will reach $4T by 2030 (a growth rate of around 4.4% annually). Although auto manufacturers mostly do not disclose manufacturing expenses and costs can range broadly depending on brand, type, economy verses high-end, etc., research indicates that manufacturing accounts for 75% of a car's total price.

Using those assumptions, manufacturing costs will reach $3T by 2030 and $1.5T will be invested in AV and electronic systems. If Arizona were to capture just 1% of the AV and electronic systems component of manufacturing, approximately $15B in value-added costs would be spent in state.

That $15B in spending translates to 77,656 total jobs, $4.2B in wages, and a total economic impact of $17.9B. State and local governments would collect $357.9M in tax revenues from capturing just 1% of the AV and electronic systems component manufacturing in 2030.

Economic & Fiscal Impacts – Global Market Capture

$17.9B Total Economic Output	77,656 Total Jobs	$4.2B Total Wages	$357.9M Total State & Local Taxes
$10.5B Primary $7.4B Secondary	32,893 Primary 44,763 Secondary	$1.8B Primary $2.4B Secondary	$194.3M Primary $163.6M Secondary

In 2019 dollars. May not sum to total due to rounding.
Sources: IMPLAN; Deloitte; McKinsey & Company; Rounds Consulting Group, Inc.

Appendix

Impact Model Methodology

RCG developed an economic and fiscal impact model to analyze effects of the specific scenarios related to the AV industry in Arizona. The model estimates the economic activity and multiplier effects in terms of output, earnings, employment, and local tax revenues.

Output captures the level of economic activity, or the total value of goods and services produced, in the broader region similar to how statistics like GDP capture economic volume in individual states and across the country. *Earnings* simply represent income to employees, and *employment* is the job count on an annualized basis. The economic activity is then converted into *tax revenues* in each of the relevant categories affected.

The economic effects occurring as a direct consequence of the initial activity create additional effects in the economy. This relationship is known as the "multiplier" effect. The basis for multiplier effects is the interdependencies between industries, how one industry impacts other sectors, and the cycle of spending and re-spending within the regional economy.

Direct, or primary, effects are the results of the development's initial activity. This would include direct AV workers including technicians, vehicle operators, and manufacturing workers for example. The secondary effects, or multiplier effects, are measured as either indirect or induced based on their source.

Indirect impacts capture additional effects as a result of increased demand in the supplier industries which supply services or products to the direct AV businesses. For example, the suppliers of materials to a direct AV company. *Induced* impacts capture additional effects generated as a result of the increased spending in the economy made by the households of both the direct and indirect employees. For example, this includes the grocery store employees that are supported by the local spending of the direct and indirect employees.

Tax revenues (fiscal impacts) are expressed as either primary or secondary based on their source. *Primary revenues* can be estimated by definable sources such as income taxes generated by the direct employees of AV companies. *Secondary revenues* are generated by the wages, residency, and spending of those indirect and induced employees. For example, this would include sales tax revenues generated when employees from supplier companies purchase dinner on their way home from work.