Final**Report**

Economic Impacts **of Autonomous Delivery Services in the US**

September 2020

steer

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This version of the Economic Impacts of Autonomous Delivery Services
is an independent report by Steer for Nuro, released in September 2020.

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Executive Summary

Autonomous Vehicles will revolutionize last-mile deliveries

The use of Autonomous Vehicles (AVs) is enhancing the convenience and efficiency of last-mile delivery. AV technology, in combination with established online platforms, is facilitating new business models across retail and food delivery.

Delivery AVs can provide an effective solution to carry goods from local stores and restaurants through an on-demand, last-mile delivery service. These vehicles are equipped with lidar sensors, radar and cameras to monitor surroundings, and are designed to carry goods rather than people. Custom on-road delivery AVs, like Nuro's R2, are space-efficient electric vehicles, which are smaller than a standard passenger car. They are built to operate on urban and suburban streets.

Delivery AV services are emerging as one of the first commercial applications for AVs in the United States (US). The use of delivery AVs for last-mile delivery has the potential to accelerate demand for home delivery considerably.

For consumers, delivery AV services are expected to influence purchasing behavior, reducing the need to drive to stores. Increased use of delivery services will be encouraged by an improved consumer experience and lower prices. While existing grocery delivery services add $10–20[1] to the cost, initial delivery AV pilots have cost $5.95, and Nuro aims to reduce the delivery cost to $0 for the consumer, providing a more broadly accessible service.[2]

For the retail sector, delivery AV services could be transformational, offering a broader range of opportunities, leading to lower delivery costs and greater demand for on-demand delivery offerings.

Car manufacturers and tech companies are investing in this future in partnership with retail players such as Kroger, Walmart, Domino's and CVS Pharmacy. This has led to an increase in the number of delivery AV pilots in recent years. Delivery AV services work like this:

1. Customers order groceries or other products online from one of the partner stores.
2. Items are picked and packed in store and brought to a waiting delivery AV.
3. A notification lets customers know when their delivery has arrived.
4. Once the customer has unloaded and accepted the goods, the delivery AV vehicle drives on to the next customer.

COVID-19 impacts

Some experts suggest COVID-19 has amplified the application of AVs in last-mile delivery services in recent months as COVID-19 has continued to impact the way people shop for groceries. Consumer demand for contactless home delivery has increased dramatically, and AV developers have increased their testing of delivery applications. At this stage of the pandemic, it is not possible to foresee whether these trends will reverse, continue, or accelerate, and this study has not attempted to forecast its impact directly.

1 *Brasler K., 2018, Grocery Delivery: How Much Extra Will You Pay to Skip the Store? https://bit.ly/2CZvh3G*

2 *Nuro, 2020, Serving America's Food Deserts, Medium, retrieved from https://bit.ly/312t6UP*

Context of this Commission

Over 85% of trips in the US are currently made by private vehicles, which adds to significant traffic congestion, collisions and transport emissions, particularly in cities and urban areas.

The use of electric AVs for deliveries has the potential to reduce congestion, collisions and transport emissions. In addition, delivery AV services can batch multiple customer orders. Compared to customers driving themselves to the store, this generates additional potential benefits through reductions in overall Vehicle Miles Traveled (VMT), lower transport emissions and user time savings.

In this context, Nuro has commissioned Steer to conduct an independent study to evaluate the potential economic impact of delivery AV services to the US economy by analyzing the following:

- Role of delivery AVs in reducing personal vehicle trips (estimating overall market potential for delivery AV services between 2025 and 2035 at a national level and for selected states);
- Economic impacts of delivery AV services for the US economy, including employment impacts; and
- Wider impacts of delivery AV services, including safety, emissions, and time savings at a national level and for selected states.

Why it's important to consider the economic impacts of delivery AVs

Replacing private vehicle trips to go shopping and run errands with delivery AV services could create a significant economic opportunity. This impact differs from the economic impacts of AV passenger services because on-demand goods delivery is a less mature service that has been limited to date by price in the US. A lower-cost delivery service enabled by delivery AVs could lead to significant growth in demand for last-mile delivery.

The technology for delivery AVs could also emerge earlier than for passenger AVs as these vehicles do not require balancing occupant safety and comfort with other road user safety, they may have more prescribed operating areas because they do not have to account for passenger expectations, and surveys[3] indicate higher levels of public trust for goods-only AVs.

Delivery AV services are expected to create an increase in demand and employment opportunities amongst retailers (who must hire pick-and-pack workers for trips where the consumer previously packed their own order) and in industries that supply raw materials and inputs to delivery AV services sector such as vehicle manufacturing, technology, supply chain companies, etc.

In addition, the relative emergence of services like grocery delivery (approx. 3% of groceries were delivered prior to COVID-19) mean that while existing workers will be affected, there is less potential for disruption to an existing workforce.

A successful transition from conventional vehicles to using delivery AVs would require significant support from both consumers and regulators. Quantifying the potential benefits of introducing delivery AV services to the US economy provides an informed basis for regulatory reform to enable wide scale adoption of delivery AV services.

3 *PAVE, 2020*

Scenario based approach

The study considers the time period 2025 to 2035 for three potential future scenarios:

1. Conservative Scenario;
2. Gradual Shift Scenario (central case); and
3. Disruptive Shift Scenarios.

The scenarios were developed by examining a range of potential factors likely to affect the demand for and supply of delivery AV services, including consumer acceptance, growth in e-commerce and curbside deliveries, cost of services, advancements in delivery AV technology and AV regulations.

Scope of the Study

This study's scope includes all on-road, last-mile delivery AVs in the US. The scope is not limited to one company or vehicle type, but rather includes passenger-style cars and vans used in local delivery as well as custom vehicles designed specifically for autonomous delivery. The scope does not include sidewalk or bike-lane robots, drones, or heavy trucks used in long-distance transportation.

Demand for Delivery AV Services (Gradual Shift Scenario)

By analyzing the trends in VMT by private vehicles for shopping and errand trips across the US, the study evaluates the proportion of VMT that could be replaced by delivery AV services.

With advancements in AV technology and increased consumer acceptance of curbside deliveries using delivery AVs, this study estimates that under the Gradual Shift scenario, about 23% of in-scope VMT (i.e. 191 billion VMT for shopping and errand trips) could be replaced by delivery AV services by 2035. We estimate that this will generate a potential US demand for delivery AVs of 3.1 million vehicles by 2035, based on 35-40 million daily AV deliveries[4].

Total Economic Impacts (Gradual Shift Scenario)

Direct Economic Impacts **$3.4 trillion** + Wider Economic Impacts **$0.719 trillion** = Total Economic Impacts **$4.1 trillion**

To meet this demand, the delivery AV services sector is expected to make a total investment of $1.1 trillion by 2035 as:

1. Direct spending into supplying industries (to acquire raw materials); and
2. Employee compensation.

US economy could potentially generate a total value of $4.1 trillion between 2025 and 2035 from direct economic impacts and wider benefits in terms of road safety benefits, time savings and a reduction in transport emissions.

4 *Average length of one-way shopping and errand trip is 7 miles (NHTS, 2017). 191 billion VMT implies about 27 billion shopping and errand round trips annually.*

Direct Economic Impacts (Gradual Shift Scenario

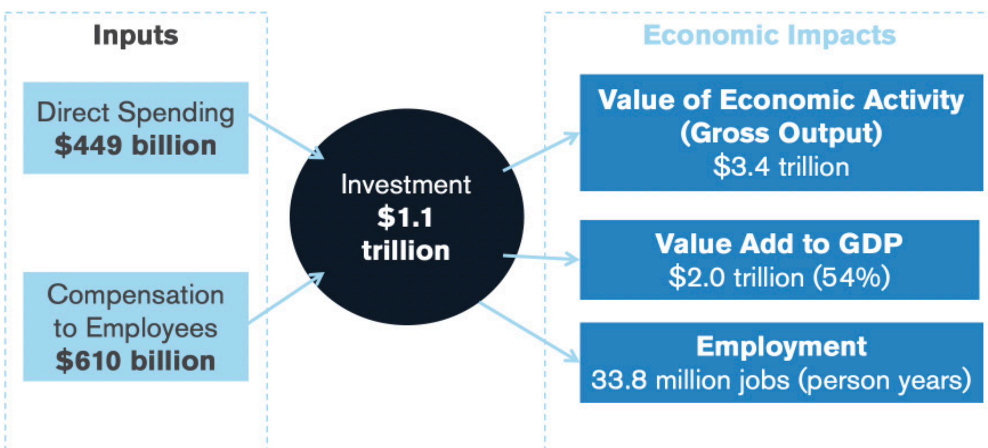
An investment of $1.1 trillion by the delivery AV services sector is expected to create total economic activity of $3.4 trillion in the US economy between 2025-2035.

Total economic activity includes $1.4 trillion from the value of goods and services produced directly in the delivery AV services sector, and an additional indirect and induced value of $2 trillion through increased production of goods and services in other related sectors within the US economy.

The investment into delivery AV services will fuel long-term returns to the US economy. Over the 10-year study period, delivery AV services are expected to create gross income of $2.0 trillion (Value Add to GDP) in the US economy, almost twice the amount of investment made, suggesting that the sector has the potential to generate meaningful wider impacts.

In addition, it would support the creation of 34 million job-years[5] in the US during the study's time period. This is the equivalent of about 3.4 million jobs per years[6] – including 24 million direct jobs among technicians and supervisors, operational staff, pick and pack workers, and software engineers in delivery AV services sector, as well as 10 million indirect and induced jobs due to higher economic activity.

Figure 0.1: Summary of Economic Impacts, 2025-2035



5 *Job-years or person-years is a unit of measurement for the amount of work done by an individual throughout the entire year, One job for one year is one "job year". If that job continues for another 12 months, it is two "job years".*

6 *Idem.*

Wider Economic Impacts (Gradual Shift Scenario)

In terms of wider economic impacts across the US from delivery AV services, we expect that between 2025 and 2035, under a Gradual Shift Scenario:

- 244,000 injury-causing road crashes and 353,000 injuries and fatalities could be avoided; equivalent to the number of such incidents in Texas during the entire 2019 [7];
- More than 21 billion hours of driving trips for shopping and errand purposes could be saved, which represents ~87 hours or as much as 11 vacation day per year per person using the service[8] ; and
- A reduction in CO2 emissions of 407 million short tons which is the annual equivalent of 88 million passenger vehicles off the road for one year.

Figure 0.2: Value of Wider Economic Impacts, 2025-2035 – Gradual Shift Scenario

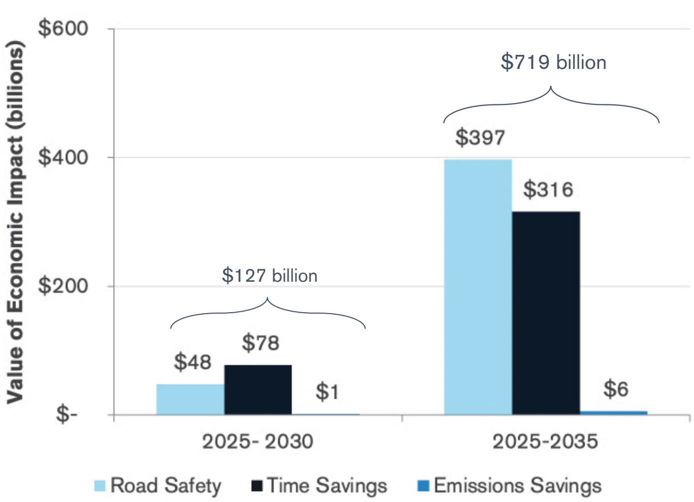


Table 0.1: Summary of Wider Economic Impacts, 2025- 2035 – Gradual Shift Scenario[9]

	Units	2025-2035
Road Safety	Road Safety Total Crashes avoided (thousands)	244
	Total injuries & fatalities avoided (thousands)	353
Time Savings	Total Hours saved (billion hours)	21.4
Emissions Avoided	NOx (thousand short tons)	236
	PM 2.5 (thousand short tons)	8
	VOC(HC) (thousand short tons)	345
	CO2 (million short tons)	407

The total estimated reduction in road safety, time savings, and emissions avoided between 2025 and 2035 has a total economic value of $719 billion:

- 55% of savings are generated from traffic injuries and fatalities avoided;
- 44% from time saved by drivers; and
- 2% from emissions avoided[10] .

7 *https://www.txdot.gov/government/enforcement/annual-summary.html*

8 *Based on the assumptions that total licensed drivers in US is 227 million in 2019 and 23% of them would use the service as we assumed it in the Gradual Shift scenario.*

9 *The following wider economic impacts are calculated based on private vehicle trips for shopping and errand purposes being replaced by delivery AV services in the US.*

10 *Note that this calculation relies on the 2017 BCA guidebook from USDOT, which revised the social cost of carbon per metric ton to $1. Previously, the social cost of carbon was set at $39; if this value were used, the emissions benefits would be $16*

Key Outputs for the Gradual Shift Scenario

$4.1T could potentially be generated for the US economy between 2025 and 2035 from Economic Activity impacts and Wider Benefits

Total Economic Activity Impacts (2035)

$486B = Total Economic Activity expected to be created in 2035

$292B = Total Value Added to GDP in 2035

$1M investment by the Delivery AV Services sector creates roughly 25-26 new jobs

Wider Benefits (2025 and 2035)

244K injury-causing road crashes could be avoided between 2025 and 2035

21B hours of driving trips for shopping and errand purposes could be saved between 2025 and 2035

407M short tons of CO2 emissions saved between 2025 and 2035

$719B = Total estimated reduction in costs associated with road safety, time savings, and emissions avoided between 2025 and 2035

Introduction

1

About the study

Context of this Commission

This study aims to assess the economic benefits to the US that would result from uptake of delivery AV services, which are just beginning to become commercially available. Delivery AV services have the potential to transform last-mile deliveries.

The purpose of this study is to assess impacts on the US economy from 2025 to 2035 under different uptake scenarios, in terms of both direct economic impacts and wider economic impacts. Uptake prior to 2025 is expected to be modest, therefore the impact analysis starts in 2025, when the commercial delivery AV fleet would begin operating at scale. (Note: The external inputs to this report were prepared prior to the current *COVID-19 crisis and do not consider related impacts in the economic impact outputs.)*

The study was commissioned by Nuro and prepared independently by Steer.

Structure of the report

This section defines the scope of the study including the type of delivery vehicles covered by this analysis.

Section 2 sets out our scenarios' key drivers for the uptake of delivery AV services on a national level and in selected states (California and Texas). It also highlights the projected demand for delivery AVs in both the US and the selected states.

Section 3 uses the demand for delivery AVs implied by each scenario to undertake an assessment of the economic impacts to the US economy in terms of Value of Economic Activity (Gross Output), Value Add to Gross Domestic Product (GDP), and Employment.

Section 4 presents the wider economic impacts of delivery AVs in terms of road fatalities avoided, time savings and pollution at both the national and selected states levels.

Finally, Section 5 sets out recommendations.

Scope of the Study

Defining Delivery Autonomous Vehicles

Generally, delivery AV options can be classified in three categories:

- Autonomous vehicles for the road (including modified passenger cars by the likes of GM, Ford, Toyota and others, as well as custom on-road delivery vehicles from companies such as Nuro);
- Last-mile personal delivery device for sidewalks (e.g. Starship robots); and
- Drones delivering by air (e.g. Prime Air by Amazon).

This study focuses solely on **autonomous vehicles for the road** with levels of autonomy of Level 4 or above (levels of autonomy are defined in Appendix A). This does not include heavy trucks (e.g. interstate transportation in Class 8 trucks).

Acronyms

AV	Autonomous Vehicle
BEA	Bureau of Economic Analysis
CO2	Carbon Dioxide
NOx	Nitrogen Oxides
PM 2.5	Particulate Matter 2.5
VOC	Volatile Organic Compound
DOT	Department of Transportation
Delivery AV	Autonomous delivery vehicle
EPA	United States Environmental Protection Agency
FARS	Fatality Analysis Reporting System
FHWA	Federal Highway Administration
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GVA	Gross Value Added
MAIS	Maximum Abbreviated Injury Scale
NHTS	National Household Travel Survey
NHTSA	National Highway Traffic Safety Administration
OEM	Original Equipment Manufacturer
SAE	Society of Automotive Engineers
SAV	Shared Autonomous Vehicles
VMT	Vehicle Miles Traveled

Sizing the US Demand for Delivery AV Services

2

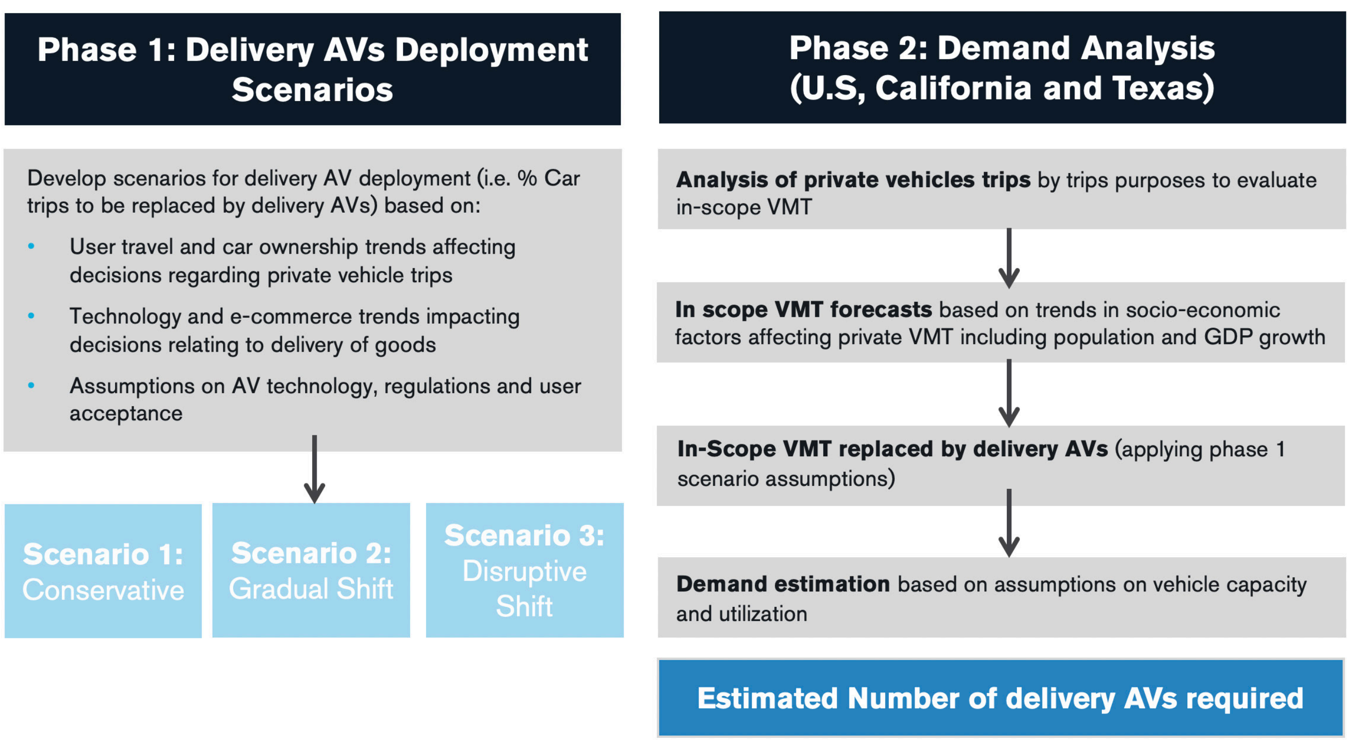
General approach

Methodology for estimating demand

The datasets used as a foundation for the analysis are the US National Household Travel Survey (NHTS) 2009 and 2017 (the latest available), conducted by the Federal Highway Administration (FHWA), which provide information on passenger trips and VMT by trip purposes and mode. Our methodology for estimating demand is illustrated in Figure 2.1

This methodology considers the specific efficiencies of delivery AV services such as multiple deliveries in a single trip and assumptions about the potential number of deliveries that a vehicle can undertake in one day. More details on the methodology can be found in Appendix B.

Figure 2.1: Proposed Methodology for In-Scope Trip Analysis and Demand Estimation



Phase 1: Delivery AV Deployment Scenarios

Key factors Considered for Scenario Development

While advancements in autonomous technology and supportive policies are key to delivery AV supply, social factors such as consumer demand for these services will also determine demand growth in the long term. Therefore, the following factors are considered to create our different scenarios:

1.Congestion and transport emissions

An average car trip in the US takes 20% longer because of congestion compared to free flow traffic conditions, and this reaches up to 42% in large cities like Los Angeles[11]. Increased congestion and the impact on vehicle emissions (transport emissions grew 9% in the last 10 years in the US), as well as the loss in productive human hours stuck in traffic, may discourage people from making vehicle trips in the future if reliable, low-emission, convenient and affordable alternatives are available. We expect that this is likely to have a positive impact on consumer choices for replacing certain in-person trips, with alternative options such as the use of home deliveries becoming more common.

2. Evolving attitude toward car ownership and emissions

California is one of the few states to maintain Low-Emission Vehicle (LEV) standards that are stricter than the federal requirements[12]. As part of these LEV standards, California has implemented a Zero Emission Vehicle (ZEV) program, which requires increasing sales of ZEVs over the next decade, and has been adopted by a further 11 states (Colorado, Connecticut, Maine, Maryland, Massachusetts, New Jersey, New York, Oregon, Rhode Island, Vermont and Washington); Nevada is expected to soon join this list[13].

Policy initiatives to promote sustainable transport and a rise in the costs of car ownership and maintenance (on average, more than 15% of income per capita[14]) has led to a steady 1-2% annual decline in the motorization rate since 2013. This evolving attitude towards car ownership is likely to continue, although there are significant variations in the motorization rate across US. We expect the outcomes of this trend to positively impact consumers' willingness to replace certain private vehicle trips with alternative options, e.g. home deliveries.

3. Autonomous Vehicles policy trends

There are currently no federal laws specifically regarding AVs, but AVs do need to comply with NHTSA's "defect" authority, which prohibits vehicles that present an unreasonable risk to safety. However, AVs are subject to certain regulatory barriers: for example, vehicles with unconventional designs, like vehicles with no occupants, may be required to include equipment like a steering wheel or airbags, even though there is no one in the vehicle. Without structures in place to scrutinize levels of safety of AV systems, adapt the regulatory barriers to innovative vehicles design, and facilitate clear assessment of liability concerns,

11 Congestion level = the current extra time drivers are experiencing on average – A 42% congestion LA, means that a 30 min trips will take 42% more time than it would during LA's baseline uncongested conditions.

12 California Air Resource Board, Low-Emission Vehicle Program, retrieved from https://bit.ly/3gdPD7x

13 Vermont DEC 2020, Zero Emission Vehicles Programs, retrieved from https://bit.ly/39FQeN1

14 INRIX, 2018, INRIX Cost of Driving Index, retrieved from https://inrix.com/press-releases/cod-us/

the disruptive impact and timeline of AV technology in the US could be delayed or diminished compared to other countries. This has the potential to limit the growth of delivery AV service.

4. Increased adoption of online shopping

US e-commerce penetration has more than doubled in the past 10 years. As the penetration has increased, consumers are diversifying their online practice. Adoption of online grocery shopping is still modest but is growing at a healthy pace. The rising demand for value-added services and adequate last mile delivery options are the factors boosting last mile delivery's growth. One expected outcome for the rise of home-delivery is a decline in physical shopping trips, which are likely to continue to decline with the rise of same-day delivery and instant delivery services.

Over the last decade, the continuous improvement in rapid delivery services has raised consumers' expectations. Potential buyers are more sensitive to shipping times of more than a day, and increasingly reluctant to pay high delivery or shipping fees. As delivery AV services lower delivery costs, we expect volumes of on-demand delivery to increase over time.

Scenarios development

This study identifies three potential futures that explore a range of possible conditions for delivery AV services by 2035. Three scenarios were developed based on the trends identified above, to estimate the possible size of the demand for AV delivery services in the US.

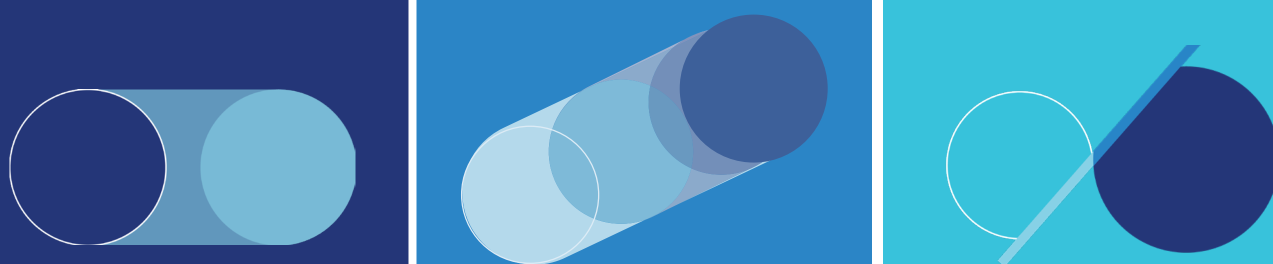
The **Gradual Shift scenario is the main scenario used to explore the economic impacts** of uptake of delivery AVs in this report. The Conservative scenario and Disruptive Shift scenario are used to provide an indication of potential slower or quicker adoption of delivery AV services. The three scenarios are summarized as follows:

- Conservative scenario: explores a future in which remaining challenges for AV services are not resolved quickly and many consumers remain untrusting of the technology. Development of full automation proves technically more difficult and expensive. As a result, the Conservative scenario assumes a very limited shift from private vehicles to AVs by 2035. This scenario also assumes limited movement from the federal government to support policy and infrastructure changes. Given this context, consumer acceptance and interest toward delivery AV services evolve more slowly and willingness to pay extra for such services remains moderate by 2035.
- Gradual Shift scenario: explores a future in which AVs are introduced more quickly, including a steady increase in the use of delivery AV services. Like in the Conservative scenario, the cost of AVs remains high and they are therefore acquired and deployed first in fleets through on-demand services. Vehicle ownership is expected to decrease under this scenario as new mobility options make it easier and cheaper to travel, buy food and groceries without owning a car. In this scenario, government support would remain modest, in line with current trends. The increased demand for delivery AV services would lead to lowering the cost of delivery and a growth in demand by 2035.
- Disruptive scenario: explores a future where rapid technology development and high uptake for AV technology is seen. The technology would evolve faster, assisted by proactive federal government support to deployment of AV trials. This scenario also assumes an

accelerated shift from private vehicles to shared autonomous services and a quicker and broader deployment of delivery AV services in the US. As a result, cost of delivery would reduce by 2035, providing more affordable and convenient access to groceries and other local commerce items.

These scenarios consider available evidence from a range of previous studies and expert interviews. This study did not attempt to consider all possible futures, but rather identified potential scenarios that present a range of possible conditions for the implementation of delivery AV services.

Figure 2.2: Scenarios Assumptions by 2035



Conservative Scenario

- Very limited shift from private vehicles to AVs;
- Limited government support;
- Limited consumer acceptance toward delivery AV services
- Moderate consumers' willingness to pay extra for AV delivery services

Gradual Scenario

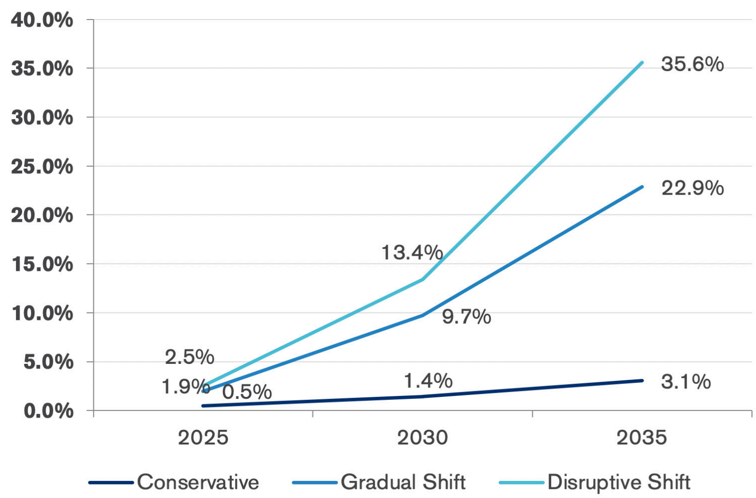
- Slow shift from private vehicles to AVs, with a steady increase in the use of shared autonomous vehicles (SAVs);
- Government support remains modest.;
- Acceleration of consumers' willingness to pay extra for delivery.

Disruptive Scenario

- AV technology evolves faster, supporting an accelerated shift from private vehicles to SAVs and a quicker and broader deployment of delivery AVs services;
- Proactive government support to deploy AVs;
- Delivery practice and consumers' willingness to would be high due to reduced cost of delivery

The potential for delivery AV services to replace in-scope VMT (i.e., private vehicle trips for shopping or errands) in each of the scenarios is outlined in **Figure 2.3.** The findings are based on expert interviews, background research and Steer's professional judgement and experience as well as being subject to peer review by our Economics specialists Detailed calculation methodology is included in **Appendix B.**

Figure 2.3: In-scope VMT replaced by Delivery AVs – All Scenarios



Phase 2: US Demand for Delivery AV Services

Key Takeaways

By 2035:

- 630,000 delivery AVs would be required to meet the demand in the Conservative scenario;
- 3.1 million delivery AVs would be required to meet the demand in the Gradual Shift scenario; and3.9 million delivery AVs would be required to meet the demand in the Disruptive Shift scenario.

Analysis of US Private Vehicle trips

Based on US NHTS 2017 data, over 306 billion trips are made annually by private vehicles in the US, out of which 125 billion trips (40%) are made for shopping and errands purposes, which are considered in-scope for our analysis. These in-scope trips correspond to about 540 billion VMT annually.

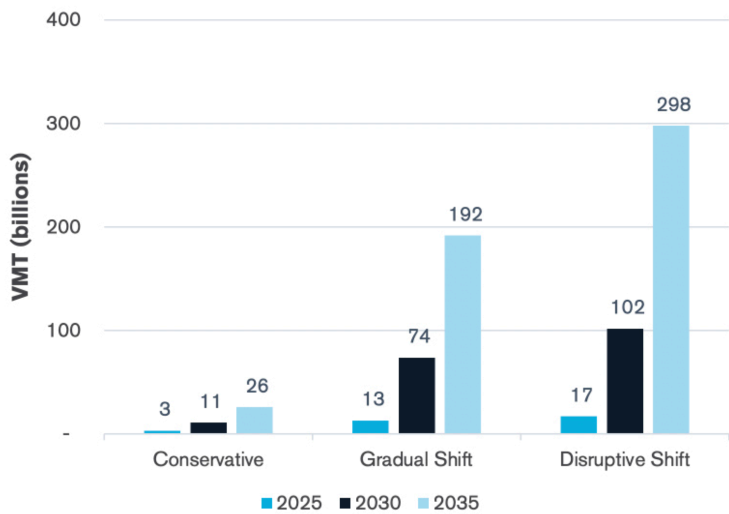
We have assumed that total in-scope VMT during the study period (2025-2035) would increase in proportion to expected growth in the US population and GDP. Therefore, the in-scope VMT is forecast to increase to approximately 673 billion VMT in 2025 and 837 billion VMT in 2035[15].

Shopping Trips that Could Move to Delivery AVs

The proportion of total in-scope trips that could be replaced by delivery AV services will vary for each scenario, depending on the factors discussed above. Using the findings on % in-scope trips replaced by delivery AVs from Figure 2.3, we have calculated the total private vehicle VMT that could be potentially replaced by delivery AV services. By 2035 for the Gradual Shift scenario, 192 billion private vehicle VMT could be potentially replaced by delivery AV services **(Figure 2.4).**

15 Detailed analysis of in-scope vehicle trips and associated VMT is included in Appendix C.

Figure 2.4: Billion VMT replaced by Delivery AVs – All Scenarios



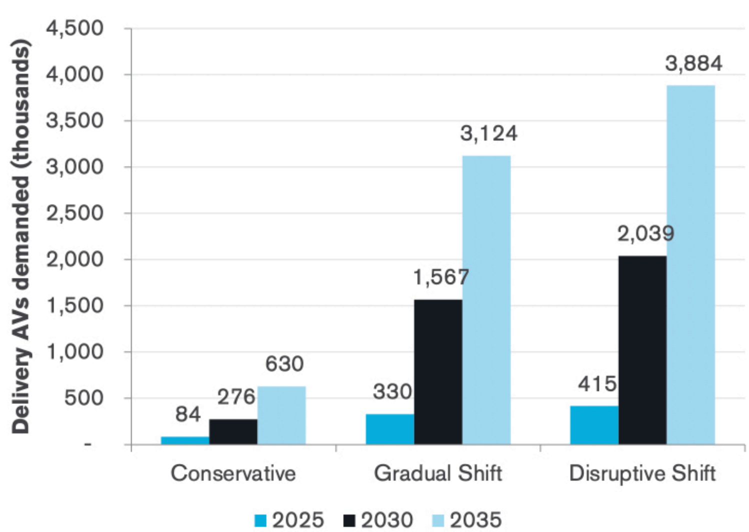
Demand Estimation

In order to evaluate the number of delivery AVs required to meet the demand for delivery AV services (i.e. to serve the in-scope VMT identified in Figure 2.4), we developed two assumptions on the capacity and utilization rate of delivery AVs, based on expert interviews and analysis of existing pooled services such as ride hailing and food delivery[16]:

- Economies of Batching: the ratio of VMT by private vehicles to VMT by delivery AVs will range between 1-2 depending on the uptake rate of delivery AVs for each of the scenarios. The delivery AVs are likely to be more efficient in the Gradual Shift and the Disruptive Shift scenarios where increase in demand for delivery AV services would allow the vehicles to make multiple stops/deliveries per trip;
- Vehicle mileage: average distance travelled by delivery AVs is expected to increase with technological and safety improvements. In this study, an average mileage by delivery AVs is assumed to be approximately 105 miles per day. Although held constant here, this number could be expected to increase over time as operations become more efficient.

Under the Gradual Shift scenario, a total of 3.1 million delivery AVs would be required to meet the demand for delivery AV services in 2035 (number of delivery AVs required to replace the in-scope VMT by private vehicles). Figure 2.5 highlights our findings on demand for delivery AV services in 2025, 2030 and 2035.

Figure 2.5: Delivery AV Number of Vehicles Demanded ('000s of vehicles), US – All Scenarios



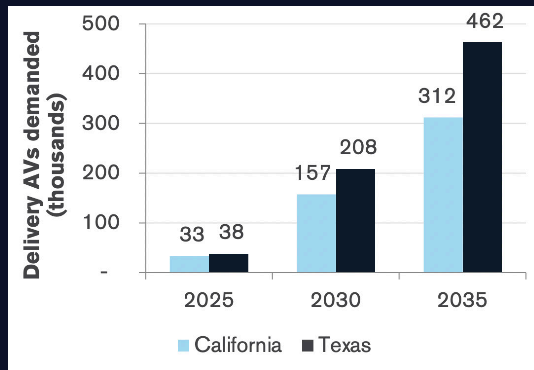
16 *Detailed methodology can be found in Appendix C.*

Demand for Delivery AVs in California and Texas

Using the same assumptions for scenarios and delivery AV utilization rate, we have estimated the demand for delivery AVs in the two US states of California and Texas, based on an analysis of in-scope VMT in these states.

Under the Gradual Shift scenario, by 2035 approximately 312,000 delivery AVs would be required in California and 462,000 delivery AVs would be required in Texas (Figure 2.6). While California has higher population (40 million) compared to Texas (29 million), Texas' high level of anticipated population growth, alongside higher usage of private vehicles for shopping and errand trips (88% compared to 81% of trips in California) is expected to generate higher demand for delivery AV services.

Figure 2.6: Delivery AV Market Size ('000), California and Texas – Gradual Shift Scenario



COVID-19 potential impacts on future demand for delivery AV services (as of Summer 2020)

COVID-19 has triggered short-term acceleration and amplification of the following elements:

- E-commerce experiencing growth in online categories like groceries;
- Acceleration of experiments and evaluation of delivery services;
- From the supply side: more appetite for delivery (vs. passenger); AV companies launching delivery initiatives (vs. solely focused on passenger)

Given this is an ongoing development, it is still too early to determine whether these changes will be permanent, but on balance they are more likely to positively impact (accelerate/amplify) take up of autonomous delivery.

Direct economic impacts

3

General approach

The transition to automated driving technology for transportation of passengers, goods and services represents a significant economic opportunity for the US economy. This section quantifies the economic impacts of replacing in-scope private vehicle trips (Section2) with delivery AV services by 2035 in terms of Value of Total Economic Activity, Gross Value Add and Employment:

- **Value of Total Economic Activity (Gross Output):** Total value of final goods and services produced, and income generated from this production.
- **Gross Value Add:** Total income generated in the US economy due to delivery AV services. This is expressed as: Gross Value Add (to GDP) = Value of Total Economic Activity minus Intermediate Consumption (Value of inputs/raw materials).
- **Employment:** Person-years or job-years[17] generated in the US economy.

We have estimated the amount of investment required to meet the potential demand for delivery AV services during the forecast period (2025-2035) and then evaluated the potential economic impacts of the corresponding investment to the US economy, as detailed above.

The **direct economic impacts** relate specifically to the investment made to provide delivery AV services. The **wider economic impacts** brought by delivery AV services, such as improved road safety, reduced emissions, and time savings, are estimated in Section 4.

17 *Job-years or person-years is a unit of measurement for the amount of work done by an individual throughout the entire year.*

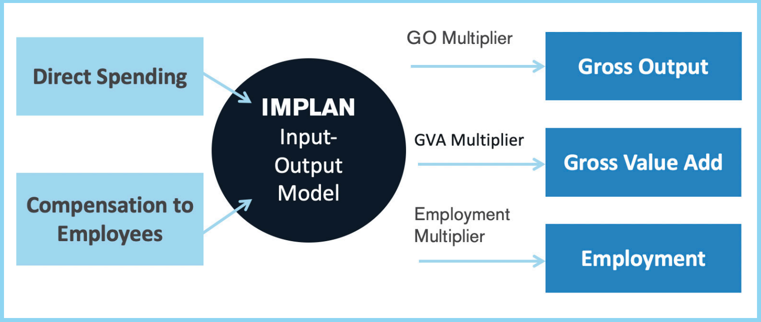
This section primarily considers total economic impacts of delivery AV services for the Gradual Shift scenario.

It is important to note that the potential opportunity for delivery AV services will not only depend on the factors discussed in Section **2**, but also on the investment made by the industry towards research and testing to develop the technology and facilitate wide-scale adoption. Investments will also need to include manufacturing delivery AVs at scale, as well as operations and maintenance.

Methodology

We have utilized IMPLAN input-output modeling software to evaluate the impacts of investment made by delivery AV services (in terms of direct payments to sectors supplying raw materials and services and salary or wage payments to people employed directly) on the US economy.

Figure 3.1: Methodology



Output: The model estimates not only the economic impacts on the core sector (i.e. delivery AV services), but also indirect (e.g. raw material suppliers) and induced (generated due to higher income) impacts, value add and employment. The detailed methodology is included in Appendix D.

Note on Methodology: Key difference between cost-benefit and economic impact analysis

The launch of delivery AV services has the potential to displace both production (total economic activity) and employment in sectors that are related to the business, for example changes in the jobs of delivery workers, or reduced parking revenue (owing to fall in private vehicle trips). This study does not attempt to provide a cost-benefit analysis of launching delivery AV services. Rather, it calculates the total economic impact (gross impacts) of the investment in the sector based on how much stimulus it provides to the economy.

This study does not examine how the resources used here might have alternative societal uses (i.e., societal opportunity cost).

Total spending by the delivery AV services sector

In order to provide a service using delivery AVs, companies are likely to make two types of investment (spending):

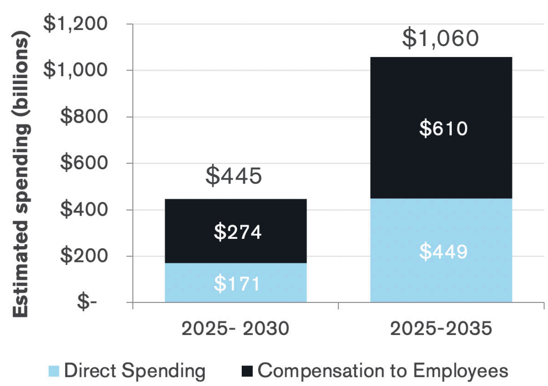
- Direct Spending into supplying industries, which includes acquiring the vehicle, hardware (sensors, computing), and equipment, as well as the service industry (e.g. warehousing and storage, real estate, insurance, utilities); and
- Compensation to Employees for software development, research and development, maintenance and supervision of vehicles, pick and pack of orders, etc.

The inputs include fixed costs (e.g. purchase of each vehicle, hardware, equipment etc.), and the maintenance and operation of delivery services for the vehicle's lifecycle, based on industry experts' cost estimates for both modified passenger vehicles and custom delivery AVs. We assume that the fixed costs per unit would decline by 25% between 2025 and 2035, while operating costs per unit would decline by around 40% during the same period. Advancements in autonomous technology and efficiencies due to large-scale demand (economies of scale) would support the decline in per unit costs.

Total spending required in terms of direct spending and compensation to employees to meet the potential demand for delivery AV services has been calculated using the estimated unit costs and the number of delivery AVs required and operated each year (Section2) for each of the three scenarios.

For the Gradual Shift scenario, a total spend of around **$1.1 trillion cumulatively between 2025 and 2035** is required to produce and operate approximately 3.1 million delivery AVs (Figure 3.2). In comparison, a total of $211 billion and $1.3 trillion would be spent in the Conservative and Disruptive Shift scenarios respectively over the same period. All values are estimated at constant 2020 prices.

Figure 3.2: Total Estimated Spending by the Delivery AV Sector, 2025-2035 – Gradual Shift Scenario



These estimates of total spending are used as inputs to evaluate the direct economic impacts of delivery AV services on the US economy during the forecast period 2025-2035.

Total Value of Economic Activity (Gross Output)

Total Value of Economic Activity (or Gross Output) represents the value of total production of final goods and services generated in the US economy, including:

1. the direct value of production in delivery AV services; and

2. the value of goods and services produced in other sectors due to indirect and induced increases in demand from delivery AV services (e.g. as employees or vendors are compensated, they go out and spend in the economy).

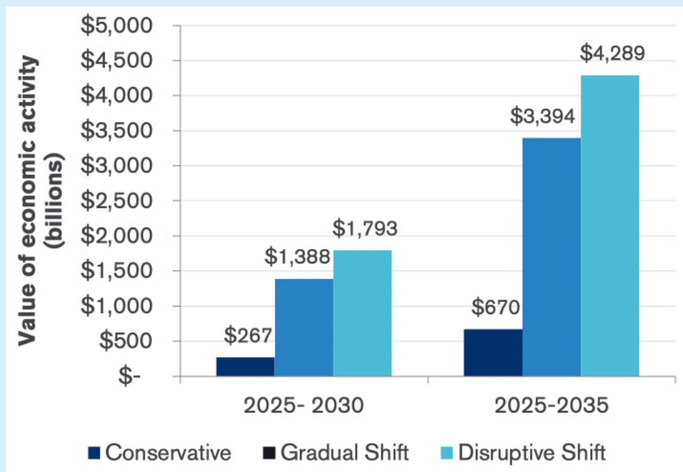
The model is set up in such a way that it assumes that the investment by delivery AV services sector is made into domestic industries such as US automotive manufacturing to procure the vehicles (who may import a certain proportion of its raw materials to manufacture the vehicle – which is in – built in the IMPLAN model as per general industry trends), but there is no direct import or export by delivery AV services sector.

Key Takeaways

Total Economic Activity worth $3.4 trillion could be potentially generated in the US economy across different sectors, in our Gradual Shift scenario, underpinned by an investment of approximately $1.1 trillion between 2025 and 2035 by delivery AVs.

Total value of Economic Activity generated in the US economy could potentially reach $4.3 trillion between 2025 and 2035 against an investment of $1.3 trillion in the context of the Disruptive Shift scenario, and is estimated to be $670 billion of Economic Activity under a Conservative scenario against a total spending of $210 million (Figure 3.3).

Figure 3.3: Total Value of Economic Activity ($ Billion), 2025-2035 – All Scenario



Delivery AV services is a high-performing sector: $1 million of spending (investment) in the delivery AV services sector as direct spending (i.e. vehicle manufacturing, technology development, and operation of services) or compensation to employees (i.e., software engineers, pick and pack service providers, vehicle maintenance staff, etc.) creates economic activity of $3.2 million in the US economy. This is calculated based on standard output multipliers[18]

18 Multiplier values generated from the IMPLAN input – output model.

observed in different sectors (NAICS) that receives the direct investment.

Over 65% of investment (spending) by the delivery AV services sector goes towards compensation of employees in highly-productive jobs (i.e. jobs that create high value of economic activity per worker), including software development, retail, electronics equipment, scientific research, or Non-Recurring Engineering (NRE) such as testing. Investments in delivery AV services yields an above-average return to the economy compared to other types of goods or services.

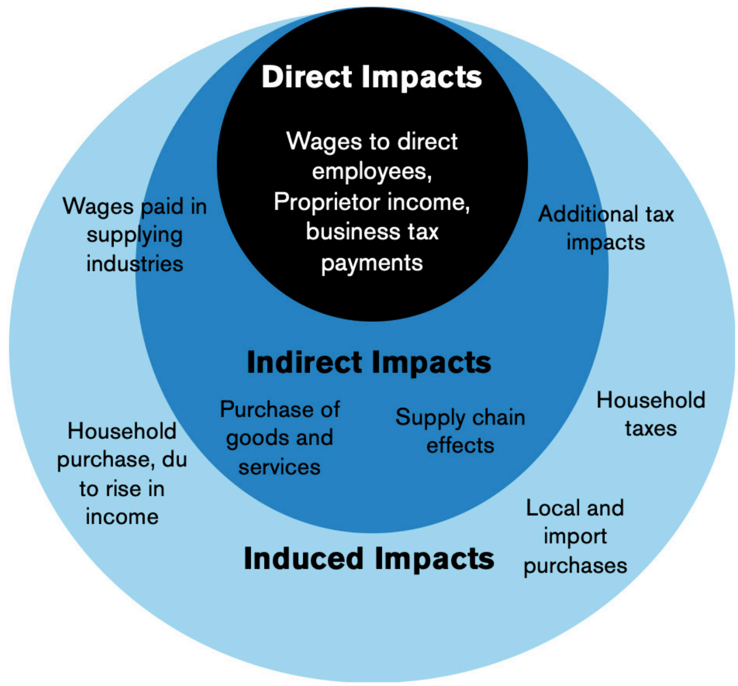
Total Value of Economic Activity by Type of Impacts

In this subsection, we consider the different impacts that generate the total Value of Economic Activity (Figure 3.4).

The direct impacts represent the total value of goods and services produced by the delivery AV services sector. It includes payments made to supplying industries, direct wage payments, proprietor's income (net profits) and tax payments. In other words, direct impacts represent total revenue that could potentially be generated from delivery AV services.

Indirect impacts are impacts that are generated by increased demand for raw materials and services by the delivery AV services industry. Induced impacts are those generated due to an increase in demand for goods and services due to higher levels of income generated in the economy. Increased income would come from higher levels of overall employment in the economy – direct or indirect jobs.

Figure 3.4: Direct Impact



The AV delivery services sector is expected to generate between 2025 and 2035, under the Gradual Shift scenario:

- Direct Impacts: A total of almost $1.4 trillion from direct impacts, based on $1.1 trillion of spending in supplying industries and compensation to employees.
- Indirect Impacts: An additional $0.8 trillion of Economic Activity, generated indirectly in the supplying industries such as automotive, sensors and electronic equipment, energy, warehousing and storage, etc.
- Induced Impacts: A further $1.2 trillion of Economic Activity, owing to induced impacts from the rise in total income for suppliers and employees in the delivery AV services sector (Table 3.1).

Table 3.1: Total Value of Economic Activity ($ Billion) – Gradual Shift Scenario

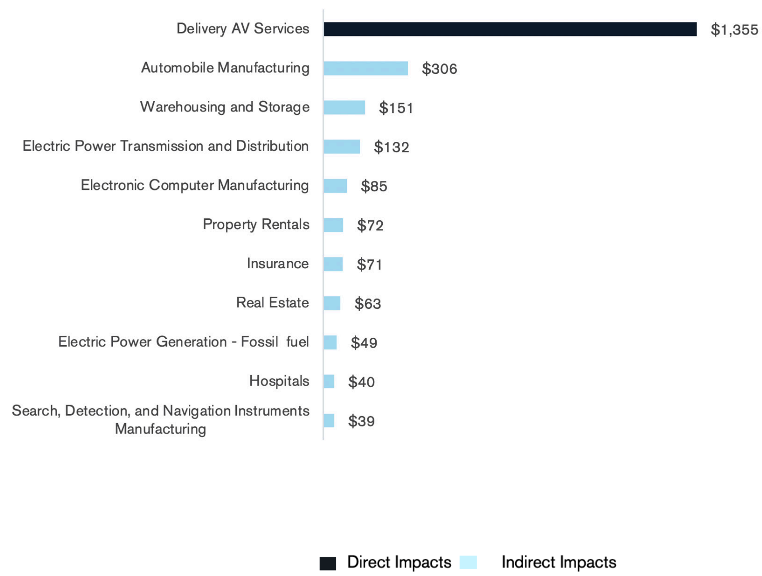
	2025- 2030	2025- 2035
Direct Impacts	$ 561	$ 1,355
Indirect Impacts	$ 322	$ 824
Induced Impacts	$ 505	$ 1,215
Total Impacts	**$ 1,388**	**$ 3,394**

Impacts by Industry

Delivery AV services directly spend in supplying industries such as automobile manufacturing, electronic goods and equipment, utilities, warehousing and maintenance to run the business, which are therefore the key industries that reflect the majority of increase in indirect and induced Economic Activity.

The top ten sectors (Figure 3.5) are estimated to account for over 50% of Total Indirect and Induced Economic Activity generated, representing approximately $1 trillion between 2025 and 2035 in the Gradual Shift scenario. The sectors most impacted are Automobile Manufacturing, Warehousing and Storage and Electric Power Transmission and Distribution (e.g., through the development of vehicle depots, use of overnight storage, and installation and use of electric vehicle chargers).

Figure 3.5: Total Value of Economic Activity ($ Billion) by Sectors, 2025-2035, Gradual Shift Scenario

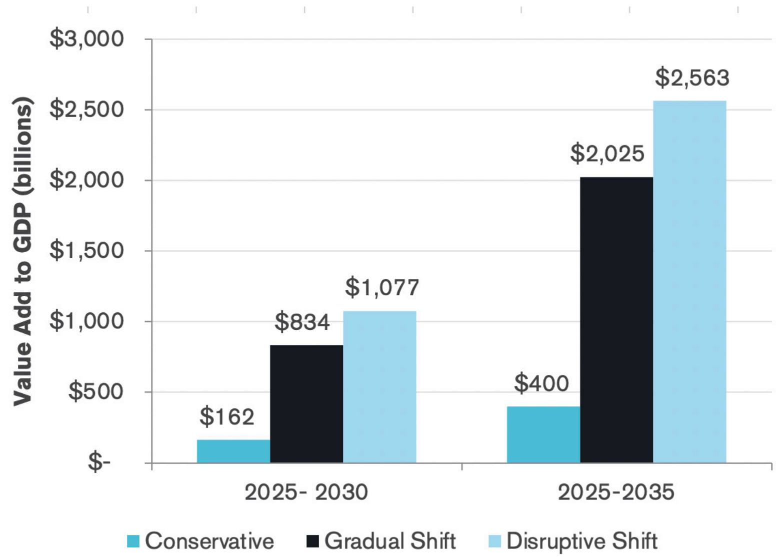


Gross Value Add

The Total Value of Economic Activity (Gross Output) presented on the previous pages provides the total value of production of final goods and services, including the value of intermediate consumption such as raw materials and other resources.

In comparison, Gross Value Add represents the difference between total value of Economic Activity and the cost of Intermediate Inputs during a specified period of time, i.e. the value of a product minus the cost of its materials. This represents the additional income generated in the economy in terms of employee compensation (wages and salaries), proprietor income (net profits), property income (rent, etc.) and government income (from taxes and duties)

Figure 3.6: Value Add to GDP ($ Billion), 2025-2035 – All Scenarios



Key Takeaways

Total Value Add to GDP by delivery AV services is expected to be approximately **$2 trillion cumulatively between 2025 and 2035** for the Gradual Shift scenario, and $2.6 trillion in the Disruptive Shift scenario. In contrast, Total Value Add to GDP is expected to be only $400 billion under the Conservative scenario (Figure 3.6). Indeed, the extent of Value Add to GDP increases more than proportionately with the rise in delivery AV penetration

60% of Total Value of Economic Activity is attributed to the additional incomes generated in the US economy (Value Add to GDP), while about 40% goes towards the purchasing of raw materials and services (cost of Intermediaries). This is much higher compared to an average sector of the US economy, where Value Add to GDP typically accounts for only 45% of the Total Value of Economic Activity[19]. This is consistent with delivery AVs relying on investment in high value-add resources such as technology, retail, and research and development.

19 *Bureau of Economic Analysis, Input-Output Model, retrieved from https://bit.ly/2DeveAW .*

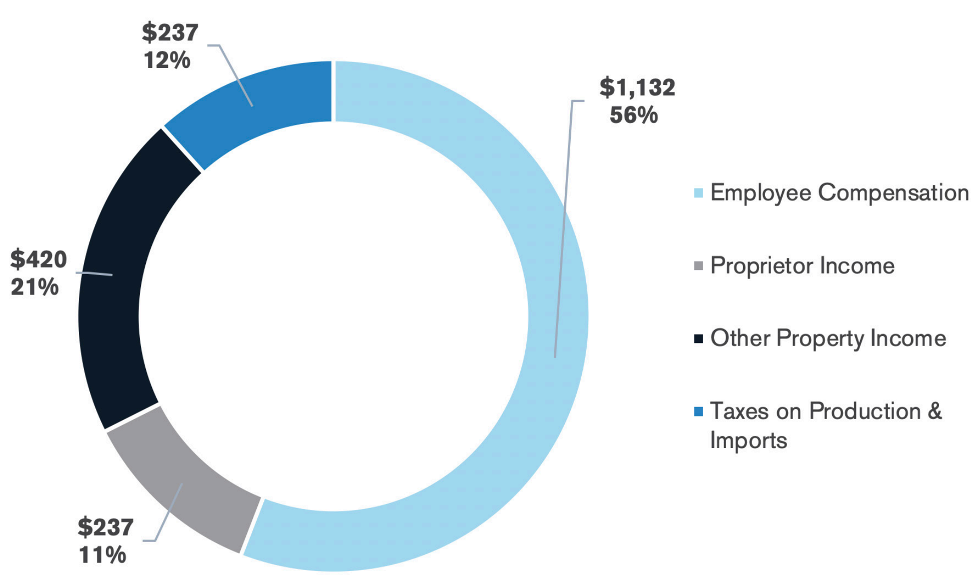
Distribution of Value Add to GDP by Income types

The additional income generated in the US economy as Value Add to GDP can be attributed to four major types of income:

- Employee compensation (labor);
- Proprietor income (entrepreneurship);
- Property income (land); and
- Taxes and duties (government).

The majority of the value added goes to labor. It is estimated that under the Gradual Shift scenario, by 2035, over $1.1 trillion (56% of the Value Add to GDP) will be additional labor income, about $420 billion (21%) will be property related income, $237 billion (12%) could be generated as production tax and import duty income for the US government, while the balance would be proprietor income/profits (**Figure 3.7**).

Figure 3.7: Distribution of Value Add to GDP by Income Type ($ Billion), 2025-2035 – Gradual Shift Scenario



Employment

The deployment of delivery AV services is expected to have a disruptive effect on several industries and professions – including car manufacturers and professional drivers. The future is still uncertain, and the scale of the impact will depend greatly on the extent and speed at which the technology is rolled out, as well as the type of jobs created and consumer practices (i.e. some people will always prefer in-person deliveries).

Factors that could influence the impact on existing employment include the concentration of demand for AV delivery services in sectors that do not yet have a large number of delivery workers (e.g. grocery delivery), demand for curbside vs. at-door or unattended delivery (i.e., the latter deliveries require human delivery workers), the proportion of delivery work that is currently completed by independent contractors versus employees, and the degree to which current delivery workers are hired for positions in delivery AV services (e.g., retail pick-and-pack work).

This section analyzes the potential employment generated by the delivery AV services sector between 2025 and 2035. The move to delivery AVs is expected to create many additional jobs in different sectors either directly or indirectly related to this new technology. This is reflected through the concept of job-years or person-years which a unit of measurement for work done by an individual throughout the entire year. One job for one year is one "job year." If that job continues for another 12 months, it is two "job years."

Key Takeaways

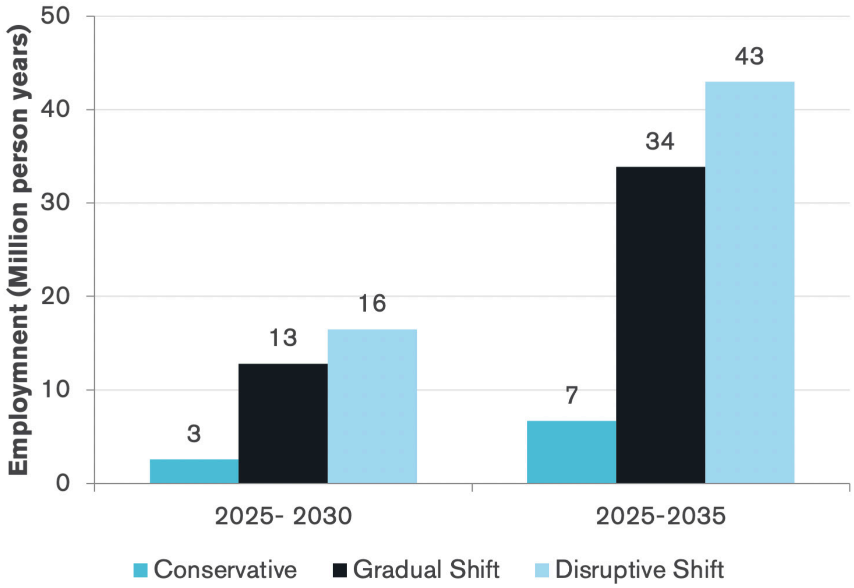
Based on the type of investment that goes into different supplying sector such as automobile manufacturing, sensors, electronic equipment and technology, business services, real estate, and the direct employee compensation made within the delivery AV services sector to technicians, pick and pack workers, software engineers, it is estimated that total employment generated would be approximately **34 million job-years between 2025 and 2035**[20] across all impacted industries under the Gradual Shift scenario. This implies an average of 3.4 million jobs every year.

At least 7 million jobs would be generated between 2025 and 2035 if demand follows the Conservative scenario, and the impact could be as high as 43 million jobs in the Disruptive Shift scenario (**Figure 3.8**)

This study is an economic impact analysis, which calculates the total gross economic impact on the US economy of the anticipated investment in delivery AV technology and services. Unlike a cost-benefit analysis, this methodology produces estimates of impacts on the whole economy and does not quantify benefits or costs for particular groups, including labor (or subsets of labor, like existing delivery workers and new retail workers), industry, or government.

20 Or 'person years' of employment.

Figure 3.8: Total Employment (Million person years), 2025-2035 – All Scenarios

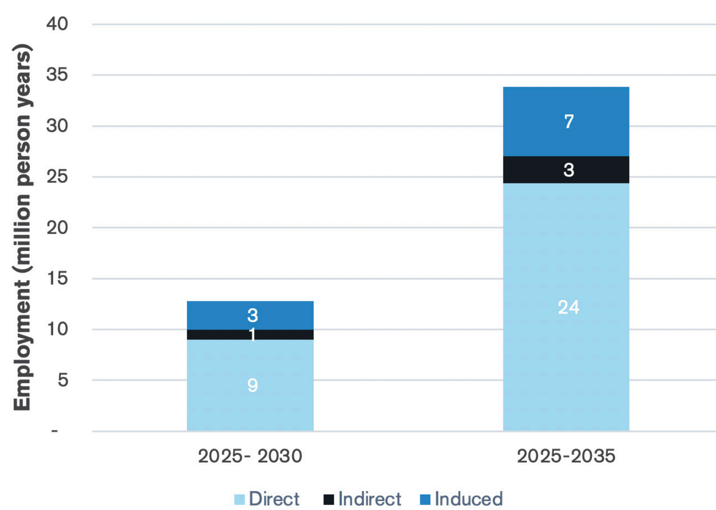


The analysis finds that each $1 million investment by the delivery AV services sector creates between 25-26 jobs under the Gradual Shift scenario.

Employment by type of Impacts

Almost 72% of the new jobs or employment created (24.4 million) cumulatively over the study period under the Gradual Shift scenario would be direct employment by the delivery AV services sector. For example, while today a consumer may drive themselves to the grocery store and pick out their own groceries, if instead they request a delivery AV, the grocery store would need additional workers to pick and pack that order, and AV operators will need fleet technicians to oversee and maintain the vehicles used (including vehicle maintenance, sensor calibration, EV charging, cleaning, dispatching, and oversight during operations). The remaining employment will be indirect or induced due to increased demand/economic activity in the US economy (Figure 3.9).

Figure 3.9: Employment (Million person years), 2025-2035, Gradual Shift Scenario



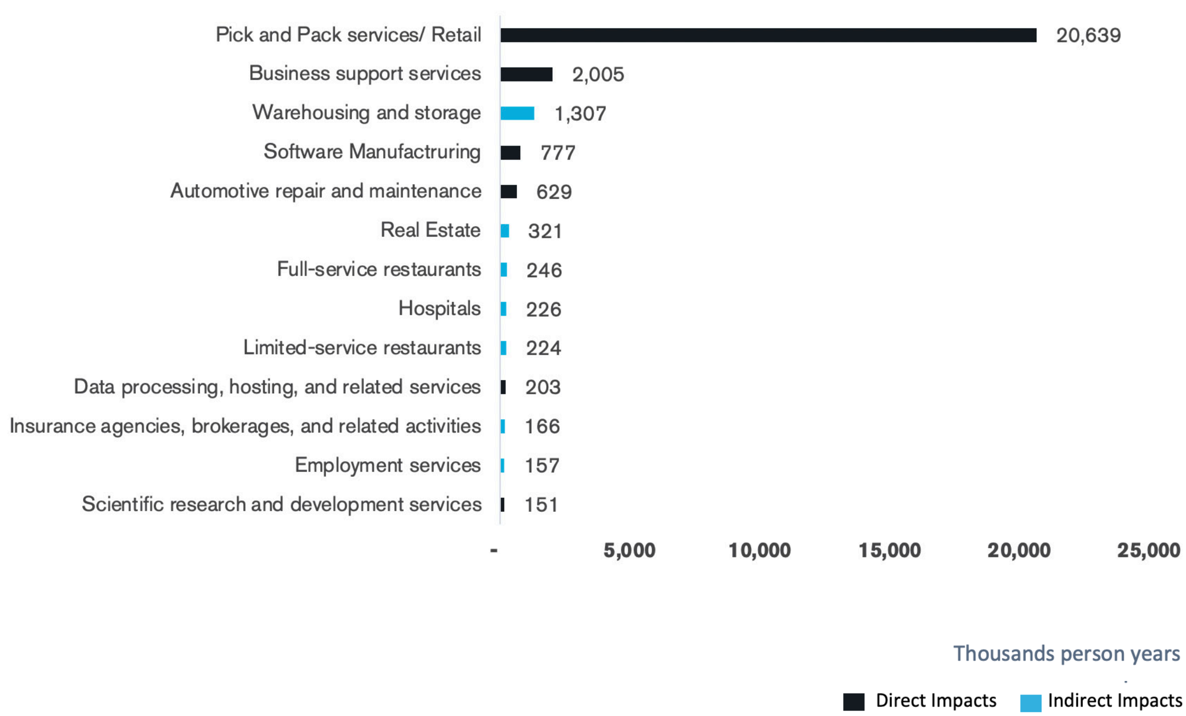
Employment by Industry

In the Gradual Shift scenario, 85% of the 24.4 million of direct employment created, would be staff required to operate the delivery AV services (such as pick and pack workers) and the remaining 15% would include software engineers, fleet technicians and business support staff.

The top industries to generate additional indirect and induced employment include Warehousing and Storage (15% of indirect and induced new employment), Restaurants (5%) and Real Estate (3%) (Figure 3.10).

These top industries combined would account for over 80% of new employment generated, representing 26 million jobs by 2035.

Figure 3.10: Employment (Thousand person years) by Sectors, 2025-2035, Gradual Shift Scenario



Wider economic impacts

4

Background

Introducing delivery AVs will provide both direct and wider social and environmental impacts within the US economy. The scale of these benefits will depend on the number of delivery AVs on the road at a given time.

The Department of Transportation (DOT) describes several potential benefits of AVs:

"…crash avoidance, reduced energy consumption and vehicle emissions, reduced travel times, improved travel time reliability and multi-modal connections, improved transportation system efficiency and improved accessibility, particularly for persons with disabilities and the growing aging population."[21]

According to DOT, these benefits arise from several potential effects of AVs on the transportation system:

- The reduction of crashes caused by human error (up to 94% of crashes);
- Dramatically improved throughput via reduced vehicle following distances and other improvements in vehicle operations and traffic management via advanced sensors and route planning software;
- Improved mobility and access to fresh food for those unable or unwilling to drive; and
- Reduced fuel consumption and associated environmental impacts as AVs are likely to be powered by an electric motor.

In addition, the use of delivery AVs allows users to save productive hours that would otherwise be spent on driving. This is even more significant in urban areas, where congestion and parking issues increase journey times by 30-40%[22].

This section aims to quantify the wider social/environmental benefits from replacing private car trips with delivery AV trips, and quantify the specific benefits in the following categories:

This section aims to quantify the wider social/environmental benefits from replacing private car trips with delivery AV trips, and quantify the specific benefits in the following categories:

- Road safety impacts;
- Time savings impacts; and
- Emission saving impacts due to the choice of electric vehicles

Benefits associated with congestion, accessibility, and avoided infrastructure expense are not quantified here.

Methodology

The USDOT's 2018 'Benefit Cost Analysis Guidance for Discretionary Grant Programs' has been used as a foundation for this analysis. The guidance provides estimated monetary (US$) values of road inefficiencies such as road crash injuries and fatalities, emissions (grams/mile) and value of lost time.

Using US traffic data on road collisions and fatalities per VMT (FARS), emissions (grams/mile) (EIA) and journey time per mile (NHTS), we have estimated the real savings in terms of road collisions avoided, emissions and time saved for each of the milestone years based on the demand for delivery AVs and total private car VMT replaced by delivery AVs (highlighted in Section 2).

Detailed methodology and data sources are included in Appendix E.

21 *US Department of Transport, 2015, Automated Vehicle Research, Research Fact Sheets, retrieved from https://www.its.dot.gov/factsheets/AutomationUSDOT.htm*

22 *TomTom Traffic Index, 2019.*

Key Takeaways

Across the US, delivery AV services are expected to result in 244,000 fewer road collisions that cause injuries and/or fatalities, leading to a reduction of 348,000 road injuries and 4,800 fatalities between 2025 and 2035 under the Gradual Shift scenario. The estimated value of road safety savings is almost $397 billion for the years 2025 to 2035.

Reduction in road collisions by delivery AVs

About 6 million road collisions occur in the US every year, out of which 1.9 million lead to minor injuries and about 35,000 are fatal collisions or lead to fatalities[22]. **Table 4.1** shows the average collision and fatality rate per 100 million VMT in the US in 2017[23].

Table 4.1: Road Collisions, Injuries and Fatalities (FARS, 2017)

	Number	Incidence per 100 million VMT
Collisions		
Total number of Collisions that leads to Injuries	1,888,525	88.5
Total number of Fatal Collisions	34,560	1.6
Impact of Collisions		
Injuries (Minor and serious)	2,746,000	128.7
Traffic Fatalities	37,473	1.8

22 *FARS, 2017 data retrieved from https://cdan.dot.gov/query.*

23 *These rates are assumed to remain constant during the forecast period (2025-2035).*

Delivery AVs are expected to improve road safety in two primary ways:

- Delivery AV technology is expected to reduce the frequency of collisions and reduce the number of people at risk in any potential collision because there are no human occupants in the delivery AV; and
- Economies of batching will lead to overall less VMT, contributing to a lower overall risk exposure to collisions.

Delivery AV technology impact on reduction in road collision injuries and fatalities

The safety benefits of AVs will improve with the increased penetration of AVs in the total fleet. Various academic studies suggest that a 10% penetration of AVs in total fleet leads to 6% reduction in crashes[24]. Given that delivery AVs will not have any passengers on board, and can be designed with additional safety features such as narrower width, lighter weight, and designs that prioritize other road users, we make the assumption that the impact of delivery AVs on injuries and fatalities should be at least double that of a passenger AV per VMT.

Applying this past research on crash reductions at different levels of penetration, we calculated the expected percentage reduction in crash frequency at different levels of delivery AV penetration for the three different scenarios (estimated in Section 2), as shown in Table 4.2.

24 *D. J. Fagnant and K. Kockelman (2015); K. Kockelman and all (2017).*

Table 4.2: % Reduction in Injuries & Fatalities due to delivery AVs avoiding crashes

Scenario	2025	2030	2035
Conservative	0.0%	0.2%	0.4%
Gradual Shift	0.2%	1.6%	8.0%
Disruptive Shift	0.2%	5.0%	22.0%

Based on these assumptions, we estimate that under the Gradual Shift scenario, approximately 23,000 collisions that would have caused 32,500 injuries and 450 fatalities could be avoided between 2025 and 2035. Indeed, the 653 billion VMT by delivery AVs under the Gradual Shift scenario are assumed to lead to up to 8% reduction in road collisions per total VMT by 2035, thanks to the technology's safer driving when compared to human operation.

The total number of collisions avoided would be up to three times higher under the Disruptive Shift scenario, with approximately 81,000 collisions avoided, equating to a reduction of 115,000 injuries and 1,600 fatalities. One reason for the much higher impacts in this scenario is that a rapid transition to higher rates of AV penetration would yield exponential improvements in road safety, as autonomous technology is able to communicate and adapt to one another, thereby reducing the potential for human errors (22% decline in road injuries and fatalities by 2035 in the Disruptive Shift scenario compared to only 8% in Gradual Shift scenario).

Economies of batching can help reduce road accident injuries and fatalities

Delivery AV services can make multiple deliveries per trip, unlike the personal car trips to and from the store that they could largely replace. Delivery AVs are expected to include diverse models, ranging from vehicles with two compartments like Nuro's R2 to vehicles that can deliver eight or more orders per trip. Customers are likely to be more tolerant of batching in delivery than in the ridehailing context, where customers directly share personal space in the vehicle. Nonetheless, we conservatively assume that in the Gradual Shift scenario, batching rates would be 1.0 orders per trip in 2025, 1.2 in 2030, and 1.6 by 2035, when overall delivery AV penetration is higher.

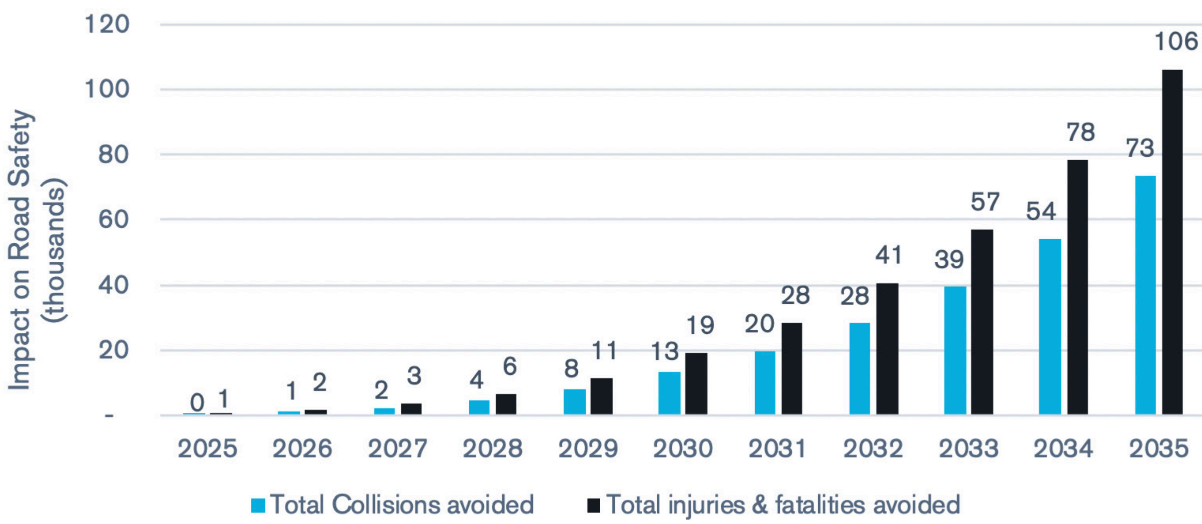
Under the Gradual Shift scenario, economies of batching would lead to 35% lower VMT compared to VMT by private car shopping trips from 2025-2035. By fully eliminating the risk exposure from a mile that's no longer driven at all, the number of collisions and associated road injuries and fatalities are reduced by 100%.

A total of 245 billion VMT could be saved between 2025 and 2035 under the Gradual Shift scenario through the economies of batching with delivery AV services. In addition to the delivery AV technology impacts described above, this reduction in total VMT would lead to an additional 221,000 reduction in road collisions, which could have led to about 316,000 injuries and 4,300 fatalities in the US during that time. This analysis does not include impacts from the potential for a lower rate of crashes per mile if there are overall fewer vehicles on the road, or from the possibility that other people could drive more if the roadways become less crowded.

Total impact on reduction in road accident injuries and fatalities

When combining both factors, under the Gradual Shift scenario, the US economy is expected to avoid 244,000 road collisions between 2025 and 2035, reducing injuries by 348,000 and fatalities by 4,800. In the year 2035 alone, about 73,000 road collisions, which might have led to 105,000 road injuries and 1,430 fatalities, could be avoided (**Figure 4.1**). The impact is estimated to be double that in the Disruptive Shift scenario, in which uptake of autonomous vehicles is higher.

Figure 4.1: Delivery AVs Impact on Road Safety, 2025-2035 – Gradual Shift Scenario



Value of Road Safety to the US economy

The value of road safety improvements to the US economy due to delivery AV services is calculated based on government standard monetary estimates of the statistical value of life[26], which varies with the severity of accident injury (Appendix C). Our analysis excludes other non-health related savings, such as property damage avoided, which if included would increase the values presented by around a third[27].

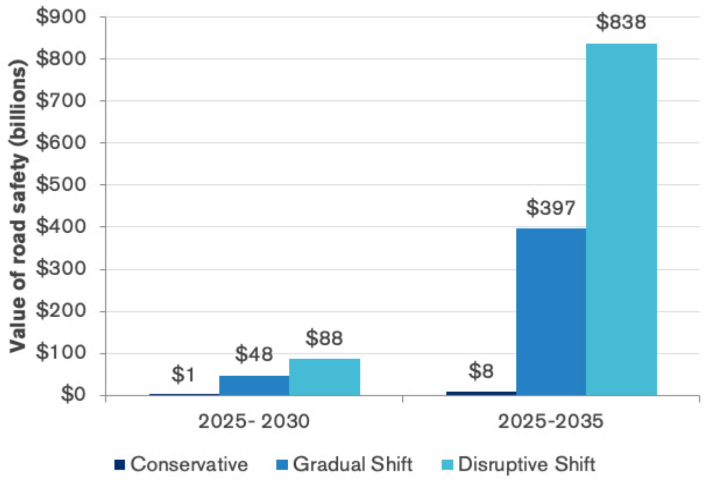
In the Gradual Shift scenario, the expected benefits of delivery AV services replacing car trips for shopping and errand purposes in reducing road accident injuries and fatalities is valued at $397 billion for the years 2025 to 2035.

The value would be more than double for the Disruptive Scenario, at approximately $840 billion between 2025 and 2035 (Figure 4.2).

26 US DOT, 2018, Benefit-Cost Analysis Guidance for Discretionary Grant Programs.

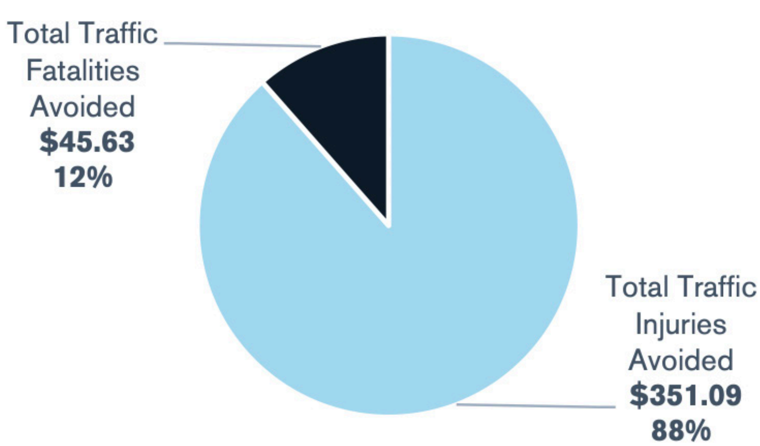
27 According to NHTSA, 29% of the cost of crashes is economic impacts beyond the lost quality of life https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812013.

Figure 4.2: Value of Road Safety ($ Billion), 2025-2035, All Scenarios



About 88% of total value created due to road safety improvements is attributed to a reduction in road injuries (minor or serious), while the remaining 12% is due to reductions in actual road fatalities. Approximately, $45.6 billion can be saved between 2025 and 2030 by avoiding road fatalities under the Gradual Shift scenario (Figure 4.3).

Figure 4.3: Value of Road Safety (by injury type), $ Billion, 2025-2035, Gradual Shift Scenario



States Analysis of Road Safety Impacts

We have estimated the road safety impacts for the two US states of California and Texas.

California: It is estimated that for the Gradual shift scenario, approximately 18,650 road collisions can be avoided between 2025 and 2035, reducing road injuries by 26,000 and fatalities by 350. The monetary value of this improved road safety is estimated at $30 billion.

Texas: Similarly, under the Gradual shift scenario, the state of Texas could potentially avoid 34,000 road collisions that might have caused 48,300 road injuries and 700 fatalities. The monetary value of this road safety savings is estimated to be $55 billion.

Time Savings Impacts

Key Takeaways

Approximately **21 billion person hours** can be saved between 2025 and 2035 in the Gradual Shift scenario. **That is roughly equivalent to 11 vacation days per year per person using the services.** The number would be 50% higher in the Disruptive Shift scenario.

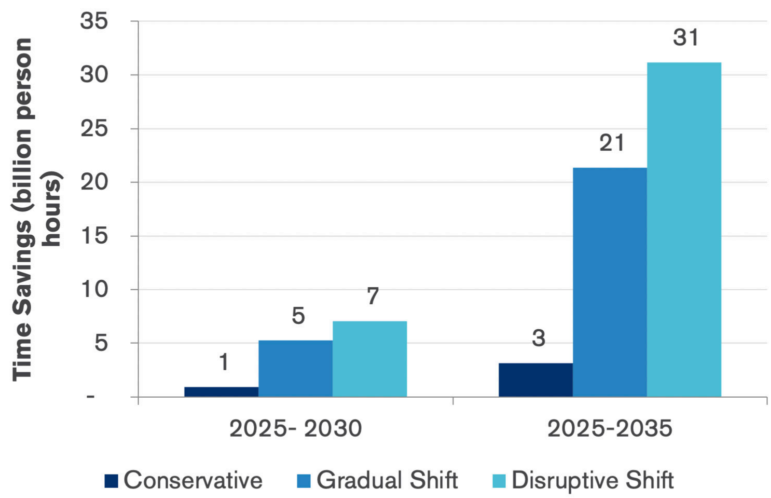
The expected time savings are valued at $316 billion for the years 2025 to 2035.

Replacing car trips for shopping and errand purposes with delivery AV services can potentially save billions of dollars for the US economy. On average, it takes about 1.5 minutes to drive a mile in a car in the US (NHTS, 2017). On this basis we have calculated the amount of driving time saved by multiplying time spent to travel per mile for shopping trips with total VMT replaced by delivery AVs for each of the scenarios.

The time savings impacts could potentially be higher as they exclude time spent shopping in stores and longer travel times, as many shopping trips are undertaken on neighborhood roads with slower traffic speeds than the national average. These calculations also only account for the time savings for the driver, although in practice shopping and errands trips have on average 1.5 people in the vehicle (NHTS,2017).

Approximately 21 billion person hours could be saved between 2025 and 2035 in the Gradual Shift scenario, and 31 billion hours could be saved in the Disruptive Shift scenario. Time saved annually for the Gradual Shift scenario rises from about 300 million person-hours in 2025, to 1.7 billion in 2030 and 4.5 billion person hours in 2035. This implies that an average person using the service can free up approximately 87 hours[28] from driving to stores in just 2035 under the Gradual Shift scenario, which is as much time as one takes off work with 11 vacation days (**Figure 4.4**).

Figure 4.4: Time Savings (Billion Person hours), 2025-2035 – All Scenarios



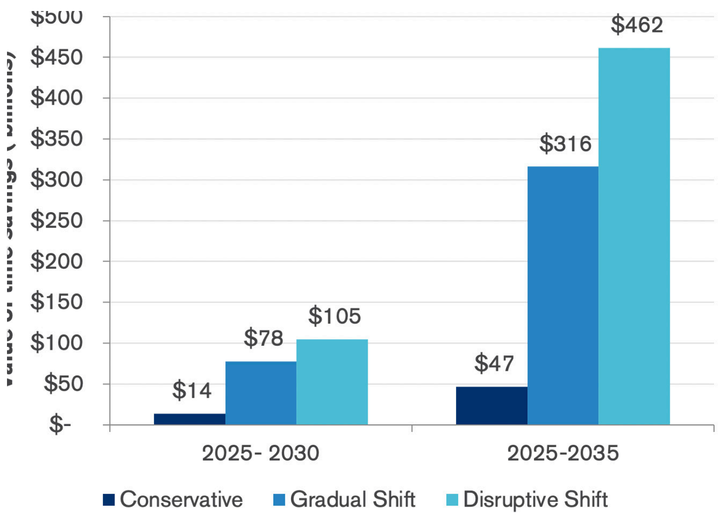
28 *Based on the assumptions that total licensed drivers in US is 227 million in 2019 and 23% of them would use the service as we assumed it in the Gradual Shift scenario.*

Value of Time Savings to the US economy

Based on the standard government monetary estimates of the value of time[29] (Appendix E), we calculated the value of total time savings for replacing car trips by delivery AV services.

The expected savings to users of delivery AV services is valued at $316 billion for the years 2025 to 2035 under the Gradual Shift scenario. The value for the Disruptive scenario would be $460 billion between 2025 and 2035, or approximately $45 billion under the Conservative scenario (Figure 4.5).

Figure 4.5: Value of Time Savings ($ Billion) – All Scenarios



States Analysis of Time Savings Impacts

We have estimated the time

savings impacts for the two US States of California and Texas.

California: For the Gradual Shift scenario, it is estimated that approximately 2.1 billion person hours of travel can be avoided between 2025 and 2035, which corresponds to 53 hours per driver per year. The value for time saving is estimated at $32 billion.

Texas: Similarly, under the Gradual Shift scenario, the state of Texas could potentially avoid 3 billion person hours of travel, which corresponds to 96 hours per driver per year. The value of time savings is estimated to be $44 billion.

Despite a lower population in Texas compared to California, the time savings impacts are more significant in Texas because a higher share of the population in Texas currently uses private vehicles for daily trip purposes, thereby creating a higher opportunity for shopping and errands trips to be replaced.

29 *US DOT, 2018, Benefit-Cost Analysis Guidance for Discretionary Grant Programs.*

Emission Savings Impacts

Key Takeaways

A total of 407 million short tons of CO2 emissions can be saved between 2025 and 2035 due to delivery AVs in a Gradual Shift scenario. This is the equivalent of 88 million passenger vehicles off the road for one year Additionally, approximately 236,000 tons of NOx, 8,000 tons of PM 2.5, and 345,000 tons of VOC could be avoided. The expected emission savings are valued at $6 billion for the years 2025 to 2035.

Delivery AVs are likely to not only be electric powered, but also lightweight compared to standard gasoline vehicles and autonomous passengers-vehicles, leading to significantly lower levels of emissions per VMT. In this study, in comparison to gasoline powered private vehicles, delivery AVs are assumed to be 50-100% more efficient in terms of NOx, PM 2.5, VOC and CO2 (Table 4.3). The analysis also assumes a reduction in emissions from lower overall VMT by delivery AVs compared to private vehicle trips, enabled by the economies of batching.

Only a very small proportion of US private vehicle fleet are currently EVs (less than 1% of all US vehicles today), although this is expected to increase over time. Additionally, the proportion of VMT travelled by private EVs for shopping trips in future years is uncertain. Therefore, for this analysis, we have assumed that all the trips replaced by delivery AVs would have otherwise been made by private gasoline vehicles. The Edison Electric Institute estimates that 7% of US cars and light trucks will be electric by 2030[30]; the avoided emissions forecast here could be proportionally reduced (e.g., by 7%) to the degree that delivery AVs replace trips by electric vehicles. For this study we do not consider the emissions generated by electricity or gasoline production, or by manufacturing vehicles

Table 4.3: Emissions by an Average Vehicle (EPA)

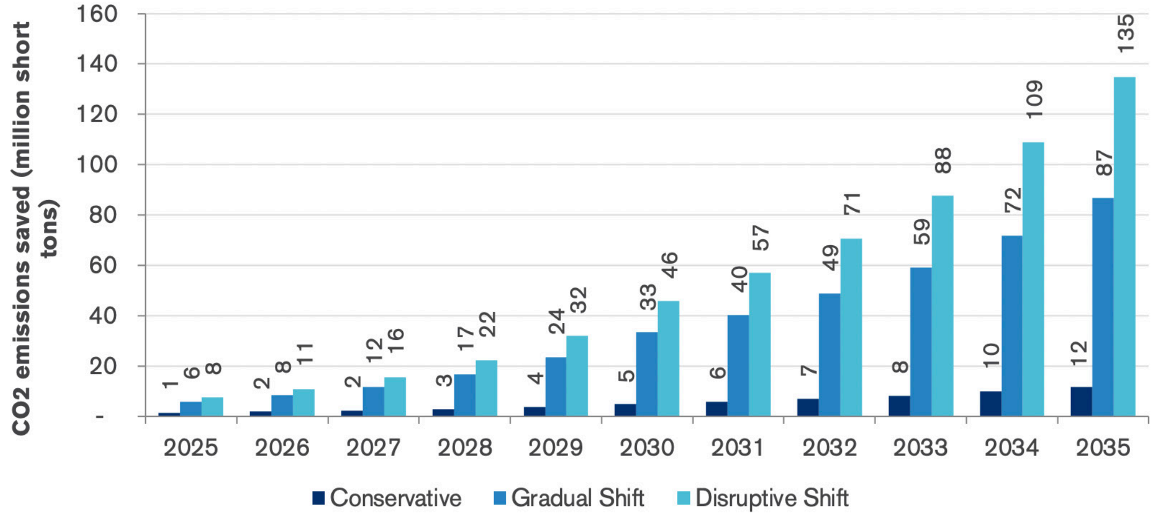
Emission type	Gasoline Light duty vehicle (grams/ mile)	Delivery AVs (grams/ mile)	% Reduction in emissions
NOx	0.289	0.069	76%
PM 2.5	0.012	0.006	51%[31]
VOC (HC)	0.350	0.002	100%
CO2	411.000	0.000	100%

A total of 407 million short tons of CO2 emissions can be saved between 2025 and 2035 in the Gradual Shift scenario. This is the annual equivalent 88 million passenger vehicles off the road for one year. This figure would be 40% higher under the Disruptive Shift scenario (**Figure 4.6**).

30 https://www.eei.org/

31 Compared to an average gasoline ICEV, EVs emit 3% less PM2.5. However, the light weight of delivery AVs would lead to higher reductions in PM 2.5. See: https://bit.ly/2DfxxUb.

Figure 4.6: Annual CO2 Emissions Saved (Million Short tons), 2025-2035 – All Scenarios



In addition to CO2 emissions, we have estimated the potential reductions in other types of emissions. Between 2025 and 2035 under the Gradual Shift scenario we estimate the following emissions savings:

- 236 thousand short tons of Nitrous Oxides (NOx);
- 8 thousand short tons of Particulate Matter 2.5 (PM 2.5); and
- 345 thousand short tons of Volatile Organic Compounds (VOCs).

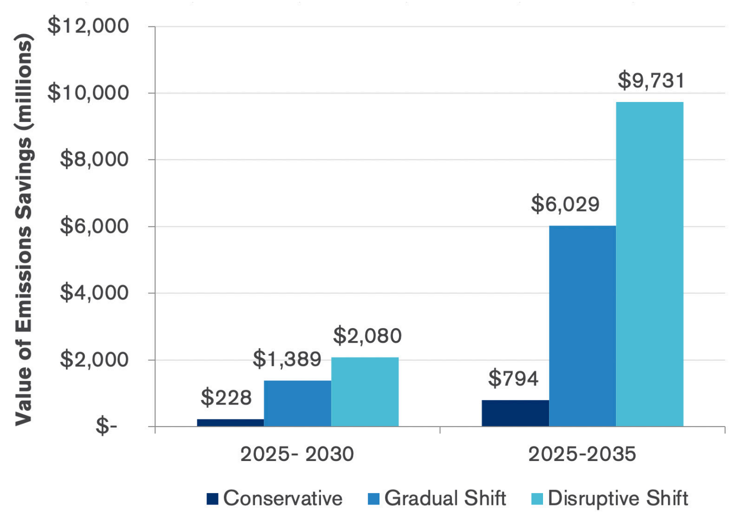
These reductions are almost 50% higher under the Disruptive Shift scenario.

Value of Emissions Savings to the US economy

Based on monetary estimates of the value of different types of emissions (Appendix E), we have calculated the value of total emission savings for replacing car trips with delivery AV services, based on the assumption that delivery AVs are likely to be electric powered compared to gasoline vehicles generally used for private vehicle trips.

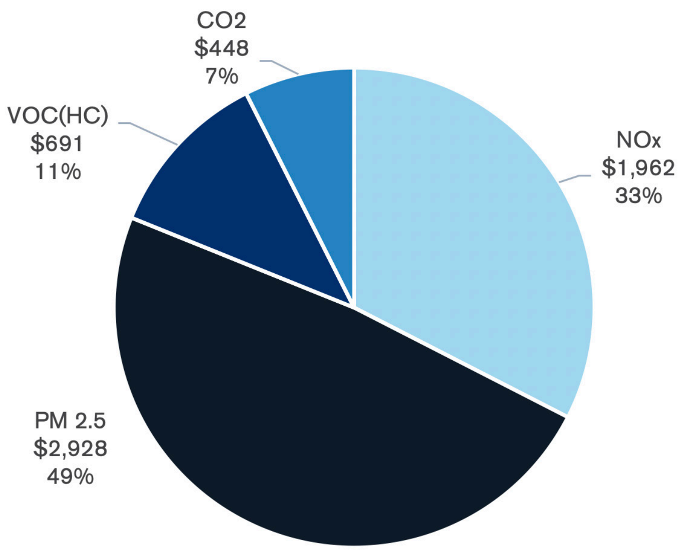
A total of $6 billion can be saved from emissions avoided in the US under the Gradual Shift scenario, which would increase to $9.7 billion in the Disruptive Shift scenario (Figure 4.7). An average of $548 million is saved every year between 2025 and 2035 in the Gradual Shift scenario.

Figure 4.7: Value of Emissions Savings ($ Million), 2025-2035 – All Scenarios



In the Gradual Shift scenario, almost 50% of the emission savings in value comes from reduction in PM 2.5, followed by NOx (33%), VOC (11%) and CO2 (7%) (Figure 4-8)[32]

Figure 4.8: Value of Emissions Savings by Type of Emissions ($ Million), 2025-2035 – Gradual Shift Scenario



States Analysis of Emission Savings Impacts

We have estimated the emission savings impacts for the two US States of California and Texas.

California: For the Gradual Shift scenario it is estimated that approximately 40.8 million short tons of CO2, 24,000 short tons of NOx, 1,000 short tons of PM 2.5 and 35,000 short tons of VOC can be saved by 2035. The value for emissions saving is estimated at $604 million.

Texas: Similarly, under the Gradual Shift scenario, the state of Texas could potentially eliminate approximately 56.6 million short tons of CO2, 33,000 short tons of NOx, 1,100 short tons of PM 2.5 and 48,000 short tons of VOC by 2035. The estimated value of emissions savings is approximately $840 million.

32 *Note that this calculation relies on the 2017 BCA guidebook from USDOT, which revised the social cost of carbon per metric ton to $1. Previously, the social cost of carbon was set at $39; if this value were used, the emissions benefits would be $16 billion higher for the time period 2025-2035, and CO2 would account for 75% of emissions benefits.*

The Way Forward

5

There is a potential for significant economic benefits to the US from the development of AV delivery services. To achieve these societal benefits (saved lives, saved time and reduced air pollution), public and private sector players will need to collaborate. Looking ahead, Steer has prepared the following recommendations to ecosystem players (operators, regulators, etc.):

- **Increase of experimentation and testing** – to identify additional potential use cases scenario for delivery AV services and a broader range of social benefits. As local context varies, a one-size-fits-all approach will not suffice.
- **A more harmonized regulatory environment** – today's heterogeneous regulatory landscape makes it more difficult for the private sector to plan, which can create compliance challenges and limit the ability for the industry to develop scalable, standardized services. Creating a harmonized regulatory environment would help improve strategic planning and investment and therefore unlock economic and wider benefits.
- **Develop community outreach and engagement** to better understand the drivers and challenges to delivery AVs' acceptability and achieve early consensus across stakeholders and geographies.
- **Ensuring equitable job creation** – further cost benefit studies should be conducted focusing on the impact of delivery AV technology on different groups and the potential for job creation in communities, so that policies (such as job training programs) may be implemented to ensure the widest societal benefit is achieved.
- **Work closely with the wider mobility ecosystem to complement multi-modality** – AV delivery services help facilitate the wider mobility ecosystem of a city (e.g. complementing transit and other mobility services to reduce the reliance on single occupancy vehicle use).
- Through collaborative work between all industry players, **assist to the best of their abilities local governments and communities in the COVID-19 crisis.**

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6

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Interview with experts

Steer has conducted interviews with external parties regarding demand outlook and economic impact. Their expertise covered a large spectrum of topics including retail, AV technology, road safety and labor. These interviews fed into the demand outlook and were used for the final recommendations.

Appendices

7

A
Levels of autonomy in-scope

The internationally recognized standard for automated driving in on-road vehicles (SAE International Standard J3016) defines six levels of driving automation, from “no automation” (Level 0) to “full automation” (Level 5) as presented below Table A.1

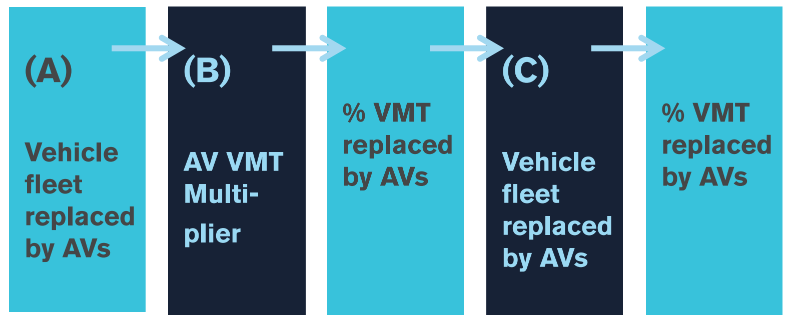
For this study,the vehicle segments included for the uptake scenarios are autonomous vehicles for the road with levels of autonomy of Level 4 or above.

A.1: Spectrum of Automated Driving

Spectrum of Automated Driving (source: NHTSA, SAE) Who does what, when?			**Sustained lateral and longitudinal vehicle motion control**	**Object and event detection and response**	**Dynamic driving task fallback**	**Opera-tional design domain**
0	**No Automation**	Human driver has complete authority on his vehicle; the driver performs all driving tasks.	Driver	Driver	Driver	76%
1	**Feet off - Driver Assistance**	Human driver has complete authority but cedes limited fundamental control to the vehicle in certain normal driving or crash-imminent situations.	Driver and System	Driver	Driver	51%
2	**Partially Hands off - Monitored Automation**	Human driver must remain engaged with the driving task and monitor the environment at all time, but the vehicle now combined automated functions	System (or ADS)	Driver	Driver	100%
3	**Hands off - Conditionally Automated driving**	The vehicle handles most functions in mapped locations. Human driver may be requested to intervene.	System	System under certain condi-tions	Driver (Fallback-ready user)	100%
4	**Eyes off - High Automation**	Full automation in some driving modes.	System	System	System	Limited
5	**Mind off - Full Automated Mode**	Human driver provides destination or navigation input but is not expected to be available for control. Responsibility for safe operation rests solely on the automated system.	System	System	System	Unlimited

B Methodology to develop Delivery AV deployment Scenarios

General approach to forecast the delivery AVs market size



(A) Vehicle fleet replaced by AVs

The approach to forecast the demand for delivery AVs involves an extensive review of existing literature on the penetration of autonomous vehicles in near term (next 5 years) and long term (by 2035). The likely vehicle fleet to be replaced by AVs (% of all vehicles replaced by AVs by 2035) is estimated for the three future scenarios through the S&P Global Ratings report[33] scenarios as per followed approach:

- Reviewed and compared extensive available different market forecast (from academic and specialized credit rating agencies and strategy consultants) estimates on the future of AV industry;
- Evaluated estimates based on date of estimate, market trends, expert interviews, and Steer experience / judgment and peer review; and
- Selected S&P forecast as reflecting the consensus results of several other forecasts and closely aligning with Steer's view.

We then applied Steer's scenarios based of primarily four factors:

Table B.1:Scenarios assumptions

#	Category	Details
1	Advancements in AV technology and safety standards globally.	The pace of technological transition towards vehicle automation in the U.S.
2	Policies and regulations supporting testing and deployment of AVs on public roads.	The level of possible government intervention to manage the deployment of AVs on U.S. public roads.
3	User acceptance and willingness to pay for autonomous vehicles.	The rate of adoption of the vehicle fleet, primarily based on all-in cost of the vehicles.
4	Attitude towards new mobility.	The pace of urban mobility no longer following traditional patterns of motorization with increased adoption of alternative modes including ridesharing, ridehailing,multimodal travel options and electric vehicles.

(B) AV VMT Multiplier

For the purposes of this study, it is assumed that:

- In a Conservative scenario, AVs are expected to be launched in shared forms only and will travel more vehicle miles per vehicle compared to non-AVs (likely AV to Non-AV VMT: 2:1);
- In a Gradual Shift scenario, AVs are expected to continue to be used in shared forms and will travel more than proportionate vehicle miles compared to non-AVs (likely AV to Non-AV VMT: 2:1); and
- In a disruptive scenario, we assume there will be higher uptake in private AVs leading to a gradual decline in ratio of non-AV VMT and AV VMT (likely AV to Non-AV VMT: 1.5:1)

It is important to note that the model assumes that the overall vehicle fleet will remain constant at current levels of approximately 200 million[34] registered private passenger cars and light trucks (a general trend witnessed since 2014) during our forecast period. It is possible that the vehicle fleet might decline over time with changing attitudes towards shared vehicles. Therefore, even though AVs may potentially travel more than 2x (Gradual Shift scenario) miles per year compared to non-AVs, the AV VMT multiplier is capped at 2.

(C) Delivery Multiplier

The key drivers' factors have been analyzed and discussed during experts' interviews in order to evaluate the potential for delivery AVs to replace private vehicle trips for shopping purposes. A qualitative scoring is then used to develop the Delivery Multiplier in order to capture the positive impact of increasing delivery demand on VMT by delivery AVs compared to standards AVs. There is evidence that suggests customer acceptance of delivery AVs will be higher compared to passenger AVs due to lower safety concerns.

Table B.2 below highlights key delivery related elements by scenario:

34 Light duty vehicle, short wheel base. Source: Bureau of Transport Statistics (https://www.bts.gov/content/number-us-aircraft-vehicles-vessels-and-other-conveyances)

Table B.2: Key performance metrics used to estimate % of VMT replaced by delivery AVs by 2035

#	Conservative	Gradual Shift	Disruptive Shift
(A) % Vehicles replaced by AVs	1.3%	9%	19%
(B) AV VMT Multiplier	2	2	1.5
% VMT replaced by AV	2.6%	16%	25%
(C) Delivery Multiplier	1.2	1.4	1.4
% VMT Replaced by delivery AVs	**3%**	**23%**	**35.5%**

C
US Demand for Delivery AV Services Methodology

General assumptions

The analysis aims to assess the addressable potential demand for delivery AVs when the vehicles could be commercially available in the U.S. Based on the estimates about future potential in-scope car trips, we have evaluated how many delivery AVs would be required for the forecast period 2025, 2030 and 2035 for each of the three scenarios.

In order to do so, the following assumptions have been made:

- Our analysis focuses on delivery AVs replacing private car trips and does not include analysis of potential impact on trips by other modes such as transit, and walking;
- this study uses 'status-quo' growth assumptions - which means socio-economic factors will greatly impact person trips and VMT and are expected to follow recent market trends to forecast annual in-scope trips and VMT for 2025, 2030 and 2035; and
- .The analysis assumes that delivery AVs will be available for commercial use, at least in a fleet model, by that time frame.

Forecast demand for delivery AVs

Vehicle and trips in Scope

Assuming annual VMT by private vehicles in US would increase in proportion to increases in socio-economic factors such as GDP and Population, we forecasted the growth in total in-scope VMT by 2035 for each of the three scenarios. The NHTS survey responses (raw data) on person trips and VMT were analyzed to calculate the trips that are in scope of the study. Table C.1 highlights the modes that are in scope:

Table C.1: Vehicle modes in scope

Vehicle mode in-scope	Vehicle mode not in-scope
Car; SUV; Taxi / limo (including Uber / Lyft); Pickup truck; Vans; Rental car (Including Zipcar / Car2Go).	Walk; Bicycle; Subway / elevated / light rail / streetcar; Airplane; public or commuter bus; Amtrak / Commuter rail; Motorcycle / Moped; Private / Charter / Tour / Shuttle bus; Golf cart / Segway; Boat / ferry / water taxi Paratransit / Dial-a-ride; School bus; RV (motor home, ATV, snowmobile); City-to-city bus (Greyhound, Megabus).

By analyzing destination trip purposes of the legacy round trips ("main purpose" of the trip) within the 2017 US NHTS survey, we estimated the proportion of legacy round trips in different categories made for buying goods/ meal purposes (i.e., in scope purposes). We determined that a portion of trips made for the below purposes could be replaced by delivery AV services:

- Buy goods (groceries, clothes, appliances, gas)
- Buy meals (go out for a meal, snack, carry-out)
- Buy services (dry cleaners, banking, service a car, pet care)
- Other general errands (post office, library)

Person trips and Vehicle Miles Traveled (VMT) Baseline Forecasts

Findings from the Regression analysis:

The forecasting model gives baseline forecasts for person trips and VMT growth, assuming socio-economic factors only. Other factors that affect peoples' travel choices, such as fuel prices, vehicle prices, congestion, etc. are not considered.

While both Person trips and VMT increase with a rise in GDP (income), a rise in population leads to a slight increase in person trips but overall decline in VMT in the US.

- Person trips

= Elasticity to GDP (Source: BEA) = 0.82, i.e. 1% growth in GDP leads to 0.8% growth in annual person trips

= Elasticity to Population (Source: Historical BES, Forecasts US Census) = 0.07, i.e. 1% growth in population leads to only 0.07% growth in annual person trips

- Vehicle Miles traveled (VMT)

= Elasticity to GDP (Source: BEA) = 0.78, i.e. 1% growth in GDP leads to 0.8% growth in annual VMT

= Elasticity to Population (Source: Historical BES, Forecasts US Census) = -0.11, i.e. 1% growth in population leads to 0.1% decline in annual VMT

Assuming a percentage of total person trips/VMT by private vehicles in scope that are constant at 2017 levels[35], we calculate total in-scope trips/VMT for the forecast period (see C3 and C4 for the methodology). This gives us the total in-scope trips/VMT that can be potentially replaced by delivery AVs:

% Total in scope trips by Private vehicles that are potentially replaced:	**41%**
% Total in scope VMT by Private Vehicles that are potentially replaced:	**30%**

Overall, baseline person trips and

VMT by private vehicles are expected to increase by CAGR 3% and 2.3% respectively between 2020-2035 as highlighted in Figure C.1 and Figure C.2:

Figure C.1: Person trips by Private vehicles (million trips), 2017, 2025, 2030 and 2035

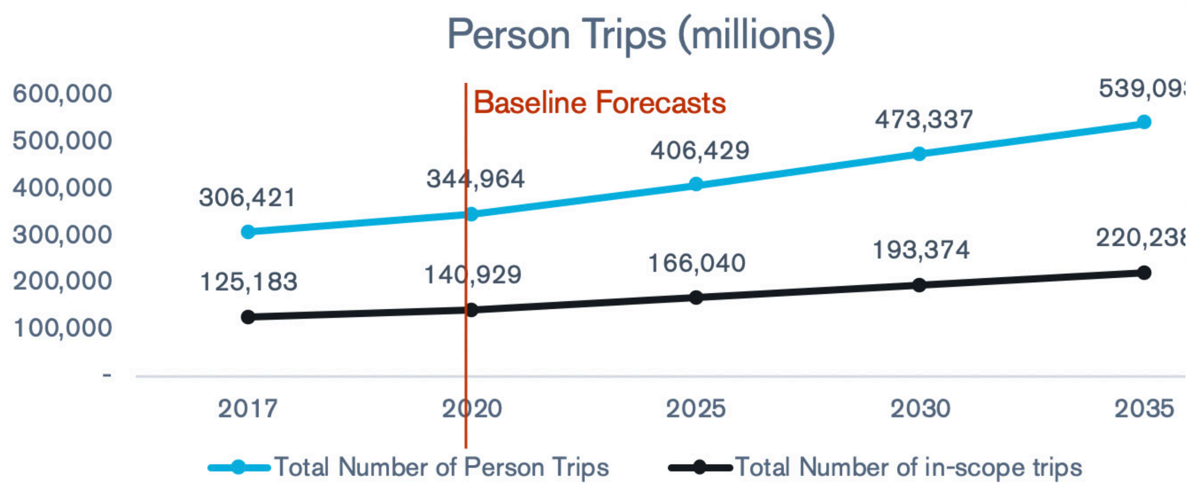
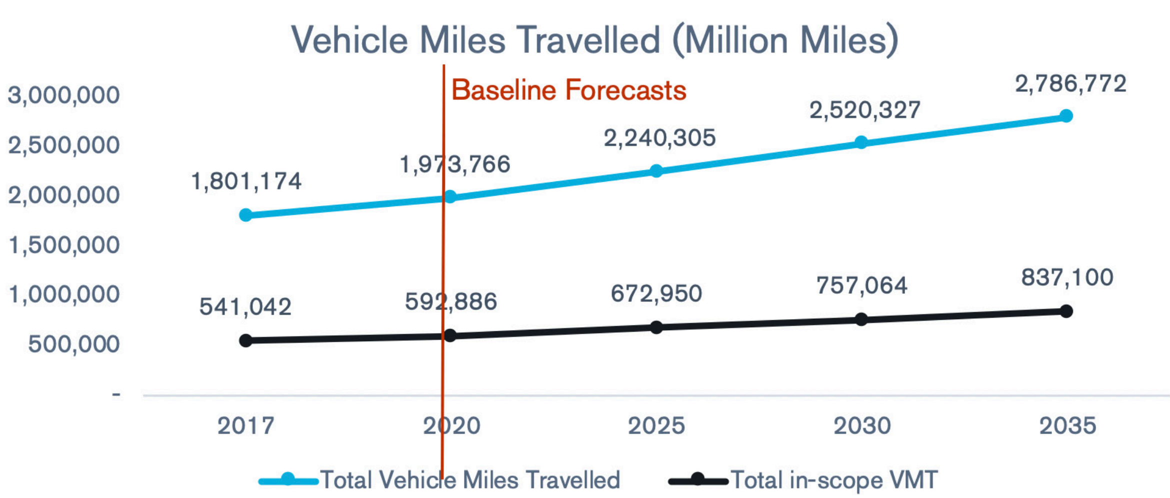


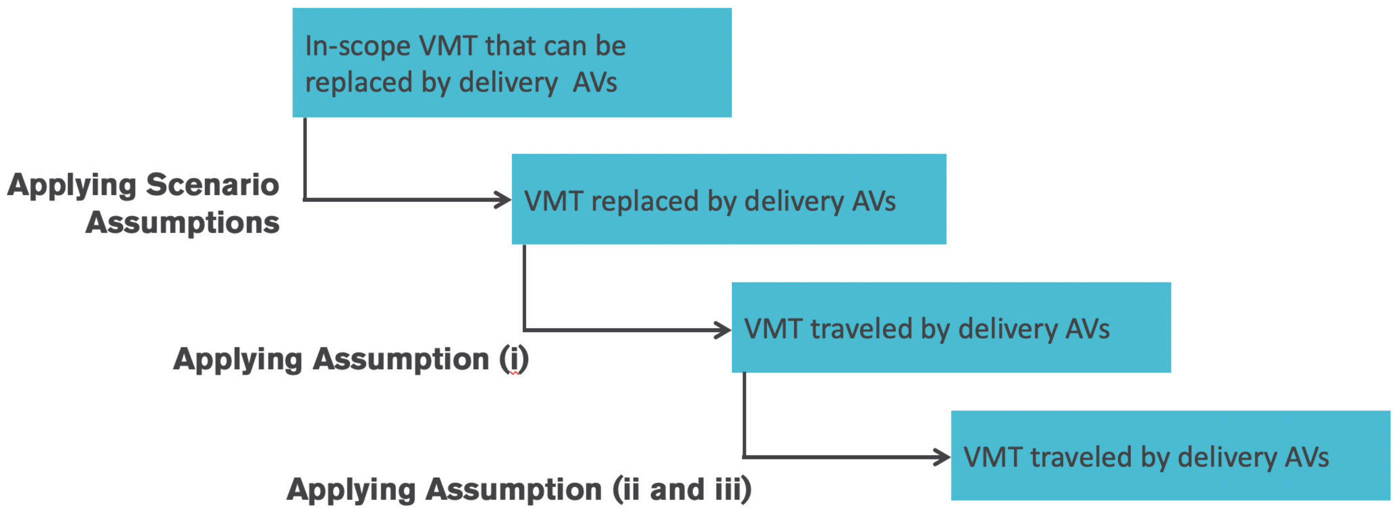
Figure C.2: VMT by Private vehicles (million miles), 2017, 2025, 2030 and 2035



Approach to forecast demand for delivery AVs

The below figure summarizes how we estimated potential demand for delivery AVs for each of the scenario:

Figure C.3: Steer approach to estimate potential market size of delivery AVs for each scenario



The following assumptions regarding delivery AVs for the forecast period (2025-2035) have been made in accordance with the literature review and expert interviews:

1. **Economies of batching:** Assuming 1 VMT by shared delivery vehicle would compensate for between 1-2 VMT by private vehicles, depending on demand, the benefits of economies of shared delivery are calculated proportionately to delivery AV penetration rate (i.e., greater batching is possible when penetration and deployment density increase), as represented in the table below

Table C.1: Economies of batching

	Ratio (VMT replaced v/s VMT travelled)			VMT travelled by ADVs as share of VMT replaced		
Scenario	2025	2030	2035	2025	2030	2035
Conservative	1.0	1.0	1.1	100%	98%	94%
Gradual Shift	1.0	1.0	1.6	97%	82%	63%
Disruptive Shift	1.1	1.3	2.0	94%	77%	50%

2. **Vehicle mileage:** average distance travelled by delivery AVs is expected to increase with technological and safety improvements. In this study, an average mileage by delivery AVs is assumed to be approximately 105 miles per day.

Although held constant here, this number could be expected to increase over time as operations become more efficient and less time is spent on loading / unloading or charging, and utilization improves overall. In the disruptive scenario, where more private AV ownership is assumed (vs. fleet model), the opposite trend could be expected.

Forecast US market size for delivery AVs

The table below highlights findings on potential demand for delivery AVs in the US for each of the milestones of the project:

Table C.2: Delivery AVs Market Size by Scenario

		2025	2030	2035
Scenario 1	% in – scope VMT replaced by Delivery AVs	0.5%	1.4%	3.1%
Total in scope VMT	Million miles	672,950	757,064	837,100
Gradual Shift	Million miles	3,224	10,837	25,782
Disruptive Shift	Million miles	3,224	10,576	24,155
Number of delivery AVs needed	**Thousands**	**84**	**276**	**630**
Scenario 2	% in – scope VMT replaced by Delivery AVs	1.9%	9.7%	22.9%
Total in scope VMT	Million miles	672,950	757,064	837,100
Gradual Shift	Million miles	13,098	73,660	191,557
Disruptive Shift	Million miles	12,650	60,047	119,723
Number of delivery AVs needed	**Thousands**	**330**	**1,567**	**3,124**
Scenario 3	% in – scope VMT replaced by Delivery AVs	2.5%	13.4%	35.6%
Total in scope VMT	Million miles	672,950	757,064	837,100
Gradual Shift	Million miles	16,857	101,577	297,678
Disruptive Shift	Million miles	15,919	78,136	148,839
Number of delivery AVs needed	**Thousands**	**415**	**2,039**	**3,884**

D Direct Economic Impacts Calculation Methodology

Methodology

As an input to the model, we require the estimation of two types of costs:

1. Direct cost/ Investment into supplying industries, and/or

2. Compensation to Employees (wages and salaries) by Delivery AV services

Direct costs/ Investment

The direct costs can be further classified into the following:

- Investment made in different sectors/ commodities (e.g. automobile manufacturing, software/ hardware manufacturing, etc.) to procure raw materials;
- Operating costs including insurance, real estate, rental and leasing, professional and business services, etc.

For the purposes of the economic impacts assessment, each type of cost must be assigned to one or more North American Industry Classification System (NAICS)[36] industry sectors or codes. The IMPLAN tool categorizes and aggregates NAICS industry sectors into their own industry categories to run the impact analyses. We use IMPLAN codes in our assessment.

Compensation to Employees

This section includes the total compensation paid out to employees in different functions including but not limited to:

- Manufacture of vehicles;
- Vehicle or software maintenance;
- Delivery services;
- R&D;
- Business support; and
- Others

36 *https://www.census.gov/eos/www/naics/2017NAICS/2017_NAICS_Manual.pdf*

E Wider Economic Impacts Calculation Methodology

The current US DOT's Benefit-Cost Analysis Guidance for Discretionary Grant Programs has been used as a foundation for this analysis[37].The table below elaborates the value of road efficiencies, as per the guidance:

Table E.1: Economic Values (US$) for Road inefficiencies, Emission and Value of Time

		Value per unit (US$)
Value of reduced fatalities and injuries	Serious collision (injuries)	$1,008,000
	Not survivable collision (Fatalities)	$9,600,000
Value of Emissions[38]	NOx (per short tons)	$8,300
	PM 2.5 (per short tons)	$377,800
	VOC(HC) (per short tons)	$2000
	CO2 (per short tons)	$1.1
Value of Time	Personal travel (per person hours)	$26.50

Note that our methodology relies on the 2017 BCA guidebook from USDOT, which revised the social cost of carbon per metric ton[39] to $1. Previously, the social cost of carbon was set at $39; if this value were used, the emissions benefits would be $16 billion higher for the time period 2025-2035.

37 https://www.transportation.gov/sites/dot.gov/files/docs/mission/office-policy/transportation-policy/14091/benefit-cost-analysis-guidance-2018.pdf

38 The guidance provides value for emissions per short ton. It has been converted to gallon by using 1 short ton= 239.65 gal

39 1 metric ton = 1.1 short tons

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