FEASIBILITY OF CAV DELIVERY SERVICE IN RURAL AREAS

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ABSTRACT

Urban areas have been experiencing pilot deployments of automated delivery technology. However, the benefits may be much more significant for rural areas with delivery distances of 20 miles or longer to the large potential savings in travel time, travel cost and crash risk. In rural areas, distances are longer, the fatality rate is higher (2.1 times higher in rural areas than in urban areas in 2017) and rural residents commonly drive larger, less fuel-efficient vehicles, which increases operation and ownership costs. The feasibility analysis of a CAV delivery service in rural areas is the objective of this research. A detailed methodology was developed and applied to two case studies; one between Hilo and Volcano Village in Hawaii, as a case of deliveries over a moderate distance (~50 mile roundtrip) in a high cost environment, and between Spokane and Sprague in Washington State, as a case of deliveries over a long distance (~80 mile roundtrip) in a low cost environment. The case study comprises the market study for grocery requirements of an average family and the detailed transport costs associated with its delivery. Three light-duty delivery vehicles were chosen, all based on a similar Nissan van. They are a person-driven NV200 (gasoline), a person-driven e-NV200 (electric), and a CAV e-NV200. The case study results suggest that the CAV e-NV200 is the most viable option implementing a delivery business for rural areas based on a break even analysis that did not monetize accident risk and crash costs.

Keywords: CAV, Driverless Vehicle, Delivery Service , Rural Areas

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CHAPTER 1. INTRODUCTION

1.1 Background

Since the 2007 DARPA driver-less competitions, continuous and rigorous research has taken place to implement automation and connectivity in vehicles to develop Automated Driving Systems (ADAS) that can facilitate humans with the ultimate goal for connected and automated vehicles (CAV). ADAS is not only designed to enable humans to ride vehicles autonomously but to ensure road safety, time optimization, and improved energy efficiency. CAV initiatives automate the delivery of household goods. The feasibility of a CAV delivery model in rural areas was investigated in this research.

1.2 Problem Discovery

Motor vehicle fatalities are one of the five leading causes of death in the U.S.; it is also the leading cause of death among people aged 1 - 44 years [1]. Rural areas have a higher rate of motor vehicle fatalities than urban areas [1]. In 2017, 15,565 fatal motor vehicle traffic crashes resulted in 17,216 fatalities in rural areas [2]. Rural areas accounted for 46% of the country's traffic fatalities in 2017, while only 19% of the population resides in rural areas [2]. Based on the Fatality Analysis Reporting System (FARS), human error caused around 90% of those crashes in rural areas [3]. Major driver errors include speeding and alcohol-impaired-driving. Pedestrians killed in motor vehicle traffic crashes in the U.S. numbered 5,977, and 19% of them died in rural areas [2]. Additionally, 783 bicyclists were killed in motor vehicle crashes in the U.S.; 24% of them died in rural areas [2]. According to the Federal Highway Administration (FHWA), 30% of the total vehicle miles traveled (VMT) in 2017 were in rural areas [2]. Furthermore, National Highway Traffic Safety Administration (NHTSA) reported that in 2017, the fatality rate per 100 million VMT was 2.1 times higher in rural areas than urban areas (1.79 and 0.85, respectively) [2].

In rural areas, an aging population presents several transportation challenges. The median age in rural areas is 44 years of age, while in urban areas, the median is 37 years. Around 18.4% of residents in rural areas are 65 or older, compared to 14.5% of those in urban areas; and 15% of the population in rural areas are disabled[1]. The percentage of people with disabilities is higher in rural areas compared to urban areas at 12% [5].

Rural households tend to drive longer distances per trip, which lead rural drivers to travel less frequently. Rural residents commonly drive larger, less fuel-efficient vehicles, which increases gas cost and carbon dioxide emissions [6, 7].

In such, more disabled and old people reside in rural areas, and more rural residents drive larger and less fuel-efficient vehicles over larger distances. Also, a disproportionately large number of total crashes occur on rural roads; it stands to reason that an unlimited delivery of goods with CAVs could help rural residents' needs and reduce the fatality toll on rural roads.

1.3 Goals

The goal of this research was to investigate delivery service in rural areas with CAVs in order to:

- Help elderly and disabled people in rural areas.
- Reduce fatalities on rural highway.
- Reduce the transportation cost for obtaining household goods in rural areas.
- Reduce the time that rural families spend on shopping (time and distance) for food, groceries, and related household goods.

To accomplish these goals, the following tasks were set:

- Obtain an understanding of rural households by collecting demographic information on rural areas.

[1] A disabled person, according to the Disability Discrimination Act (DDA), is someone who has a physical or mental impairment, which affects his or her ability to carry out typical day-to-day activities [4].

- Obtain transportation and traffic information.
- Select data needed to analyze rural delivery services.
- Select case study locations and identify distances to stores and delivery parameters.
- Conduct a detailed assessment of the costs incurred for these trips.
- Compare modes by type of vehicle and conduct break-even analysis.

1.4 Thesis Outline

The thesis is grouped into five chapters. Chapter 1 has an introduction with background, problem discovery, and goals of the research.

Chapter 2 contains a detailed literature review in rural areas, driving cost, grocery delivery service, CAV, and CAV deployment challenges. Chapter 3 presents the research methodology and the assumption of the study.

Chapter 4 covers the two case studies with data of customer and delivery service providers. This chapter also includes the overall summary of the result with two graphical representations of break-even analysis. Chapter 5 demonstrates conclusions with the future scope of research.

CHAPTER 2. LITERATURE

The literature review chapter is divided into five main sections; rural areas, driving costs, delivery service, CAVs, and the challenges of CAVs deployment. Under the rural area section, rural demographics, transportation and traffic classifications, and access to food were reviewed. The driving costs section defines and reviews five parameters that drive the costs of vehicle ownership; these are depreciation, finance, fuel, insurance, and maintenance costs. The third section studies delivery service, and compares the delivery costs in rural and urban areas. The CAVs section gives a brief history of CAVs, discusses different automation levels, explains how CAVs work, and reviews existing delivery services using CAVs. The last section of the literature review chapter addresses the challenges of CAVs deployment, such as government regulations, cybersecurity, public trust, economy, and weather conditions.

2.1 Rural Areas

According to the U.S. Census Bureau, "rural" refers to a territory, housing, or population outside urban areas. It is crucial to understand the term "urban area," which the Census Bureau further classifies into two - urbanized areas, containing a population of 50,000 or more people and urban clusters whose population range between 2,500 and 50,000 people. Other than population density, rural areas, and urban areas differ significantly in terms of demographics, economic activities, climate, and topography [8].

2.1.1 Rural Demographics

About one-fifth of the U.S. population, or close to 61 million, live in rural areas. According to the U.S. Census division definition, the median age of rural population is 44 years, while the age of urban equivalents is 37 years. The population in both rural and urban areas are experiencing an increase in aging. Rural communities have a substantial proportion of residents ages 65 and older, 18.4% compared to 14.5% in urban communities. Figure 2.1 shows the change in the percentage of the population, which is 65 years or older, at the county level, comparing 2011-2015 5-year estimates to ACS 2006-2010 5-year estimates. Also, Figure 2.2 shows that most of the counties have an increase in the percentage of aging. As a result, rural counties have the largest growth in the senior population [5, 9].

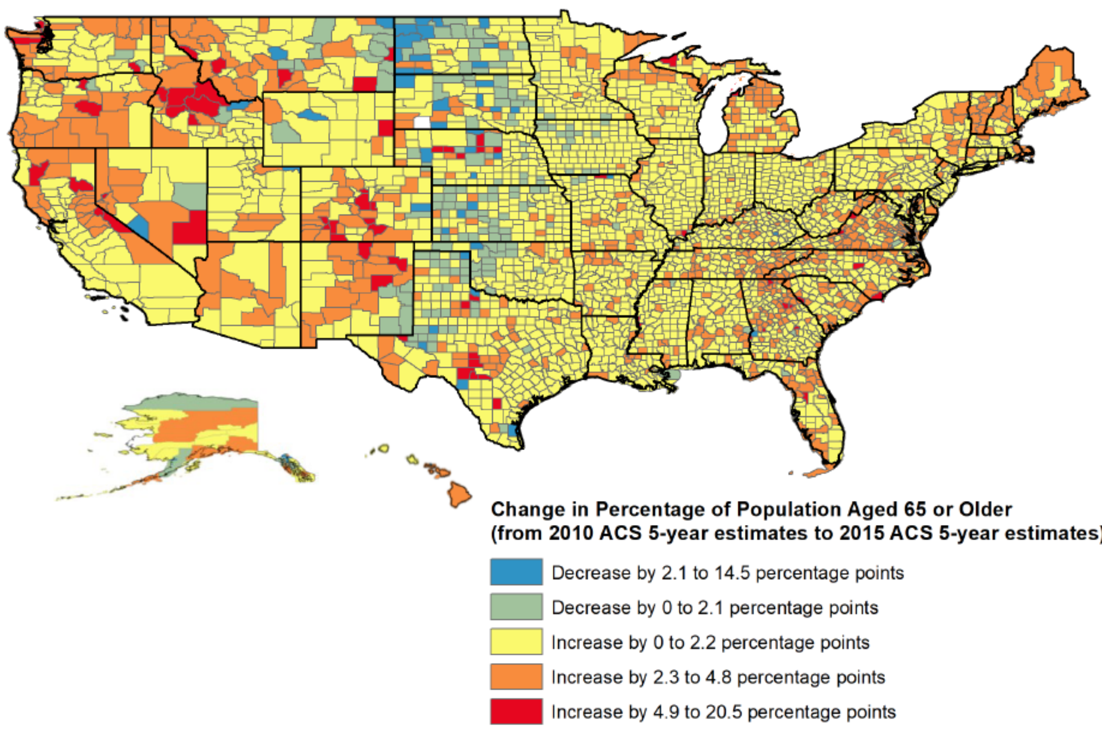


Figure 2.1: Change in Percentage of Population Aged 65 or Older, by County [5]

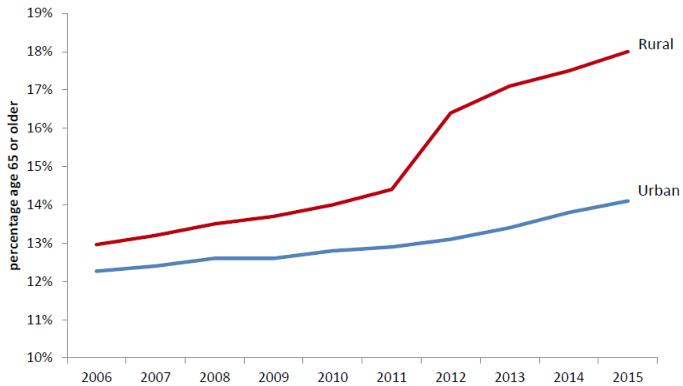


Figure 2.2: Percentage of Population Aged 65 or Older, 2006-2015 [5]

According to the 2013-2017 American Community Survey five-year estimates, the percentage of people with disability who live in rural areas is 15%, where in urban areas the percentage with disability is 12% [10]. Figure 2.3 shows the population with disabilities, respectively, at the county level [5].

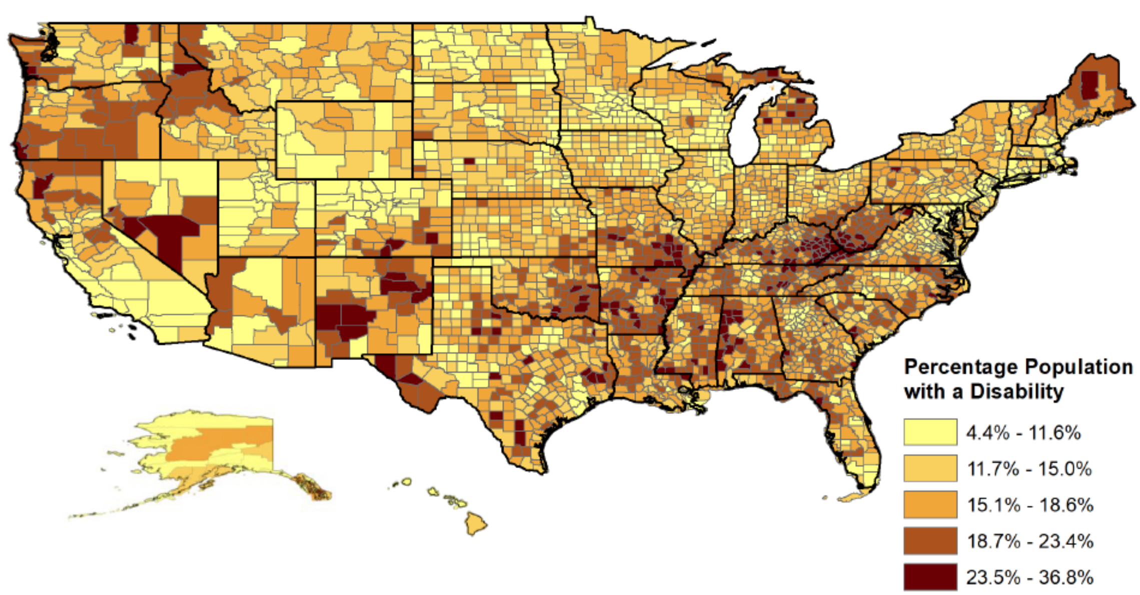


Figure 2.3: Population with Disabilities for Non-metropolitan Counties [5]

2.1.2 Transportation and Traffic Characteristics

According to Society of American Foresters, a rural road is a road, highway, thoroughfare, or bridge that is located in an unincorporated area and that is not privately owned or controlled, any part of which is open to the public for vehicular traffic, and over which the state or any of its political subdivisions have jurisdiction [11].

Data from the National Household Travel Survey (NHTS), FHWA, and American Housing Survey (AHS) show there are variations in transportation and travel behavior between rural and urban areas [5]. The first variance is that rural counties have the lowest percentage of households without vehicles, as shown in Table 2.1. A tiny portion of 0.4% trips are made by public transportation in rural areas, as shown in Table 2.2. Rural residents are more dependent on vehicles due to long travel distances and very little public transportation. Based on Road Usage Charge West (RUC)[1], rural households tend to drive fewer trips than urban households. Meanwhile, urban households make more trips with short distances, where rural households drive more miles than their urban counterparts as shown in Table 2.3 [6].

Table 2.1: Vehicles Available in Household [5]

Number of Vehicles	**U.S.**	**Urban**	**Rural**
None	8.9 %	10.1 %	4.2 %
1	33.5 %	35.5 %	25.1 %
2	37.2 %	36.6 %	39.8 %
3 or more	20.3 %	17.8 %	31.0 %

Table 2.2: Mode Shares [5]

Mode	Total	Urban	Rural
Auto	85.1 %	83.9 %	90.3 %
Transit	2.3 %	2.9 %	0.4 %
Bicycle	0.7 %	0.8 %	0.5 %
Walking	10.0 %	11.0 %	6.4 %

[1] RUC west funded a research study to evaluate an RUC in urban, rural and mixed communities. Researchers reviewed several states and national travel surveys [6].

Table 2.3: Travel Behavior for Urban and Rural Residents, by Age Group [5]

Age	**Number of Trips Per Travel Day**		**Annual VMT Per Person**		**Used Transit on Travel Day**	
	Urban	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**
19-33	3.9	3.6	7,898	12,246	7.8 %	1.0 %
34-49	4.4	4.0	10,999	15,079	5.9 %	0.7 %
50-64	4.1	3.9	9,412	13,862	5.6 %	0.8 %
65-74	3.7	3.5	6,458	9,735	4.0 %	0.4 %
>74	2.7	2.7	3,459	5,535	3.8 %	0.7 %

Table 2.4 shows the trip purpose for public transit and non-transit trips in urban and rural areas. According to data from NHTS, Americans make 220 billion vehicle trips a year. In rural areas, more than 20% of these trips are for shopping, including grocery shopping. Most of those trips (90.3%) are made by personal cars, which expose drivers and passengers to the risk of an traffic crash [5].

Table 2.4: Trip Purpose for Public-transit and Non-Transit Trips [5]

Trip Purpose	**Public-transit trips**		**Non-transit trips**	
	Urban	**Rural**	**Urban**	**Rural**
Work	27.3 %	27.4 %	15.3 %	16.5 %
Work-related business	4.0 %	1.7 %	2.8 %	4.0 %
Shopping	17.6 %	7.8 %	21.3 %	20.9 %
Other personal business	9.7 %	11.5 %	19.5 %	19.1 %
School/church	10.4 %	20.4 %	9.6 %	9.7 %
Medical/dental	6.3 %	7.4 %	2.5 %	2.4 %
Vacation	1.6 %	4.7 %	1.1 %	1.2 %
Other	4.4 %	2.5 %	0.7 %	0.6 %

In 2018, the crash death rate per 100 million miles traveled was 1.68 in rural areas compared with 0.86 in urban areas. In the same year, 66% of pickup truck occupant deaths, 69% of large truck occupant deaths, and the percentage of SUV occupant deaths was 56% in rural areas. These crash deaths happened on roads with speed limits of 55 mph or higher. The percentage of fatally injured intoxicated drivers was 27%, and speeding drivers was 24%. In terms of seat belt use, only

47% of fatally injured passenger vehicle occupants 13 years and older were belted in rural areas [12].

2.1.3 Household Goods and Groceries

Whereas accessing a grocery store in an urban setting is an easy task regardless of the time of the day as some grocery stores operate for 24 hours a day; accessing a grocery store in rural areas is a time consuming, expensive, and often an inconvenient task [13]. The ease of accessing good and groceries in a rural setting is further dependent on the household's financial status, the number of people residing in the household, and their age [13]. In rural areas, some households have resorted to producing their own food through horticulture, livestock keeping, and poultry keeping; however, this is labor and time-intensive, especially for people without a farming background or the required expertise and resources. As a result, goods and groceries access in rural areas is more dependent on transportation, making it more difficult for the elderly and people with disabilities to access grocery and big box stores conveniently [14]. Access to goods and groceries in the right quantity is a deeper problem for isolated rural communities due to lack of convenient grocery stores. Furey, Sinéad, Christopher Strugnell, and Heather (2001), refer to "food deserts," which are geographic areas where residents cannot access affordable and healthy food due to limited or lack of grocery stores within a convenient traveling distance [15].

2.2 Driving Cost

In 2017, the total expenditure for personal vehicles was $1.1 trillion, which includes purchasing, operating, and maintaining the vehicles with purchasing of new and used vehicles amounting to $425.4 billion [16]. In rural areas, households lean to buy big and fuel-inefficient vehicles to help them navigate the country gravel roads during all seasons [17].

As shown in Table 2.1, approximately 95% of rural households in the U.S. had access to a car, whereas 89% of urban households have a car. The disparity between the two can be attributed to the lack of reliable public transportation in rural areas compared to urban areas. However, a significant proportion of rural counties still registers at least double the average rate of “carlessness” compared to urban counties. Economic Research Service (ERS) reports that more than 1.6 million households in rural America, especially in Alaska, Appalachia, the Southwest, and in the South, do not have cars due to persistent poverty and high concentration of low-income earners. People in high poverty areas tend to rely on inconvenient public transportation [6, 17].

Owning a car comes with fixed and variable costs, which except for parking and registrations, tend to be higher in rural areas than in urban areas; these include financing, depreciation, fuel costs, insurance, licenses and taxes, and maintenance.

2.2.1 Depreciation

Cars depreciate with usage and passage of time. According to the National Automobile Dealers Association (NADA) Official Used Car Guide, Midwest Edition [18], a car with 5,000 fewer miles than the standard fetches $200 more during resale. iSeeCars, a car sales website, reports that vehicles lose at least over 38% of their value after three years of usage; however, some models depreciate faster than others. Vehicles in rural areas are more likely to depreciate faster due to larger distances. Another reason that causes vehicles in rural areas to depreciate faster is the poor conditions of roads. According to a TRIP report [19], a national transportation research nonprofit organization, rural America struggles with road and bridges deficiency, inadequate connectivity and capacity, and high crash rates because of dilapidated roads. In 2013, 15% of major rural roads across the United States were in poor condition, while 39% were in a mediocre or fair condition. The States of Michigan, Rhode Island, Hawaii, Idaho, and Kansas are the leading states in terms of rural pavements in poor condition, as illustrated in Table 2.5, with over 30% of their rural pavements in poor condition. Pennsylvania, Rhode Island, Iowa, and South Dakota score over 20% in a rank of states with structurally deficient rural bridges, as illustrated in Table 2.5 [18, 19].

Table 2.5: States with the highest share of pavements in poor condition, structurally deficient rural bridges [19]

Rank	State	Rural Pavements in Poor Condition	State	Rural Bridges Poor/Structurally Deficient
1	Rhode Island	41%	Rhode Island	22%
2	Oklahoma	36%	West Virginia	21%
3	Hawaii	32%	Iowa	20%
4	West Virginia	29%	South Dakota	18%
5	New Mexico	28%	Pennsylvania	17%
6	Arkansas	26%	Louisiana	15%
7	Mississippi	24%	Maine	13%
8	Connecticut	24%	New York	12%
9	Alaska	23%	Michigan	12%
10	Maine	21%	North Dakota	11%
11	California	21%	Oklahoma	11%
12	Washington	21%	North Carolina	11%
13	Missouri	21%	Mississippi	9%
14	New Hampshire	20%	Missouri	9%
15	Louisiana	19%	Alaska	9%
16	Pennsylvania	19%	Nebraska	9%
17	Vermont	17%	Hawaii	9%
18	Massachusetts	16%	New Hampshire	9%
19	Michigan	16%	South Carolina	9%
20	South Carolina	15%	California	9%

2.2.2 Finance

Finance is proportional to the loan costs for the acquisition of the car or truck. In exchange, the borrower pays the lender interest and possibly A fee over a specific number of months. The interest rate that the bank applies to the purchaser represents the finance costs of purchase. According to Experian data, the average auto loan interest rate in the last quarter of 2019 was 5.76% for a new vehicle and 9.49% for a used vehicle [20, 21].

2.2.3 Fuel

Fuel is the cost of the energy used for the vehicle, including fossil fuels and electricity [22]. In the case of fossil fuels, U.S. regular gasoline price is $2.506/gal, as of Jan 27, 2020 [23]. On Jan 29, 2020, Hawaii state had the highest gas price, at $3.658/gal, and Missouri State had the lowest cost at $2.148/gal [24].

In November 2019, a national average cost of electricity was 13.04 cents per Kilowatt-hour (KWh). As of November 2019, Hawaii had the highest price, at 30.99 cents per KWh, and Washington State had the lowest average cost at 9.54 cents per KWh [25].

2.2.4 Insurance

Due to national legislation, a car owner must purchase annual coverage of the car or truck for potential accidents and undesirable events. The average cost of minimum coverage car insurance is $78 per month or $937 per year. For full coverage, the average is $200 per month or $2,390 per year. Insurance companies consider several factors, such as State, population density, vehicle type, age, gender, crime in the area, and the situation of local roads. Rural areas are at an advantage when population density and crime are considered, as these are more intense in urban areas; however, rural areas may pay higher premiums due to poorly maintained roads, longer commutes, and poorer weather conditions compared to urban areas [26, 27].

2.2.4.1 License and taxes

License, registration, and taxes are costs that depend on local governmental rates and taxes for cars, trucks, and drivers. Those fees must be paid at a monthly or annual frequency [28].

2.2.5 Maintenance

The costs for maintenance of the vehicle are proportional to its usage. Different parts require repair or replacement according to the life expectancy of each part of the vehicle, such as tires, brakes, oil, and other fluids [28].

Car owners in rural America spend more on maintenance than their counterparts in suburban and urban areas [29]. Therefore, most rural residents have trained themselves to repair their cars; "many men were excellent auto repairmen, and there was hardly a man in the community who could not perform an impressive range of auto repair and maintenance activities" [29]. According to Liberty Mutual, an average American household spends approximately 1.5% of its annual income, about $817, on car repairs and maintenance [30]. Expenditure on car maintenance increases with an increase to its use, age, and mileage. People in rural areas spend more on tires compared to city dwellers due to higher annual mileage and the poorer state of the majority of rural roads [30].

2.3 Grocery Delivery Service

Grocery delivery is a courier service where a grocery store or independent grocery-delivery company delivers groceries to a customer. An order could be made through a grocer's website or phone, or a grocery ordering company. Deliveries take at least one day to deliver using third-party services. Other companies offer same-day delivery or 2-hours delivery in select areas, such as AmazonFresh, Whole Foods Market Prime, Walmart, and Safeway. Grocery delivery service using CAVs is described in section 2.4.3 [31, 32].

2.3.1 Delivery Cost in Rural Areas

Delivery services in rural areas are the largest and most inefficient portion for all businesses in the delivery industry because customers tend to be far apart from the store or warehouse and carriers have to charge the customer who lives in rural areas more for fuel surcharges and the travel time, especially for large package deliveries. Costly deliveries are a hindrance to access of goods by the rural communities considering that as of 2017, the rural poverty rate was at 16.4%, whereas that of urban areas was 12.9% [17, 33].

Despite the high number of companies in the logistics industry, just a few deliver to remote rural areas; companies like FedEx and Amazon do not deliver to such areas leaving rural communities with limited options such as the government-owned USPS. Private companies such as FedEx are reluctant to deliver in remote areas because it is less profitable and safe [33].

Today, online shopping is popular; delivery companies should come up with a way to improve delivery so that rural households can have goods delivered to their doorstep without incurring extra costs. Improving the efficiency of delivery in rural areas would benefit rural residents, enabling them to access quality food and freight carriers [33].

2.4 Connected and Autonomous Vehicles (CAVs)

Since the 2007 DARPA driverless competitions, there has been increasing interest in deploying connected and automated vehicles (CAVs) on road networks worldwide. As of 2020, there have been significant developments in CAVs, spearheaded by companies such as Tesla, Waymo (Google), and several others. The definition of CAVs, their development over time, and their classifications are discussed below.

2.4.1 Defining CAVs

Connected and autonomous vehicles (CAVs), refers to driver-less cars or transport systems using public roadways that do not rely on human drivers [34]. The National Conference of State Legislatures defines a self-driving vehicle as a "vehicle capable of navigating roadways and interpreting traffic-control devices without a driver operating any of the vehicle's control systems" [35]. CAVs require the combination of other technologies, as shown in Figure 2.4, such as Global Positioning System, cellular communication, electric drive, computing capacity, and the use of sensors. Another technology CAVs use is communication technology to communicate with the driver, other vehicles on the road, roadside infrastructure, and the information cloud [36]. Institute of Electrical and Electronics Engineers (IEEE) lists the following four communication technologies [37]:

- Vehicle to Vehicle – V2V communication technology mitigates traffic collisions and improves traffic congestion by exchanging necessary safety information such as location, direction, and speed between vehicles within a range of other vehicles. It can improve active safety features, such as forward collision warning and blind-spot detection.

- Vehicle to pedestrian – V2P encompasses a broad set of road users such as people walking, children being pushed in strollers, people using wheelchairs or other mobility devices, passengers embarking and disembarking buses and trains, and people who ride bicycles.

- Vehicle to Infrastructure – V2I communication directly links road vehicles to their physical surroundings, first and foremost. Infrastructure components such as lane markings, road signs, and traffic lights can wirelessly provide information to the vehicle, and vice versa.

- Vehicle to Cloud – V2C connectivity, communication between vehicles using applications like GPS would result in fluid traffic flow when current traffic information is communicated through cloud for the vehicle's entire route.

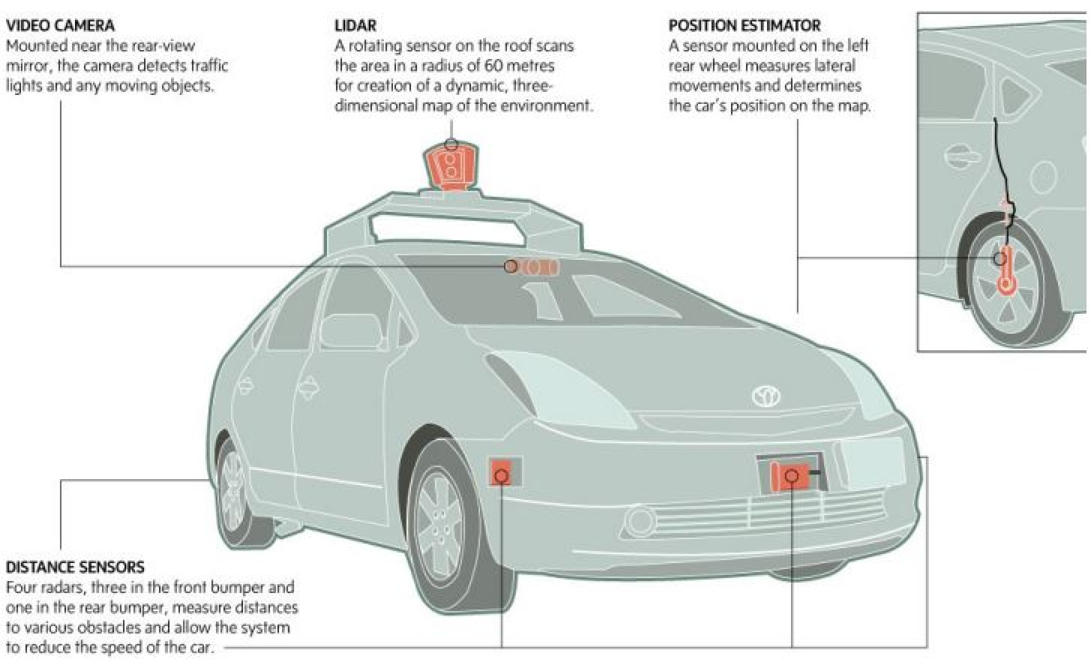


Figure 2.4: Driveless Technology [38]

NHTSA supports self-driving car development due to their ability to save lives, prevent injuries, and reduce the economic costs brought about roadway crashes caused by human error such as panic, inattention, or drowsiness [35]. CAVs can continuously monitor the environment, thus making up for lapses in driver attention and preventing panic responses natural to human beings.

According to Bajpai [39], CAVs enhance the quality of life by improving the efficiency of transportation systems and reduces car insurance premiums and the number of people needed in traffic enforcement departments. Bajpai also estimates that the use of CAVs will lead to a 70% drop in traffic accidents in 25 years. CAVs will redefine car ownership with households requiring fewer vehicles as CAVs can drop a person at a location and return home to be used by other household members. People with disabilities hindering them from driving and the elderly will also benefit from CAVs, while those without driving licenses will rely less on traditional forms of public transportation such as taxis and public transit [39].

2.4.2 Development of CAVs

The first versions of modern CAVs were developed in the late 1970s to early 1980s, where the cars were equipped with all the necessary technology to allow them to drive themselves through typical traffic without any external input [40].

The DARPA Grand Challenge of 2007 was a defining event for CAVs. Several teams were challenged to a contest of CAVs capable of driving in urban traffic and performing complex maneuvers such as negotiating intersections, passing, parking, and merging in less than 6 hours. The 2007 race was a follow up of similar races held in 2004 and 2005; however, unlike the previous races, the 2007 DARPA Challenge required CAVs to encounter other manned and unmanned vehicles on the course. Out of 11 contestants, six robotic vehicles managed to successfully finish the race, with the Carnegie Mellon team's "Boss" taking home a US $2 million prizes after winning the race. "Boss," a heavily modified Chevrolet Tahoe completed the 60 miles race with the winner averaging 14 miles an hour for approximately 55 miles. This events' challenge was to develop a mechanism that can survive basic maneuvers and develop algorithms and software that can handle autonomous driving even in unexpected situations while strictly adhering to safety and correct driving behavior. The success of the race proved that CAVs could interact with both manned and unmanned vehicle traffic in an urban setting [41].

The first CAVs to be tested on public roads was developed in 2015 by Audi, augmented with Delphi technology [42]. Since then, there has been fast-paced development in CAVs with 19 companies, including Tesla, Volvo, Nissan, Toyota, Ford, Google, Uber, and BMW, working towards commercially releasing CAVs by 2021 [40]. 2018 was a defining year for CAVs with 22 states and Washington D.C passing legislation related to autonomous cars and 17 cities running pilot programs for CAVs [40]. Uber and Tesla were among the first companies to commercially use CAVs. Uber introduced CAVs in 2016 in Pittsburgh; however, the project was paused for six months after a fatal accident in March 2018, where a car hit and killed a pedestrian in the city [43]. In late August 2018, Uber reinstated its CAVs services in Pittsburgh but has not reintroduced it in other testing cities in the U.S. [43] .

NHTSA classifies vehicles into six levels of CAV, as shown in Figure 2.5 [44]. These are:

- Level 0 (No automation): Corresponds to a vehicle where the human driver performs all driving tasks.

- Level 1 (Driver Assistance): a driver controls the vehicle with a little driving assist features. The vehicle contains at least one driver-assistance feature, such as lane-keeping technology.

- Level 2 (Partial Automation): The vehicle contains automated functions; however, the human driver must be engaged throughout the drive and monitor the environment. The vehicle automatically steers, brakes, and accelerates while the human driver stays as a backup. The majority of modern cars fall at this level.

- Level 3 (Conditional Automation): Human driver is not required to monitor the environment as the automated system executes all driving tasks. The CAVs has a human driver who should be ready to take back control of the vehicle immediately.

- Level 4 (High Automation): CAVs perform all driving functions without a human driver's intervention. However, the vehicle could be limited to a certain speed and geographical areas.
- Level 5 (Full Automation): CAVs can drive on any road and through all environmental conditions without human intervention.

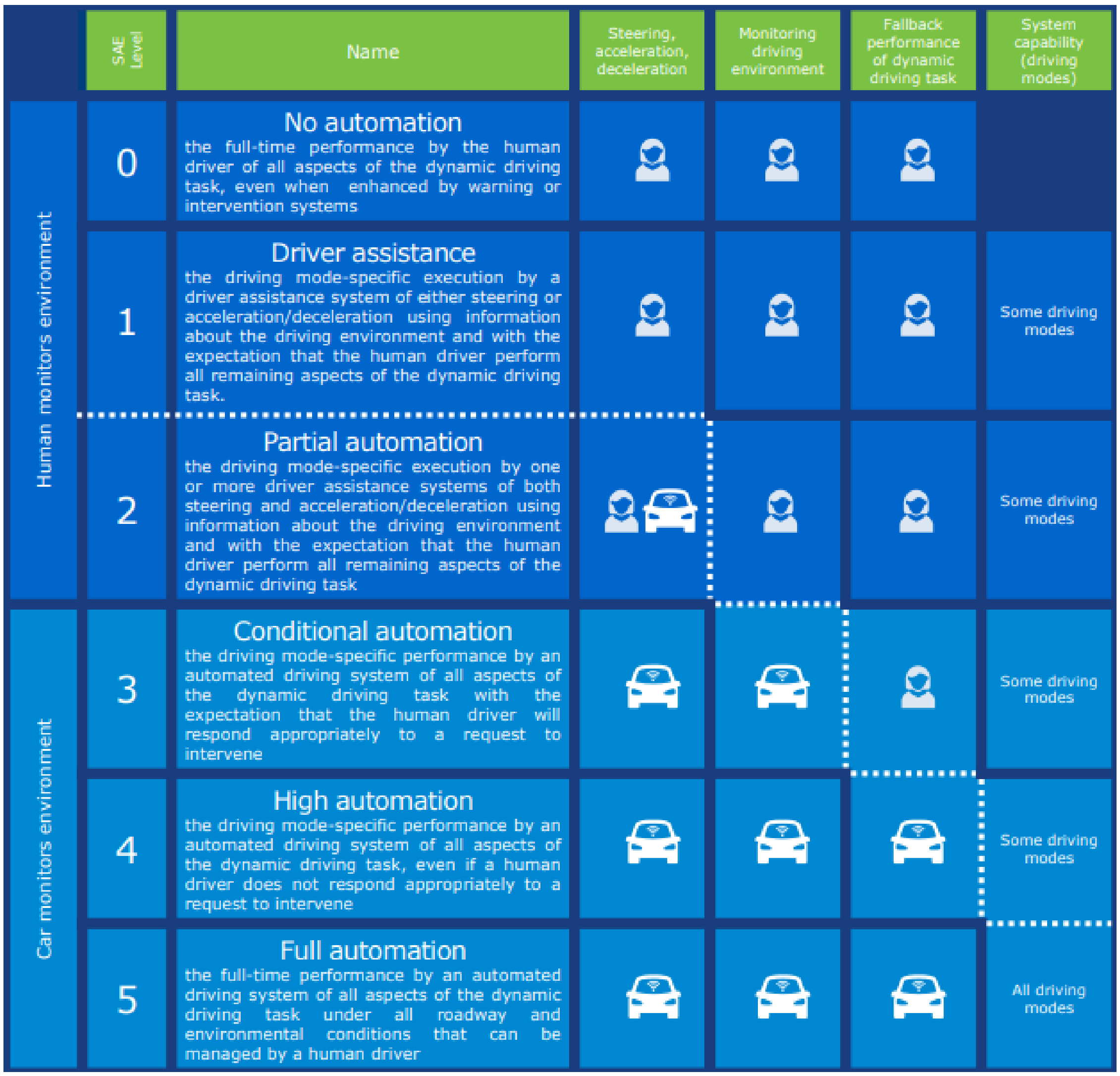


Figure 2.5: SAE Automation Levels

2.4.3 Existing Delivery Service Using CAV

Logistics was among the first industries to benefit from CAVs; the liability and risk in transporting goods using CAVs is much less than transporting people. The logistics industry will be the biggest beneficiary of CAVs [45]. While the use of CAVs to transport people is still under development, there are already numerous applications of CAVs in logistics. Besides CAVs, drones have been widely adopted in the delivery of food, medicine, packages, and other goods [45]. Several companies across the world have already implemented the use of CAVs to make deliveries. In the United States, Houston, San Francisco, Pittsburgh, Michigan, and Phoenix are cities where people can receive deliveries from CAVs [46]. The Coronavirus pandemic in 2020 has increased the use of CAVs to deliver goods as people avoid physical contact [45]. Despite the technical and legal difficulties facing CAV delivery services, the success of CAVs delivery during the Coronavirus pandemic is an indication that automated on-road delivery is ready for mass adoption across the U.S. and the world [45].

Table 2.6 shows the CAV delivery companies and their locations of the launch.

Table 2.6: CAV Delivery Companies

Company	Partner with	Location
Nuro	Fry's food	AZ ,U.S.A
	Domino's Pizza	U.S.A.
	Kroger	U.S.A.
	Walmart	U.S.A.
Udelv	Draeger's Market	U.S.A.
	Walmart	U.S.A.
Ford	Walmart	U.S.A
Waymo		
5G	-	China
Neolix	-	China
Kar-go	-	Europe

Nuro is an American robotic company based in Mountain View, California; it was founded in June 2016. In 2017, Nuro used Toyota Prius sedans that are equipped with CAV technology for testing as well as for pilot grocery deliveries in Arizona and Texas. Kroger, the nation's largest grocery chain, got into the CAV delivery service with Nuro. In December 2018, Kroger and Nuro announced the world's first unmanned grocery delivery service to customer's homes in Scottsdale, Arizona. The CAV, which Kroger and Nuro used, is called The R1, as shown in Figure 2.6 (a). The R1 traveled within a 1-mile radius of the Fry's food store in east Scottsdale, Arizona, at speeds up to 25 MPH. R1 can only go on residential roads but stay clear of main roads and highways. Customers place an order on Fry's food website. Customers get a message when the groceries are on their way. Customers will receive another message that has a code to punch in to open the R1's door. The delivery fee for this service is $ 5.95, with same-day or next-day delivery options [47, 48, 49]. Nero Also partnered with Domino's Pizza and configured the vehicle with a warmer to maintain the pizza hot until delivery to the customer [50].

Walmart is of No. 1 on Progressive Grocer's 2018 Super 50 list of the top grocers in the U.S.. Currently, the retailer operates more than 11,200 stores and offers grocery delivery in nearly 100 metropolitan areas. In November 2018, Ford unveiled a joint grocery and delivery service with Walmart. The collaboration is aimed at creating delivery services for Walmart customers to deliver fresh groceries, which will use CAVs manufactured by Ford. Brian Wolf, an executive in Ford's CAV unit, said "Like Ford, Walmart believes that self-driving vehicles have an important role to play in the future of delivery, and that true success comes from first learning how individuals want to use them in their daily lives," He added, " Ford has said it expects to launch commercial production of automated vehicles by 2021" [51].

In 2019, Walmart teamed with Udelv. Udelv is the first custom-made, public-road CAV delivery service. The company started delivering groceries using the second-generation mini-CAV in Arizona and California shown in Figure 2.6 (b). The minivan has 32 secure compartments to help keep groceries safe and chilled. Udelv has delivered groceries to thousands of clients [52].

5G delivery vehicle has been unveiled at an intelligent transport forum held by the Beijing Bicycle and Electric Vehicle Industry Association. The 5G mini-CAV shown in Figure 2.6 (c), was developed and manufactured jointly by a company under the Beijing Institute of Technology (BIT) and Dewin Technology. The 5G is still in the testing stage, and with a capacity of 10 cubic meters, it can carry dozens of small packages [53].

Neolix is another CAV delivery service in Beijing, China, shown in Figure 2.6 (d). Neolix has deployed CAV around China. Neolix has already delivered 150 CAV units, and it is expecting to sell 1,000 units by early 2020 [54].

In 2019, Kar-go unveiled mini-CAV at the Goodwood Festival of Speed, hosted in the south of England, which is Europe's first CAV delivery service. It was built and designed by the Academy of Robotics, a UK company, registered in Wales. Kar-go has a unique design like a green egg on wheels, as shown in Figure 2.6 (e). Kar-go plans to launch its first road tests by the end of 2020 [55].

(a) R1 mini CAV Grocery Delivery

(b) Udelv mini CAV Grocery Delivery

(c) 5G mini CAV Grocery Delivery

(d) Neolix mini CAV Grocery Delivery

(e) Kar-go mini CAV Grocery Delivery

Figure 2.6: Mini-CAV for Delivery Service

2.5 CAV Deployment Challenges

Despite the considerable success that CAVs have experienced, CAVs are yet to be deployed in rural areas or being sold to the public. CAVs are sensitive to environmental conditions and complex geography, making rural areas a challenging environment for their deployment. Other challenges stagnating the deployment of CAVs as discussed below include government regulations, reliability of CAV software and hardware, public trust, impact on the economy, and weather conditions.

2.5.1 Rural Area Challenges

Rural roads are characterized by their curviness and physical condition, such as ruggedness. The climate of rural areas should be factored in, paying attention to areas with foggy, snowy, and rainy conditions. One of the greatest tests for CAVs in rural areas is the ability to avoid hitting animals. For example, in Pennsylvania State in 2016, there were 4,081 crashes with animals or 3.1% of all crashes [40].

2.5.2 Government Regulations

The deployment of CAVs faces obstacles from the government and political considerations. Although federal agencies in the U.S. are currently supporting the development of CAV technology, they admit that they lack a regulatory structure [56]. According to USDOT, “More effective use of NHTSA’s existing regulatory tools will help expedite the safe introduction and regulation of new Highly Automated Vehicles (HAV)” [57]. However, since the current statutes and regulations were developed when HAV was only a remote notion, they might not be sufficient to oversee the safe introduction of HAV to the public and to realize the full safety promise of new technologies [57].

The DOT potentially needs new legislation, such as pre-market approval and cease-and-desist powers. According to the autonomous vehicles legislative database from the National Conference of State Legislatures, 33 states have introduced laws related to CAVs over the last 33 years allowing them to adopt independent CAV laws [56, 58]. However, governments need to add new measures and regulations to manage CAVs risks. Li et al. (2018) employ a framework, as shown in Table 2.7, for the types of strategies that could be adopted by various governments to govern the technological risks brought by CAVs, which classified as no-response, prevention-oriented, control-oriented, toleration-oriented, and adaptation-oriented [59].

Table 2.7: Categorisation of Governance Strategies and CAVs-related Examples [59]

Strategy	**Definition and CAVs example**
No-response	Policy-makers do not take any specific actions to address risks, and may delay decisions due to their uncertain nature. For example, the US federal government has not taken any measures to address the risk of mass unemployment when CAVs displace human drivers in future. In this scenario, policy-makers may not have any back-up plans or robust institutional frameworks to address impending threats. For instance, the criteria and provisions of unemployment insurance have not been amended to incorporate technological unemployment. Furthermore, most governments have yet to outline training programmers specifically for displaced drivers. No-response might also imply that policy-makers are ignorant about the potential negative consequences of risks.
Prevention-oriented	The main aim of this strategy is to avoid risks by taking preventive action. Prohibiting the adoption of innovative technologies is one such display of risk avoidance, as it seeks to prevent the existence of risk. One example is to temporarily prohibit or restrict CAVs testing on certain routes if a safety concern is identified [60]. This strategy is suitable to address risks of a more predictable nature, but is ineffective when risks are unexpected.
Control-oriented	Policy-makers allow for the existence of risks, but take steps to control them by implementing formal policies and regulations. Traditional methods of risk assessment are adopted to predict and regulate risks. One example is the regulation of safety risks is introducing new geographical parameters for the use of CAVs on roads and introducing new eligibility standards for the authorisation of manufacturers to make on-demand automated vehicle networks available to the public [61]. Another example is imposing a host of requirements on CAVs testers, such as application requirements, compulsory training programmers and emergency plans [62] (article 3.7).
Toleration-oriented	Policy-makers take action to ensure that the system or organisation's performance is robust to risks in a wide range of situations. For instance, the UK government's Vehicle Technology and Aviation Bill [63] lays out a comprehensive list clarifying the liability of insurers and CAVs owners in the event of an accident and under a wide range of circumstances. Policy-makers also make forward-looking plans to mitigate potential consequences, such as by developing alternative solutions.
Adaptation-oriented	This strategy aims to improve the adaptive capability of the system or organisation. It emphasises on embracing uncertainty and improving its performance in response to shocks. One example is the Singapore government's intentions to adapt to the employment risks that CAVs pose to other industries. The Singapore government intends introduce programmers that retrain future displaced workers progressively, help them acquire new skills and enable them to get higher value-added jobs [64]. Here, policymakers view risk as an opportunity to change the system for the better, rather than as a threat that should be ignored, suppressed, controlled or tolerated.

2.5.3 Hardware Reliability

Just like any other technology, CAVs are prone to cybersecurity threats. Tesla Model S, CAV, was remotely hacked by a group of hackers in 2016 while another CAV, Jeep Cherokee, was similarly hacked in 2015 [65, 66]. The two events exposed weaknesses in CAVs, raising fear among the public. To prevent further attacks, companies venturing in CAVs resorted to rewarding hackers who could find bugs in their software [67]. CAVs collect a massive amount of data as part of their operations, which can also be "feedstock" for business purposes [68]. Responsible authorities took caution of the cyber threat and have been coming up with draft regulation to counter future attacks [69].

2.5.4 Public Trust

According to a poll by Reuters/Ipsos in 2019, approximately 50% of Americans are not ready to use CAVs, as they perceive them to be more dangerous than human drivers. Approximately 67% of the responders would not prefer to buy a CAV. A further 15% do not believe that there will be CAVs on the market any time soon. Another study conducted by AAA showed that 71% of Americans were scared of CAVs in 2019 compared to 63% in 2017. Uber and Tesla's autonomous driving fatalities have also aggravated the fear of CAVs [70].

2.5.5 Economy

Historically, technological advances have varied effects on the job market leading to loss of employment as well as creation of new jobs. The number or type of jobs to be adversely affected by artificial intelligence automation is difficult to predict. Researchers estimate that for the 9% to 47% of current jobs are under threat over the next decade resulting in an increase in unemployment rate; however, the numbers could be even considering the creation of new jobs such as the development and supervision of CAV – these jobs will lead to higher incomes resulting in higher living standards. According to Researchers at the Organization for Economic Cooperation and Development (OECD), CAV will target tasks rather than occupations; with this argument, only 9% of jobs could end up being completely displaced leading to job displacement for millions of Americans both on a short and medium term [71].

According to a report by Goldman Sachs in 2017, CAVs could eliminate as many as 300,000 driving jobs every year [58]. Nevertheless, "How fast new technology disrupts driving jobs is important, said Amitai Bin-Nun, vice president of autonomous vehicles and mobility innovation at Securing America's Future Energy, a nonpartisan nonprofit that advocates for reducing U.S. oil dependence. Jobs will not disappear overnight, Bin-Nun said. There are many steps between zero and full automation. The workforce has shown resilience during gradual transitions in the past, said Bin-Nun. One example is the change in the agriculture industry. A century ago, most Americans worked on farms. Today, few do. "It is not because Americans stopped eating," Bin-Nun said" [58].

On the other hand, CAV could make the economy more efficient as witnessed with the impact of robots on employment [71]. In 2015, a study conducted in 17 countries showed that the use of robots had led to a 0.4% growth in their annual GDP between 1993 and 2007. The use of robots stimulated the economy by allowing more production while employing few workers in some facilities [71]. Despite a projected loss of jobs due to the adoption of autonomous vehicles, the economy is likely to receive a boost following more production, efficiency in transport and deliveries, as well as higher income among people working in the industry. Nevertheless, the economic impact of jobs losses through mass adoption of CAV will heavily fall on people whose skills and services will become redundant or entirely useless [71]. CAV may also contribute to unemployment by creating more jobs related to CAVs industries, as shown in Figure 2.7 [72].

In addition, Cities worldwide are prone to lose a major source of revenue, as traffic fines are a huge source of revenue. An example is Seattle, which stands to lose 2.6% of its operating fund. Cities should come up with a new revenue stream as CAVs are designed to observe traffic rules correctly. Seattle's plans include developing a mileage tax or a CAV registration tax to limit the loss of revenue [73].

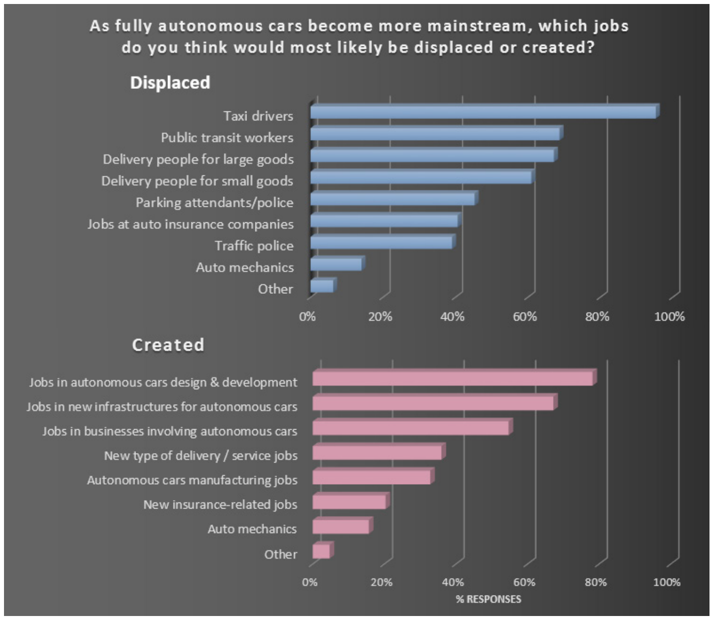


Figure 2.7: "Poll results for how the areas in which people perceive jobs will be displaced and in which areas they will be created"

Despite the difficulty in predict the economic effects to be brought about by CAVs, policymakers should protect jobs through educating and training workers on the jobs of the future, investing and developing artificial intelligence, and helping and empowering workers during the transition from their current occupations to the occupations of the future. Policymakers should prepare Americans for CAVs disruption through continuous training and re-training on artificial intelligence [71].

2.5.6 Weather Conditions

Weather conditions play a significant role when it comes to current CAV capabilities. CAVs are programmed to operate in rather predictable operating envelopes [74]. They depend on camera sensors and LIDAR lasers, etc. to navigate safely, [75]. When there is snowy, rainy, and stormy weather, the CAV may stop rather than operate in conditions where the sensors have problems "seeing," and the AI has difficulty "understanding" the surrounding environment. Most drivers typically drive through moderated risky conditions. Here is where C "connected" in CAV comes into play, enabling communication between the vehicles' connected system and the road [75]. Many of these developments include installing sensors into the pavement to forecast how weather conditions would affect driving [75]. This type of technology may help guide the CAV along the road safely. Accurate and accessible weather forecasting is a part of the successful application of autonomous vehicles on the way [75].

CHAPTER 3. METHODOLOGY

The overall methodology is illustrated in two parts in Figures 3.1 and 3.2. The research process summary started with a literature review on the topics of rural area definition, cost of driving, characteristics of delivery service, and CAVs. The literature review also covered the challenges faced with CAV deployments, such as rural area deployment, government regulations, hardware reliability, public trust, economy, and weather conditions. Knowledge on these subjects enabled us to conduct quantitative analysis in the form of case studies.

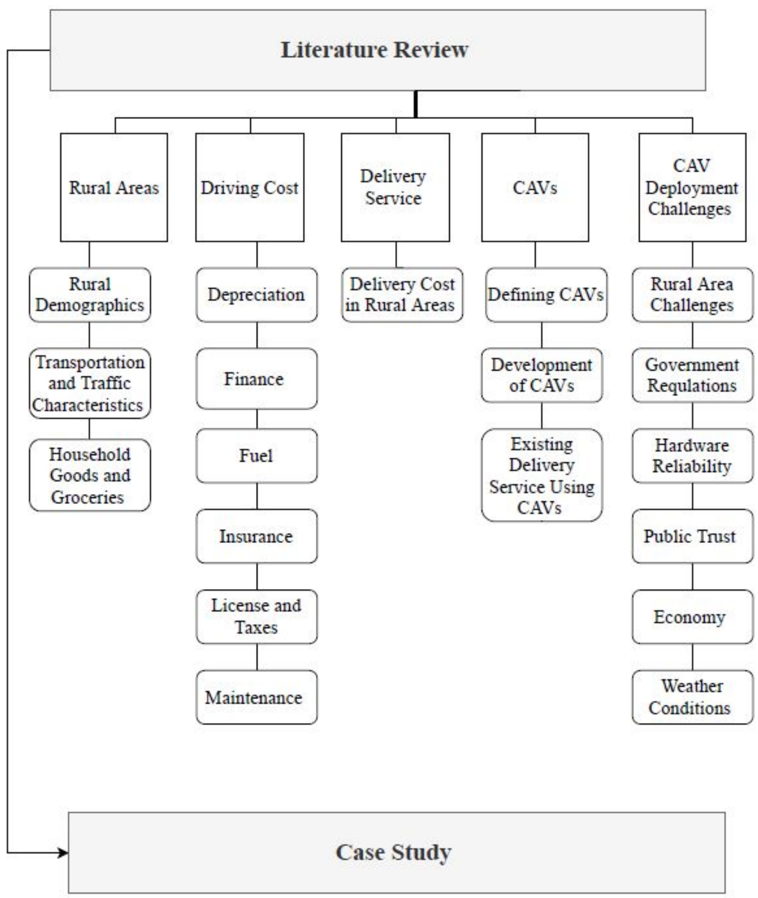


Figure 3.1: Methodology Diagram, Part 1

Two rural areas with substations different distances and costs were selected:

- Sprague, Washington State as a long distance area with moderate gasoline cost and low electricity cost.
- Volcano Village, Hawaii as a moderate distance area with high costs for both gasoline and electricity.

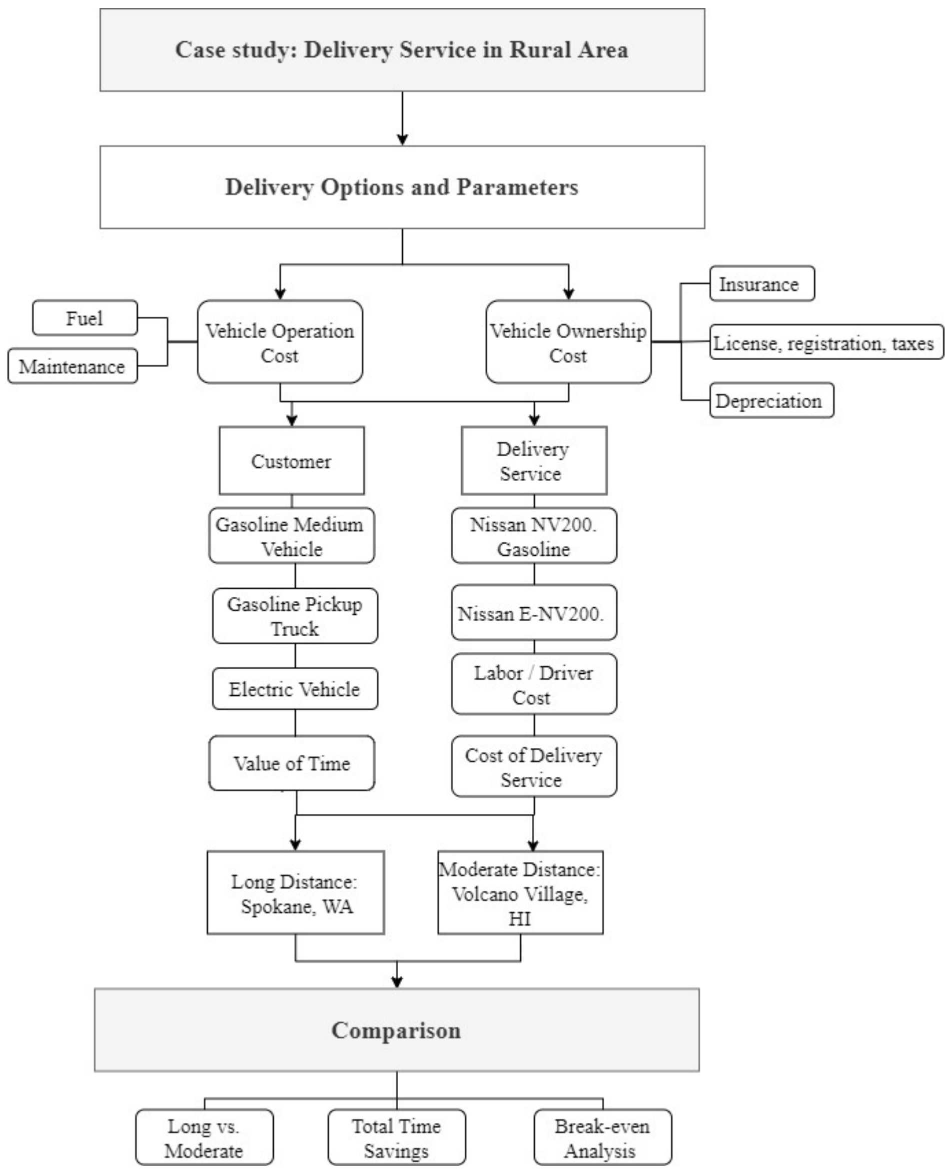


Figure 3.2: Case Studies, Part 2

The case study included a detailed analysis of vehicle operating costs and vehicle ownership costs obtained from chosen sources for both customer and delivery service provider. The customer is a rural household that goes to the nearest city to buy groceries or goods. The delivery service provider refers to a courier service where an independent company or branch of major retailer/grocer delivers groceries to customers. Operating cost contained fuel and maintenance costs per mile, whereas ownership cost corresponded to vehicle insurance, license and tax, and depreciation costs per day. The case studies also covered a fringe rate or benefit rate for the delivery drivers, which is the rate of an employee's benefit multiplied by the total payroll then added to base salary. the base salery for the Delivery Driver (DD) is $20.36 and $ 46.09 for Field Autonomy Engineer(FAE) [76, 77]. A fringe rate included pension accumulation, pension administration, retiree health insurance, employees' health insurance, workers' compensation, unemployment compensation, social security, and medicare, as shown in Table 3.1.

Table 3.1: Fringe Rate [78]

Type of cost	**Percentage of employee's base salary**	**Base salary (DD) $20.36/hr**	**Base salary (FAE) $46.09/hr**
Pension Accumulation	18.00%	$3.66	$8.30
Pension Administration	0.01%	$0	$0
Retiree Health Insurance	10.14%	$2.06	$4.67
Employees' Health Insurance	7.69%	$1.57	$3.54
Workers' Compensation	1.24%	$0.25	$0.57
Unemployment Compensation	0.02%	$0	$0
Social Security	6.20%	$1.26	$2.86
Medicare	1.45%	$0.3	$0.67
Other post-employment benefit	14.33%	$2.92	$6.60
Total	**59.08%**	**$32.39**	**$73.32**

Two types of vehicles were selected. Customer vehicles with which rural residents will go to get their groceries and delivery service vehicles with which groceries will be delivered to rural households. For the customers, three types of popular vehicles, 2015 models, were used to form the basics of costs on the customer side.

with vehicle life ranging between 10 and 15 years, we opted to use a five-year-old vehicle to reflect current operations and ownership cost better:

- 2015 Toyota Camry Base.
- 2015 Ford F-150 XLT.
- 2015 Nissan Leaf S.

For the delivery service providers, two vehicles were selected:

- 2019 Nissan NV200 running on gasoline.
- 2019 Nissan e-NV200 running on electricity, relying on a human driver
- 2019 Nissan e-NV200 running on electricity, running on CAV.

The data collected on the chosen vehicles and the two regions under study were processed and analyzed to compare the total time saved, total operating costs, ownership costs, and conduct break-even analysis. The data was also used to compare the time and cost implications for long and moderate distances, e.g., one vehicle can make many deliveries over moderate distances, but fewer deliveries in a day over long distances.

This study assumed that:

1. The value of time a customer spends getting goods came from their discretionary time multiplied by their median household income. Discretionary time was determined by subtracting the number of work hours, sleep hours, and eat/travel/other mandatory hours per year, as shown in Table 3.2. The value of time varies by household.

2. Vehicle ownership cost was based on 15,000 miles driven annually for customers driving themselves to the stores, and 32,500 miles driven annually for delivery service providers.

3. The Delivery fare based on the Uber Eats method, which includes pickup fees, drop-off fees, and a per-mile rate. The per-mile rate was set as $0.58 based on the standard mileage method

Table 3.2: Discretionary Time

Discretionary time	
Weeks per year	52
Week hours	168
Work hours per week	(40)
Sleep hours per week	(56)
Eat/other mandatory per week	(16)
Discretionary time per week	56
Annual hours of discretionary time	**2912**

of the IRS [79]. The distance chosen was the average between moderate and long-distance to be multiplied by the mile rate to have the fare fixed for both areas as shown in Table 3.3.

Table 3.3: Base Delivery Fare [80]

Parameters	**Unit**	**Value**
The average distance	mi	26
Fee per mile rate	$	0.58
Pickup fee	$	2.5
Drop-off fee	$	3
Total delivery fare	**$**	**22.32**

4. A rural household drives to the grocery store once per week, for a total of 52 trips per year, but this was varied as part of the analysis.

5. The annual savings were based on the three chosen modes for getting groceries and households supplies as listed below:

   - 0% delivery-order option, 100% driving option (current situation).
   - 25% delivery-order option, 75% driving option.
   - 50% delivery-order option, 50% driving option.
   - 100% delivery-order option, 0% driving option.

6. The three delivery vehicles are financial purchases of 3% interest in 60 months and a compounding period of 12, as shown in Table 3.4.

7. A CAV delivery fleet consists of five vehicles, which will be controlled by one FAE. The FAE's base salary has divided into five to yield the base salary per vehicle per hour of $12.22.

8. In the early 2010s LIDAR, which is essential equipment for Level 4 and 5 CAV operations, had a cost of $75,000. As of 2017, this cost has been reduced to $7,500 due to Waymo designing their own device [81, 82]. LIDAR was assumed to be approximately one-third of the cost of the total CAV management package, which comes to $22,500 added to the cost for an e-NV200 van.

Table 3.4: Purchase price

Parameter	Nissan NV200	Nissan e-NV200	Nissan e-NV200 (CAV)
Purchase price [83, 84]	$24,512	$27,802	$27,802
CAV	0	0	$22,500
Loan amount	$24,512	$27,802	$50,302
Interest rate	3%	3%	3%
Periods (term in month)	60	60	60
Compounding periods per yr	12	12	12
Monthly payment	**$440.45**	**$499.57**	**$903.86**

CHAPTER 4. CASE STUDY

4.1 Overview

4.1.1 Long Distance: Sprague, WA

Sprague, WA was considered for this delivery business feasibility study as a long-distance, moderate gasoline cost, and low electricity cost. Sprague is a rural Village in Washington State with a population of approximately 452 people per 2010 census, 128 families, and 197 households [85]. 15.2% of all households had someone aged 65 years or older living alone. Sprague's population density is 707.9 people per square mile [85]. The median household income in Sprague is $30,833 [86]. As of 23rd March 2020, the price of gasoline per gallon at Sprague was $2.70, while the electricity was at $0.09 per kWh as of 1st January 2020 [87, 88].

4.1.2 Moderate Distance: Volcano Village, HI

Volcano Village, HI has been taken into consideration for this delivery business feasibility study as a moderate distance and high gasoline and electricity costs. Volcano Village is a census-designated place in Hawaii County on the big island in Hawaii state. The population of Volcano Village was 2,575 in 2019 [89]. Volcano Village has 1,340 total housing units, whereas the median household income is $30,639 [89]. As of 5th of April 2020, the price of gasoline per gallon at Volcano Village was $3.24, while the electricity was at $0.32 per kWh as of 1st January 2020 [87, 88].

4.2 Analysis and Results

4.2.1 Customer

Table 4.1 shows the value of customers' discretionary time in both long-distance and moderate distance drive scenarios. Commuting the value of the hourly discretionary income multiplied by the time spent on a round trip and average time inside the store gave a value of $7.06 and $6.45 for long-distance Sprague, WA and moderate distance Volcano Village, HI. The value of the time spent on a round trip and inside the store are a useful metric in analyzing monetary terms customers who choose to drive to store by themselves and those who opt for delivery services.

Table 4.1: The Value of Time a Customer Spends

		Value	
Parameter	Unit	WA	HI
Time spend inside store [90]	Hour	0.72	0.72
Time spend on round-trip	Hour	1.28	1.12
Median household income	$/year	30,833	30,639
Discretionary income	$/year	10,278	10,213
Discretionary income	$/Hour	3.53	3.51
Value of time per trip	$	**7.06**	**6.45**

Operating cost metrics for the three customer vehicles analyzed, as shown in Table 4.2. Fuel consumption and mileage, as well as the expected average maintenance and repairs, are analyzed to arrive at a value that represents the total operating cost per mile. In comparison, Table 4.2 shows that the highest operating cost can be seen in the 2015 Ford F-150 customer vehicle at $0.268 and $0.300 cost per mile for both long-distance Sprague, WA and moderate distance Volcano Village,HI, respectively. Subsequently, the 2015 Nissan Leaf S has the lowest operating cost per mile of the three vehicles analyzed.

Table 4.2: Operating Cost

	2015 Camry (28 MPG) [91]		2015 F-150 (20 MPG) [92]		2015 Leaf (112 MPGe) [93]	
Parameter	WA ($)	HI ($)	WA ($)	HI ($)	WA ($)	HI ($)
Fuel	0.096	0.116	0.135	0.162	0.028	0.095
Maintenance	0.061	0.063	0.093	0.095	0.058	0.046
Repairs	0.030	0.032	0.040	0.043	0.042	0.032
Total cost per mile	**0.187**	**0.211**	**0.268**	**0.3**	**0.128**	**0.173**

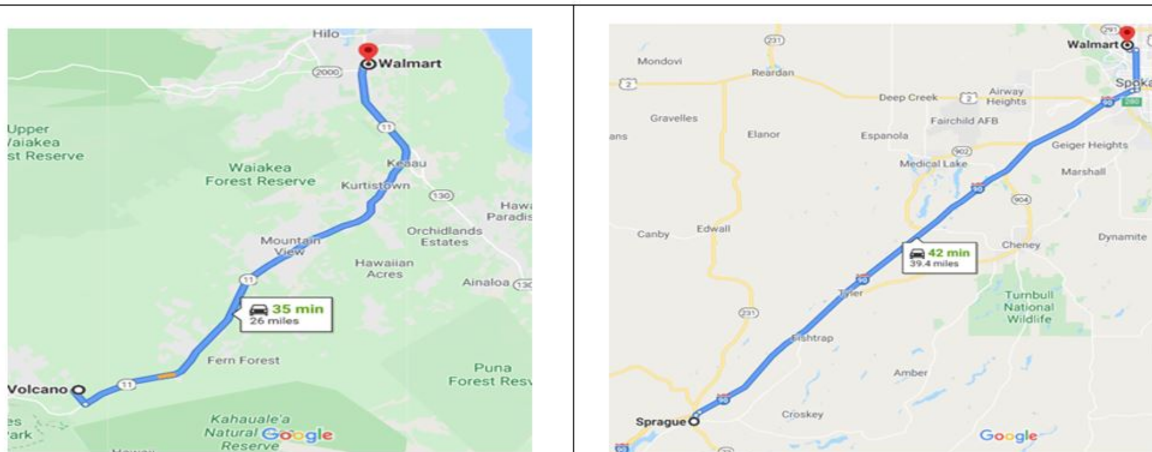
Table 4.3 took into consideration the ownership costs associated with each of these vehicles. Ownership costs such as insurance, taxes and fees, and depreciation value have been factored into

the operation of these vehicles per day. Analyses show that the highest depreciation can be expected from the 2015 Ford F-150, while the 2015 Nissan Leaf S depreciated the least. The ownership costs are highest in the 2015 Ford F-150 at $11.865 for Sprague, WA and $12.340 for Volcano Village, HI locations, respectively. The total ownership cost for the 2015 Toyota Camry was calculated to be $7.407 and $8.108 for Sprague, WA and Volcano Village, HI, respectively, while the Nissan Leaf came in at $6.497 and $7.257.

Table 4.3: Ownership Cost

	2015 Camry [91]		2015 F-150 [92]		2015 Leaf [93]	
Parameter	WA ($)	HI ($)	WA ($)	HI ($)	WA ($)	HI ($)
Insurance	2.189	2.900	2.367	3.061	2.324	2.932
Taxes and Fees	0.799	0.628	1.450	0.966	0.539	0.497
Depreciation	4.419	4.580	8.048	8.313	3.363	3.828
Total cost per day	**7.407**	**8.108**	**11.865**	**12.340**	**6.497**	**7.257**

Table 4.4 is one of the most critical tables that summarize the cost per trip for using any customer vehicle options. Table 4.3 and 4.3 analyzed operating costs, ownership cost, and the discretionary time value for going to the grocery store in WA and HI. Table 4.4 harmonizes all these costs and depicts the total cost incurred for using any of the three customer vehicle options in this study. According to the data obtained from google maps shown in Figure 4.1, the average round trip distance covered in miles to a grocery store in Sprague, WA, is 79 while that of Volcano Village, HI, is 52. The distances are multiplied by the operating cost per mile that incorporates the vehicles' fuel consumption, maintenance, and repairs. Finally, the total operating cost is added to the ownership cost and discretionary time value (in dollars) to arrive at the total cost per trip to a grocery store in WA and HI. The results show that the 2015 F-150 has the highest cost per trip at $40.13 and $34.41 in WA and HI, respectively, while the 2015 Leaf had the least operating cost per trip to the grocery store $23.72 and $22.73 respectively. Data analysis from Table 4.4 is significant in commuting the annual savings from these vehicles in four different modes of getting groceries.



(a) Distance from Volcano to the Shopping Center of Hilo
(b) Distance from Sprague to the Shopping Center of Spokane

Figure 4.1: Distance from the Two Selected Areas to their Closet Shopping Center[94]

Table 4.4: Total Cost Per Trip

	2015 Camry		2015 F-150		2015 Leaf	
Parameter	WA	HI	WA	HI	WA	HI
Round-trip distance to Store (mi)	79	52	79	52	79	52
Operating cost ($)	14.75	10.97	21.20	15.62	10.16	9.02
Ownership cost ($)	7.41	8.11	11.87	12.34	6.50	7.26
Value of Time ($)	7.06	6.45	7.06	6.45	7.06	6.45
Total cost per Trip ($)	**29.22**	**25.53**	**40.13**	**34.41**	**23.72**	**22.73**

Table 4.5 compares each customer vehicle's annual savings for four different modes of getting groceries in WA and HI. These four modes vary different percentages of delivery-order options with corresponding percentages for driving options to analyze customer vehicles' total savings per year. The first option in Table 4.5 (a) compares the current situation of savings on a 0% delivery option with a 100% (52 times) diving option. No delivery service fee was recorded in these services and subsequent zero number of savings on each vehicle model. The second in Table 4.5 (b) compares each customer vehicle's savings at a 25% (13 times) delivery option with a corresponding 75% (39 times) driving option. This hypothetically means that customers used delivery options 25% of the time to get groceries per year. The highest amount of savings was recorded with the 2015 F-150

at \$254 and \$180 in WA and HI, respectively. This value is expected, seeing that this particular vehicle costs more to operate for the customer. Other vehicles such as, 2015 Leaf S saved \$41 and \$28, while the 2015 Camry saved \$112 and \$64 on long-distance Sprague, WA, and moderate distance Volcano Village, HI, respectively.

With a 50% (26 times) delivery-order option with a corresponding 50% (26 times) driving option shown in Table 4.5 (c), each of these vehicles' total savings significantly increases. This mode hypothetically assumed that customers opted to use delivery-order services 50% of the time whenever they needed to get from the grocery stores. Again, customers using the 2015 F-150 will have saved more as the value stands at \$508 and \$360 for WA and HI. This total savings almost double that recorded for the 25% delivery option as expected. Customers using 2015 Camry and 2015 Leaf also experience similar increases in savings if they opt to use delivery-order options for 50% of their grocery shopping. Lastly, the fourth mode assumes that customers will choose to use delivery service options 100% (52 times) of their grocery shopping, as shown in Table 4.5 (d). A similar trend on the increase in savings can be seen as all vehicles continue to record increased yearly savings on round trips in both localities. The highest obvious saving increase can be seen in the 2015 F-150 as it recorded a savings of \$1,016 and \$719 on long-distance grocery shopping in WA and moderate distance grocery shopping in HI, respectively. The 2015 Camry model recorded a savings of \$449 and \$258 on WA and HI respectively, while the 2015 Leaf S model recorded the least savings on a 100% delivery option.

4.2.2 Delivery Service Provider

Table 4.6 and 4.7 took a comparative look at the cost of operating three delivery vehicles; the 2019 Nissan NV200 running on gasoline, the 2019 Nissan e-NV200 running on electricity, relying on a human driver, and the 2019 Nissan e-NV200 running on electricity, running on CAV. Table 4.6 addressed explicitly the operation cost of these vehicles estimating the average dollar value of the cost of fuel and maintenance per mile.

Table 4.5: The Annual Savings of the Four Modes for Getting Groceries

(a) 0% delivery-order option, 100% driving option (current situation)

	2015 Camry		2015 F-150		2015 Leaf	
Parameter	WA ($)	HI ($)	WA ($)	HI ($)	WA ($)	HI ($)
Total cost	1,1519	1,328	2,086	1,789	1,233	1,182
Cost of driving option	(1,519)	(1,328)	(2,086)	(1,789)	(1,233)	(1,182)
Delivery service fee	-	-	-	-	-	-
Total annual savings	**-**	**-**	**-**	**-**	**-**	**-**

(b) 25% delivery-order option, 75% driving option.

	2015 Camry		2015 F-150		2015 Leaf	
Parameter	WA ($)	HI ($)	WA ($)	HI ($)	WA ($)	HI ($)
Total cost	1,1519	1,328	2,086	1,789	1,233	1,182
Cost of driving option	(1,139)	(996)	(1,565)	(1,342)	(925)	(886)
Delivery service fee	(268)	(268)	(268)	(268)	(268)	(268)
Total annual savings	**112**	**64**	**254**	**180**	**41**	**28**

(c) 50% delivery-order option, 50% driving option.

	2015 Camry		2015 F-150		2015 Leaf	
Parameter	WA ($)	HI ($)	WA ($)	HI ($)	WA ($)	HI ($)
Total cost	1,1519	1,328	2,086	1,789	1,233	1,182
Cost of driving option	(760)	(664)	(1,043)	(895)	(617)	(591)
Delivery service fee	(535)	(535)	(535)	(535)	(535)	(535)
Total annual savings	**224**	**129**	**508**	**360**	**81**	**56**

(d) 100% delivery-order option, 0% driving option.

	2015 Camry		2015 F-150		2015 Leaf	
Parameter	WA ($)	HI ($)	WA ($)	HI ($)	WA ($)	HI ($)
Total cost	1,1519	1,328	2,086	1,789	1,233	1,182
Cost of driving option	-	-	-	-	-	-
Delivery service fee	(1070)	(1070)	(1070)	(1070)	(1070)	(1070)
Total annual savings	**449**	**258**	**1,016**	**719**	**163**	**112**

Table 4.6 shows that 2019 Nissan e-NV200, and the 2019 Nissan e-NV200 (CAV) had a significant reduction in maintenance cost compared to the 2019 Nissan NV200. Specifically, both vehicles (Nissan e-NV200 and Nissan e-NV200 (CAV)) had an operating cost of $0.055 and $0.126 on WA and HI. In comparison, the 2019 Nissan NV200 has an operating cost of $0.24 and $0.21 per mile on WA and HI, respectively.

Table 4.6: Operating Cost

	Nissan NV200 (25 MPG) [83]		Nissan e-NV200 (124 MPGe) [95]		Nissan e-NV200 (124 MPGe) CAV [95]	
Parameter	WA ($)	HI ($)	WA ($)	HI ($)	WA ($)	HI ($)
Fuel	0.11	0.13	0.03	0.10	0.03	0.10
Maintenance	0.11	0.11	0.025	0.025	0.025	0.025
Total cost per mile	**0.22**	**0.24**	**0.055**	**0.126**	**0.055**	**0.126**

Table 4.7 covered the ownership cost of these delivery vehicles. The ownership cost included such determinants as insurance, taxes and fees on the vehicles, depreciation value, and vehicle loan payment. The Nissan e-NV200(CAV) is the most expensive because it was equipped with CAV, which cost $22,500 and came with a total price of $47,425 while the other two vehicles, Nissan NV200 and Nissan e-NV200 were valued at $24,925. The loan payment can be calculated from this purchase price, and the Nissan e-NV200 (CAV) option bore the most burdens of loan payments. Therefore commuting all other ownership related costs, the Nissan e-NV200 (CAV) costs $46.77 and $46.29 in WA and HI respectively per day while the Nissan e-N200 will cost $33.48 and $33. The least ownership cost is recorded with the Nissan NV200.

Table 4.8 provides an analysis of the breakeven point of the three delivery service options for both case study locations. A one-way trip from the store to the customer was factored; where there is more than one delivery per trip, and then an increment of one mile was added for each additional delivery at the rural location. The driver's cost was calculated per roundtrip (back and forth to the store). Using a Nissan NV-200, the delivery service for one delivery is $99.2, generating a revenue of $20.58, leading to a $78.68 loss. For a Nissan NV-200 EV, the delivery cost reduced to $90.38, resulting in a $69.80 loss. For the Nissan e-NV200 CAV, the delivery service cost reduces

Table 4.7: Ownership Cost

Parameter	Nissan NV200 [83] WA ($)	HI ($)	Nissan e-NV200 [95] WA ($)	HI ($)	Nissan e-NV200 CAV [95] WA ($)	HI ($)
Insurance	3.21	3.42	3.21	3.42	3.21	3.42
Taxes and Fees	1.46	0.76	1.46	0.76	1.46	0.76
Depreciation	10.92	10.92	12.39	12.39	12.39	12.39
Loan Payment	14.48	14.48	16.42	16.42	29.72	29.72
Total cost per day	**30.07**	**29.59**	**33.48**	**33**	**46.77**	**46.29**

to $76.63, leading to a $56.06 loss. Clearly, one delivery per trip is not a viable option, regardless of the type of van. By progressively incrementing the number of deliveries we reach a point that the first positive amount of profit appears. This number is shown as the "number of deliveries" in 4.8. It represents the transition from loss to profit.

The driver labor on Nissan NV-200 and Nissan E-NV200 significantly increased the cost of operating these vehicles; however, the break-even point for NV-200 and E-NV200 is 6 and 5 for Sprague, WA and they both have a break-even of 5 trips each for Volcano, HI. In both locations, the CAV van is the option that requires the lowest number of deliveries in order to turn a profit.

Table 4.8: Break Even Analysis

Parameter	WA NV-200	WA E-NV200	WA E-NV200	HI NV200	HI E-NV200	HI E-NV200
Break even point	6	5	4	5	5	4
Distance (mi)	44.5	43.5	42.5	29	29	28
Time (min)	1.70	1.65	1.60	1.58	1.58	1.50
Delivery Charges ($)	123.48	102.90	82.32	102.9	102.90	82.32
Driver Labor ($)	55.19	53.33	19.58	51.01	51.01	18.33
Operating Cost ($)	19.39	4.80	4.69	13.90	7.33	7.08
Ownership Cost ($)	35.06	39.04	54.54	34.51	38.49	53.99
Net Cost ($)	109.64	97.39	78.81	99.42	96.83	79.40
Net Profit ($)	**13.48**	**5.51**	**3.51**	**3.48**	**6.07**	**2.92**

4.2.3 Summary

For a customer dwelling in rural areas, owning a Nissan Leaf presents the most economical means to travel for obtaining household groceries and goods compared to popular household vehicles such as a Toyota Camry or a Ford F-150. However, pickup trucks are far more popular than EVs and sedans in rural areas and substitution of their trips by deliveries will yield the largest household benefits.

It is evident that providing delivery services in rural areas can be a viable option no matter which type of van is chosen; rural households will save time and money, and reduce their crash risk. Of course this is predicated on sufficient daily demand for this service. Note that we examined only one rural area (Sprague, WA) anchored to a big box retailed in Spokane, WA, but various other rural areas around Spokane can be added, substantially enlarging the rural market and demand for delivery.

Figure 4.2 and 4.3 report graphically illustrates each delivery service vehicles' break-even point in long-distance shopping in Sprague, WA, and moderate-distance in Volcano, HI. The graph shows an increasing number of deliveries plotted on the X-axis and increasing net profit on the Y-axis. The break-even line is plotted with those of the three delivery vehicle options to identify areas of intersection. As the number of deliveries needed to reach break-even increases, so those the net cost of reaching that break-even increase.

Figure 4.2 graphically shows that the break-even line intersects the 2019 Nissan e-NV200 (CAV) at four deliveries per day. At a break-even of 4 deliveries per day, the net cost of reaching that break-even cost is significantly lower. 2019 Nissan e-NV200 is intercepted at a break-even of 5 deliveries per day while 2019 Nissan NV200 is intercepted at six deliveries per day. At a break-even of 5 and 6 deliveries, the net cost of reaching those deliveries is significantly higher than the 2019 Nissan e-NV200 (CAV) in long-distance, which shows that the 2019 Nissan e-NV200 (CAV) is more profitable in the long run.

Figure 4.3 graphically represents the break-even analysis of using these delivery vehicles on a moderate distance of Volcano, HI. The chart shows that the break-even line intersects the 2019

Nissan (CAV) at four deliveries per day, which is the same break-even delivery point recorded in the long-distance Sprague, WA chart. Subsequently, the break-even line also intersects the 2019 Nissan gasoline propelled model and the 2019 e-NV200 model at five deliveries per day on each line. The break-even for the 2019 Nissan NV200 slightly reduced from 6 to 5 in the moderate distance in Volcano, HI. However, the break-even for both the 2019 Nissan e-NV200 and 2019 Nissan e-NV200 (CAV) remained at 5 and 4 deliveries per day. Repeatedly, the 2019 Nissan e-NV200 (CAV) proved to be the most profitable of the three delivery vehicle options.

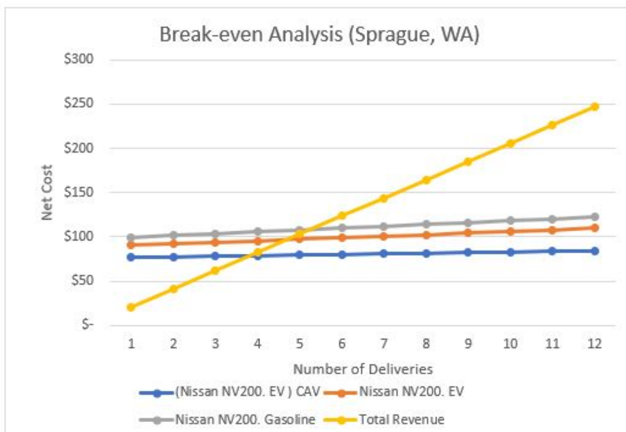


Figure 4.2: Break-even Analysis WA

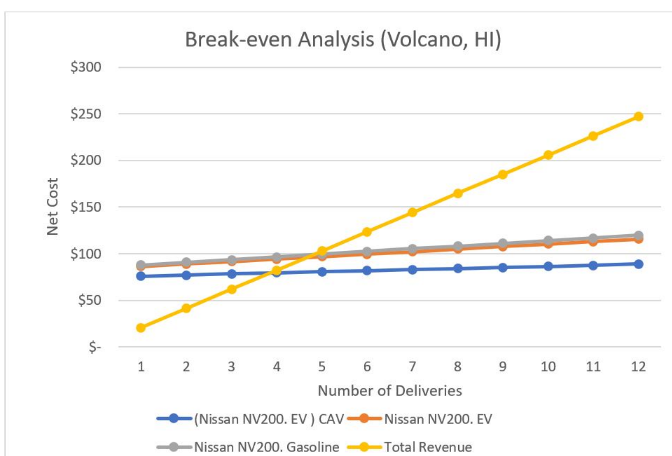


Figure 4.3: Break-even Analysis HI

CHAPTER 5. CONCLUSIONS

The objective of this research was to investigate delivery service in rural areas with CAVs in order to help the larger proportions of elderly and disabled people, reduce the disproportionally higher number of fatal crashes on rural highways, reduce the household transportation cost for obtaining goods in rural areas given that rural resident typically drive older, larger and less efficient vehicles; and reduce the time that rural household spend on shopping for food, groceries, and other household goods. The objective was accomplished by conducting a two-fold analysis: One part concentrated on the rural household; this represents the demand or the customer. Rural delivery to these customers only makes sense if it saves them time and money. Additional benefits include pollution reduction and crash safety risk reduction, but these are not practical and monetized consideration of rural customers. They we discussed but they were not included in the estimates.

The second part included detailed analysis for delivery by three modes based on an economical compact van running with a driver and propelled with in gasoline fueled internal propulsion engine; the same with a batter electric power plant; and a third option as an EV operating as a Level 4 or 5 CAV. Two case studies were deployed in order to assess the impact of vehicle ownership and operating costs, distances, household incomes and value of time spent on obtaining household goods and groceries.

The conclusion of the analysis is that CAV delivery service can be more convenient, fuel-efficient, safer, and provides a generally better performance leading to reduced time, money, and effort that rural households spend to access a grocery store or big box retailer. CAV will reduce the number of the elderly on rural roads making it safer and reliable for them to access food and supplies from stores.

Human factors cause approximately 94% of crashes [3] and an additional 2% of crashes are due to issues with the vehicle; a CAV can assess itself and refuse operation if there are problems with itself (sensors, tires, headlights, etc.) Thus, about 96% of crashes can be attributed as the responsibility of the driver or the vehicle. This represents a very high potential for crash reduction by Level 4 and 5 CAV which will always operate within the limits of the law and have the ability to reduce at-fault crashes substantially. They will only partly protect their occupants from non-CAV vehicles crashing onto them so the maximum expectation for crash reduction is about 75% based on NHTSA's National Motor Vehicle Crash Causation Survey [96].

The deployment of CAVs in rural areas faces several challenges. One of the challenges is the curviness and ruggedness of roads in rural areas due to the topography and climate. CAVs have to overcome government regulations as there is no existing regulatory structure to oversee the safe introduction of CAVs to the public. Being purely dependent on software, CAVs are prone to cybersecurity threats. CAVs do have to win public trust following a few well publicized fatal crashes with Uber and Tesla self-driving vehicles. The introduction of CAVs could also have a major influence on the economy with the loss of jobs; however, there could be a balance as the industry may create new employment opportunities.

A concluding positive note on CAV deployment refers to the implications of the Covid-19 pandemic in the development and deployment of CAVs. The combination of distancing requirements at crowded stores (with long wait times and crowd management) along with the substantial sensitivity to the disease by older persons and persons of various ages with specific health conditions provide a strong impetus for contactless delivery of goods and services, which bodes well for urban delivery with mini CAVs and rural delivery with Level 4 and 5 van CAVs.

5.0.1 Future Research

The study's process and results are scalable and can be applied in different rural areas. Moreover, specific questions were suggested to be investigated in the future, such as:

- Sensitivity analysis by income to save time and costs due to delivery options (trip avoidance).
- Methodology for calculating and allocating the delivery CAV fleet's indirect overheads in rural areas.

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APPENDIX A. ADDITIONAL MATERIAL

A.0.1 Long Distance: Sprague, WA

Table A.1: Break-even Analysis for 2019 Nissan NV200 Gasoline

No.	Delivery fee	Distance (one way)	Time (hr)	Driver labor	Operating Cost	Ownership Cost	Net Cost	Net Profit
1	$ 20.58	39.5	1.45	$ 46.98	$ 17.21	$ 35.06	$ 99.26	$ (78.68)
2	$ 41.16	40.5	1.50	$ 48.63	$ 17.65	$ 35.06	$ 101.33	$ (60.17)
3	$ 61.74	41.5	1.55	$ 50.27	$ 18.08	$ 35.06	$ 103.41	$ (41.67)
4	$ 82.32	42.5	1.60	$ 51.91	$ 18.52	$ 35.06	$ 105.49	$ (23.17)
5	$ 102.90	43.5	1.65	$ 53.55	$ 18.95	$ 35.06	$ 107.56	$ (4.66)
6	**$ 123.48**	**44.5**	**1.70**	**$ 55.19**	**$ 19.39**	**$ 35.06**	**$ 109.64**	**$ 13.84**
7	$ 144.06	45.5	1.75	$ 56.83	$ 19.82	$ 35.06	$ 111.71	$ 32.35
8	$ 164.64	46.5	1.81	$ 58.47	$ 20.26	$ 35.06	$ 113.79	$ 50.85
9	$ 185.22	47.5	1.86	$ 60.11	$ 20.69	$ 35.06	$ 115.87	$ 69.35
10	$ 205.80	48.5	1.91	$ 61.75	$ 21.13	$ 35.06	$ 117.94	$ 87.86
11	$ 226.38	49.5	1.96	$ 63.39	$ 21.57	$ 35.06	$ 120.02	$ 106.36
12	$ 246.96	50.5	2.01	$ 65.03	$ 22.00	$ 35.06	$ 122.10	$ 124.86

Table A.2: Break-even Analysis for 2019 Nissan e-NV200

No.	Delivery fee	Distance (one way)	Time (hr)	Driver labor	Operating Cost	Ownership Cost	Net Cost	Net Profit
1	$ 20.58	39.5	1.45	$ 46.98	$ 4.36	$ 39.04	$ 90.38	$ (69.80)
2	$ 41.16	40.5	1.50	$ 48.63	$ 4.47	$ 39.04	$ 92.13	$ (50.97)
3	$ 61.74	41.5	1.55	$ 50.27	$ 4.58	$ 39.04	$ 93.89	$ (32.15)
4	$ 82.32	42.5	1.60	$ 51.91	$ 4.69	$ 39.04	$ 95.64	$ (13.32)
5	**$ 102.90**	**43.5**	**1.65**	**$ 53.55**	**$ 4.80**	**$ 39.04**	**$ 97.39**	**$ 5.51**
6	$ 123.48	44.5	1.70	$ 55.19	$ 4.91	$ 39.04	$ 99.14	$ 24.34
7	$ 144.06	45.5	1.75	$ 56.83	$ 5.02	$ 39.04	$ 100.89	$ 43.17
8	$ 164.64	46.5	1.81	$ 58.47	$ 5.13	$ 39.04	$ 102.64	$ 62.00
9	$ 185.22	47.5	1.86	$ 60.11	$ 5.24	$ 39.04	$ 104.39	$ 80.83
10	$ 205.80	48.5	1.91	$ 61.75	$ 5.35	$ 39.04	$ 106.14	$ 99.66
11	$ 226.38	49.5	1.96	$ 63.39	$ 5.46	$ 39.04	$ 107.89	$ 118.49
12	$ 246.96	50.5	2.01	$ 65.03	$ 5.57	$ 39.04	$ 109.64	$ 137.32

Table A.3: Break-even Analysis for 2019 Nissan e-NV200 (CAV)

No.	Delivery fee	Distance (one way)	Time (hr)	Driver labor	Operating Cost	Ownership Cost	Net Cost	Net Profit
1	$ 20.58	39.5	1.45	$ 17.73	$ 4.36	$ 54.54	$ 76.63	$ (56.05)
2	$ 41.16	40.5	1.50	$ 18.35	$ 4.47	$ 54.54	$ 77.36	$ (36.20)
3	$ 61.74	41.5	1.55	$ 18.96	$ 4.58	$ 54.54	$ 78.08	$ (16.34)
4	**$ 82.32**	**42.5**	**1.60**	**$ 19.58**	**$ 4.69**	**$ 54.54**	**$ 78.81**	**$ 3.51**
5	$ 102.90	43.5	1.65	$ 20.20	$ 4.80	$ 54.54	$ 79.54	$ 23.36
6	$ 123.48	44.5	1.70	$ 20.82	$ 4.91	$ 54.54	$ 80.27	$ 43.21
7	$ 144.06	45.5	1.75	$ 21.44	$ 5.02	$ 54.54	$ 81.00	$ 63.06
8	$ 164.64	46.5	1.81	$ 22.06	$ 5.13	$ 54.54	$ 81.73	$ 82.91
9	$ 185.22	47.5	1.86	$ 22.68	$ 5.24	$ 54.54	$ 82.46	$ 102.76
10	$ 205.80	48.5	1.91	$ 23.30	$ 5.35	$ 54.54	$ 83.19	$ 122.61
11	$ 226.38	49.5	1.96	$ 23.92	$ 5.46	$ 54.54	$ 83.92	$ 142.46
12	$ 246.96	50.5	2.01	$ 24.54	$ 5.57	$ 54.54	$ 84.65	$ 162.31

A.0.2 Moderate Distance: Volcano Village, HI

Table A.4: Break-even Analysis for 2019 Nissan NV200 Gasoline

No.	Delivery fee	Distance (one way)	Time (hr)	Driver labor	Operating Cost	Ownership Cost	Net Cost	Net Profit
1	$ 20.58	25	1.28	$ 41.30	$ 11.98	$ 35.01	$ 88.28	$ (67.70)
2	$ 41.16	26	1.35	$ 43.72	$ 12.46	$ 35.01	$ 91.19	$ (50.03)
3	$ 61.74	27	1.43	$ 46.15	$ 12.94	$ 35.01	$ 94.10	$ (32.36)
4	$ 82.32	28	1.50	$ 48.58	$ 13.42	$ 35.01	$ 97.01	$ (14.69)
5	**$ 102.90**	**29**	**1.58**	**$ 51.01**	**$ 13.90**	**$ 35.01**	**$ 99.92**	**$ 2.98**
6	$ 123.48	30	1.65	$ 53.44	$ 14.38	$ 35.01	$ 102.82	$ 20.66
7	$ 144.06	31	1.73	$ 55.87	$ 14.86	$ 35.01	$ 105.73	$ 38.33
8	$ 164.64	32	1.80	$ 58.30	$ 15.33	$ 35.01	$ 108.64	$ 56.00
9	$ 185.22	33	1.88	$ 60.73	$ 15.81	$ 35.01	$ 111.55	$ 73.67
10	$ 205.80	34	1.95	$ 63.16	$ 16.29	$ 35.01	$ 114.46	$ 91.34
11	$ 226.38	35	2.03	$ 65.59	$ 16.77	$ 35.01	$ 117.37	$ 109.01
12	$ 246.96	36	2.10	$ 68.02	$ 17.25	$ 35.01	$ 120.27	$ 126.69

Table A.5: Break-even Analysis for 2019 Nissan e-NV200

No.	Delivery fee	Distance (one way)	Time (hr)	Driver labor	Operating Cost	Ownership Cost	Net Cost	Net Profit
1	$ 20.58	25	1.28	$ 41.30	$ 6.32	$ 35.01	$ 82.62	$ (62.04)
2	$ 41.16	26	1.35	$ 43.72	$ 6.57	$ 35.01	$ 85.31	$ (44.15)
3	$ 61.74	27	1.43	$ 46.15	$ 6.83	$ 35.01	$ 87.99	$ (26.25)
4	$ 82.32	28	1.50	$ 48.58	$ 7.08	$ 35.01	$ 90.67	$ (8.35)
5	**$ 102.90**	**29**	**1.58**	**$ 51.01**	**$ 7.33**	**$ 35.01**	**$ 93.35**	**$ 9.55**
6	$ 123.48	30	1.65	$ 53.44	$ 7.59	$ 35.01	$ 96.03	$ 27.45
7	$ 144.06	31	1.73	$ 55.87	$ 7.84	$ 35.01	$ 98.72	$ 45.34
8	$ 164.64	32	1.80	$ 58.30	$ 8.09	$ 35.01	$ 101.40	$ 63.24
9	$ 185.22	33	1.88	$ 60.73	$ 8.35	$ 35.01	$ 104.08	$ 81.14
10	$ 205.80	34	1.95	$ 63.16	$ 8.60	$ 35.01	$ 106.76	$ 99.04
11	$ 226.38	35	2.03	$ 65.59	$ 8.85	$ 35.01	$ 109.44	$ 116.94
12	$ 246.96	36	2.10	$ 68.02	$ 9.10	$ 35.01	$ 112.13	$ 134.83

Table A.6: Break-even Analysis for 2019 Nissan e-NV200 (CAV)

No.	Delivery fee	Distance (one way)	Time (hr)	Driver labor	Operating Cost	Ownership Cost	Net Cost	Net Profit
1	$ 20.58	25	1.28	$ 15.58	$ 6.32	$ 50.51	$ 72.41	$ (51.83)
2	$ 41.16	26	1.35	$ 16.50	$ 6.57	$ 50.51	$ 73.58	$ (32.42)
3	$ 61.74	27	1.43	$ 17.41	$ 6.83	$ 50.51	$ 74.75	$ (13.01)
4	**$ 82.32**	**28**	**1.50**	**$ 18.33**	**$ 7.08**	**$ 50.51**	**$ 75.92**	**$ 6.40**
5	$ 102.90	29	1.58	$ 19.25	$ 7.33	$ 50.51	$ 77.09	$ 25.81
6	$ 123.48	30	1.65	$ 20.16	$ 7.59	$ 50.51	$ 78.26	$ 45.22
7	$ 144.06	31	1.73	$ 21.08	$ 7.84	$ 50.51	$ 79.42	$ 64.64
8	$ 164.64	32	1.80	$ 22.00	$ 8.09	$ 50.51	$ 80.59	$ 84.05
9	$ 185.22	33	1.88	$ 22.91	$ 8.35	$ 50.51	$ 81.76	$ 103.46
10	$ 205.80	34	1.95	$ 23.83	$ 8.60	$ 50.51	$ 82.93	$ 122.87
11	$ 226.38	35	2.03	$ 24.75	$ 8.85	$ 50.51	$ 84.10	$ 142.28
12	$ 246.96	36	2.10	$ 25.66	$ 9.10	$ 50.51	$ 85.27	$ 161.69