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Let the Cars Drive Themselves.

-The Benefits of Autonomous Vehicles on Socioeconomics.

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Abstract

This thesis studies the costs and benefits of having Autonomous Vehicles (AV) on the roads of the United States in the future. The technology is closer to becoming a reality than most imagine.

The review exclusively analyzes the United States' market, which is the world's largest automotive market. The vast availability of data and statistics make it a useful model within its own context, and it is also applicable and translatable to the markets of the rest of the world. The almost 2.4 million accidents that lead to over 33,000 motor vehicle related deaths, plus the cost of congestions, cost Americans 121 billion dollars annually. It is believed that the autonomous vehicles will eliminate all of these negative events, and pose a both economic and social potential benefit to society.

Analysis of the available data and statistics was completed using Cost-Benefit Analysis (CBA), and shows that there is a potential to save three dollars for every one dollar spent on the previously mentioned accidents, deaths, etc. With the government, insurance companies, and car makers investing heavily in the research and manufacturing of these systems, this data show that the technology is worth the large financial investment, and it also demonstrates that not only is there a monetary benefit, but that AV can potentially improve the quality of life for the people that live in United States. This would help the government of the United States reach its ultimate goal, which is to promote welfare for its citizen.

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1 Introduction

The year is 2021. You just finished dinner at a restaurant, and you are waiting to pick up your car from the valet. The car arrives and no one steps out; it drove there autonomously. This is part of a system of autonomous vehicles that already exists today. There are cars on the road in United States and in Europe that are driving by themselves with the help of different sensor-technology-based systems built into standard cars. The autonomous vehicles will revolutionize the way we transport ourselves, and they are closer to reality than we think. The benefits are endless and the cost to society seems minimal. Car manufacturers, insurance companies and the government are spending millions of dollars on the technology, but who are the real beneficiaries? Is it the auto-maker, the government, or the private citizen?

By allowing the assumption that these cars are on the road today, we can model the potential benefits and costs of these autonomous vehicles on society. (ENO 2013) Nevertheless, it is important to note that currently the technology has several hurdles to overcome before it hits the mass consumer market.

1.1 Background

At the world's fair in New York City, Futurama 1939, sponsored by General Motors, the company talked about a crash-free world where cars autonomously drove people around (General Motors 1939). Several decades later we are seeing this futuristic world come to fruition. Companies like Google and Audi have already registered and been accepted for permits to drive their AV in Nevada (ENO 2013). In California, these companies are already able to drive their AV as long as there is a person with a valid driving license in the car. (Hirsch 2013) Google is in the forefront of the pack with a Toyota Prius clocking over 400,000 miles of autonomous driving, which has been on the road since 2010 (Markoff 2010). However, it was in 2004 when AV began to catch the public eye. At this time, the Defense Advance Research Projects Agency (DARPA 2007) initiated a grand challenge. DARPA manages research for the Department of Defense in United States. In 2004 they challenged fifteen teams to drive 142 miles in a desert course autonomously, yet no one completed the task. It was not until the following year that a team was able to capture the $2 million prize by completing the now 132 mile course in just under 7 hours (DARPA 2007).

Finally, the technology has started to catch up to the dream of the autonomous vehicles of the future. In 2009, Volvo introduced a system called City Safety, the first technology of its kind to come standard in a vehicle. City Safety works by detecting a car moving in the same direction as your vehicle, or that is standing still. If a crash is eminent, based upon calculations of speed and distance of both vehicles, the car will, at the last minute, avoid or mitigate a collision by automatically applying the brakes (Volvo Cars Corporation 2013c). This type of automatic braking system is now available in most car makes and models. The technology has only continued to advance, to semi-autonomous systems that are able detect nearly everything around us using cameras and sensors, and warn the driver if there is a potential of danger. These systems will only continue to grow. The AV of the future will be able to think by itself and connect to other cars, trucks and the infrastructure around it. This may seem far-fetched, but in reality the system is already being tested and will be here sooner than we think. This system is part of an autonomously vehicle system, which will be a self-driven car that will work on all roads and streets. This type of system of AVs is predicted to be on roads and fully automated by 2018 (KPMG and Car 2012). As to be discussed, some of the costs and benefits of these cars are the elimination of accidents and deaths from motor vehicle accidents, less wear and tear on both the cars themselves and the surrounding infrastructure such as roads and bridges. From there, one can deduce that fewer accidents could lead to fewer emergency first responders being needed, police officers and firemen, which will lead to saving in government spending (KPMG and Car 2012) but this also comes with a loss of jobs, a downfall of the advances of these technologies. This is just the tip of the iceberg in understanding the effect of putting AVs on the road.

With the technology of self-driven cars being on the brink of revolutionizing the automotive industry, we need to have a better understanding of the costs and benefits. In the United States, the National Highway Transportation Safety Administration (NHTSA) has engaged in researching the AV and has created definitions of different levels of automated vehicles. They start at level 0: the driver has complete control over the vehicles and is only provided with warnings. The scale goes through level 4 which is a car fully automated and drives by itself with no need for a driver within (Table 1) (NHTSA 2013b). Today, we have cars on Level 2 that you can buy as a privet consumer.

No-Automation (Level 0):	The driver is in complete and sole control of the primary vehicle controls – brake, steering, throttle, and motive power – at all times.
Function-specific Automation (Level 1):	Automation at this level involves one or more specific control functions. Examples include electronic stability control or pre-charged brakes, where the vehicle automatically assists with braking to enable the driver to regain control of the vehicle or stop faster than possible by acting alone.
Combined Function Automation (Level 2):	This level involves automation of at least two primary control functions designed to work in unison to relieve the driver of control of those functions. An example of combined functions enabling a Level 2 system is adaptive cruise control in combination with lane centering.
Limited Self-Driving Automation (Level 3):	Vehicles at this level of automation enable the driver to cede full control of all safety-critical functions under certain traffic or environmental conditions and in those conditions to rely heavily on the vehicle to monitor for changes in those conditions requiring transition back to driver control. The driver is expected to be available for occasional control, but with sufficiently comfortable transition time. The Google car is an example of limited self-driving automation.
Full Self-Driving Automation (Level 4):	The vehicle is designed to perform all safety-critical driving functions and monitor roadway conditions for an entire trip. Such a design anticipates that the driver will provide destination or navigation input, but is not expected to be available for control at any time during the trip. This includes both occupied and unoccupied vehicles.

Table 1. NHTSA Grading of autonomous vehicles.

Research continues to perfect the vehicles, to create a level 4 AV that works 100% of the time. Beyond developing the technology, companies and governments are working to figure out how to integrate these vehicles to the market and society. This includes studying changes in laws and regulations, to understand liabilities, and research to see the demand that is present and how much these vehicles will cost to be manufactured and eventually purchased and put on the road. Its important to note that we are currently at level 1, and that it will be a gradual increase of each level with both legislation and technology obstacles.

The missing pieces of the puzzle lie in understanding the unforeseen costs and benefits. The government is spending millions of dollars on researching how to regulate and implement the technology, and similarly, the major automakers are investing heavily in both working with the government and other companies like insurance companies to make the cars work optimally. (NHTSA n,b,) While we work to understand the intricacies of the budding technologies, it is important to consider how they will affect our society. In the near future these AV will be able to talk to each other, with the roads, with the networks surrounding them. Currently, we don't know what the cost on the society will be. The benefits appear endless, but what are the costs?

With this said there is research presented that believe the car will hit the mass market by 2018 (KPMG and Car 2012) with a gradual impact on the market from their on. The paper will look at the cost and benefits it would have had on the 2012 automotive market, as well as do a sensitivity analysis to investigate the impact of the gradual introduction of AVs.

1.2 Purpose

The purpose of this thesis is to explore AV's socioeconomic impact. The benefits and costs of having AV on the road are numerous, and so not every topic can be covered in this project. Here we will look at the current situation in United States. With an exante (that looks at the future) cost benefit analysis, we can take a glimpse into the potential future so that lawmakers, politicians, decision makers and private companies can more wholly understand the impact of this new phase in the automotive industry, and they will ideally be able to make more accurate budgets and decisions.

1.3 Question

What are the main socioeconomic benefits and costs of Autonomous Vehicles in United States?

1.4 Limitation

By solely studying the market in the United States, this paper will not study other countries such as Sweden, Spain and Japan where development of AVs is being done as well (Volvo Car Corporation 2013c., SARTRE n,d, Nissan 2013). The varying economic and government models in these countries make the costs and benefits highly variable between them. Each country will likely experience their own socioeconomic effects specific to their current culture and economy. Additionally, there are more benefits and costs of AV that will not be discussed. These include but are not limited to the benefits to infrastructure, environmental benefits, the building of new businesses, cost of ownership and implementation. Beyond AV for personal use, there are also other kinds of vehicles that could be or already are autonomous, such as trucks, buses, boats, and airplanes. These commercial and public type vehicles will not be discussed here. This work is looking into the future, which makes it inherently imprecise, but will provide a big picture of the socioeconomic costs or benefits that the technology can bring about.

1.5 Autonomous Vehicles

There are many different levels and kinds of autonomous vehicles. We covered the different levels of AV in the background but here we will cover the actual technologies being used. Today we have cars that people can buy with autonomous features, but that are not fully automated. These features, which are available in a wide variety of cars and are becoming more and more common, can keep you in the correct lane on the highway, parallel park, avoid pedestrians, cars and trucks, and keep an even distance from the car in front of you. Each automaker assigns its own creative name to these features, but all use essentiality the same technologies. The future fully autonomous vehicle will be using Light Detecting and Ranging (LIDAR), radar, global positioning system (GPS), internal gyroscopes, and duel-cameras combined with a powerful computer that is connected to the internet. All of these features combine to mimic the human senses, particularly sight. This is referred to as a converged solution, which is the most cost-effective and also provides the necessary security and redundancies so that the technology will work 100% of the time. (KPMG and Car 2012)

1.6 Research Strategy and Design

The overall research strategy will be to do a quantitative study, which according to Alan Bryman (2011) is a study that is characterized as quantifying the data and analysis. This study will be heavily based on prior empirical research from publications by KPMG and Car, *Self-driving Cars: the Next Revolution,* as well as a study form ENO, *Preparing the Nation for Autonomous Vehicles*. The purpose of the thesis is to show if there is a benefit or cost of having autonomous vehicles on the roads in United States. However, although many cars have AV features, complete Level 4 AV are not available for personal ownership and are not being mass-produced. With this in mind, an exante CBA will be calculated. Exante CBA is when you look a case that will happen in the future. Shown in earlier research, in particular KPMG and Cars publications, Level 4 AV will be on the road by 2018. Using this groundwork, this analysis will analyze data from the viewpoint of the year 2021, and also we will assume a 100 percent market penetration of AV in the automobile industry. There are three important characteristics when doing a social science study: validity, reliability and replication (Bryman 2011:73). Validity and reliability are the most important in this type of analysis (Bryman 2011:49). While choosing the items and researching data to be used in the CBA, the validity of the data was one of the biggest hurdles to overcome. The data needed to not only be collected and available, but applicable in the future (Bryman 2011:50). Validity and reliability are tightly related, and if the data analyzed is invalid it leads the results to be unreliable (Bryman 2011:49).

The study is done in such a fashion where the result should be able to transfer to a future date; also it is completed so that if factors change in the future, the data and results are easily transformable to reflect the most up to date and accurate data available. To be able to replicate the study puts pressure on the author to be detailed and describe which methods were used to analyze available data and where the data came from (Bryman 2011:49). This project makes the effort to be as clear as possible in both the sources of data and how each calculation was completed. Both quantitative and qualitative sources are being used and the newer sources and figures will be given a higher relevance factor.

2 Theory

To be able to analyze the impact of Autonomous Vehicles on the future roads of United States and its socioeconomic effects, we need to utilize previous economic theories. In this research we are looking at quality of life, market penetration and the cost/benefit to welfare in United States. In the following chapter we will talk about market failures and external effects that are related to the AV's. Exorbitant costs and a lack of supply and demand are potential costs to society. Additionally, individuals as members of society are also guaranteed a certain standard of living a part of social welfare. All of these play a role in neoclassic economics, a theory which goes back to the late 1800s. By utilizing the principles of neoclassic economics, we will approach this analysis from the previously described angles.

2.1 Market Failures and External Effects

Most of us have bought a Coca Cola product but have we ever thought about the cost of how to get that product in our hand? They use airplanes, trains, and trucks to transport their goods. All of these vehicles use fossil fuels which pollute the environment, and the companies which introduce the pollution do not pay for the pollution nor efforts to remove it. As a consequence of these potential negative effects such as pollution that are not covered or paid by the market, these costs are then distributed to the society and private citizens. With harmful emissions being released into the air, either from vehicles or factories, there is a byproduct that the company is not charged for. The producer of these goods does not pay for the cost (in this scenario, pollution) they are bringing on the society or compensate those affected by these external effects.

This is one reason why it is important to consider the issue form both a social and economic perspective, and quantify the effects and costs in monetary terms. In a modern industrial society these external effects are common and the difference between private and socioeconomic cost leads to market failures and thus leads to inaccurate resource allocations. (Brännlund, 1998:s15)

The classic national economics are designed to improve the marketplace and economic conditions for the individual. This leads to some aspects, such as external effects, being ignored or unaccounted for. The market has a hard time dealing with external effects and presence of the collective goods. (Söderqvist, Hammer & Gren 2007:50)

However, there is a way to accomplish optimal and effective allocation of societies resources.
This is to use a so called Pareto efficacy, and to make sure every market is Pareto-efficiency, which means that there are no changes that lead to someone having a better outcome without anyone else at the same time being worse. Secondly, every Pareto optimal situation can be achieved by market equilibrium. The assumption of a perfect market economy however, is based on a number of strict conditions, such as complete information about the economy as well as the absence of externalities and public goods.

This shows that the reality does not comply with the theory's requirement of a perfect market situation and that the resource allocation thereby is inaccurate. Despite our current reality not being a Pareto efficiently equilibrium, it is still the goal of the economy to reach such an equilibrium. (Söderqvist, Hammer & Grenn 2007, s.11,12)

2.2 Welfare Theory

Welfare is there to offer the society a range of guaranteed services like health care and education, but it also is expected to say what the minimum wage is for citizen, to support those who get sick, lose their job or are receiving social security. Vilfredo Pareto's approach to welfare, which we spoke about earlier, is called Pareto efficiency which states that the situation is effective if there is no way to make it better for someone without making it worse for someone else. This aspect might sound great in theory, but in the real world there are unsolvable practical and logical problems. This means that some will be at a greater advantage than others. Because of this, we now use a value judgment in Cost Benefit Analysis. (Pålsson Syll, Lars 2007:316)

If there is a well functioning welfare, it means that the living standards are high, and some people might argue that spending money on welfare is better used on other resources. The monetary terms are not the only way to look at how well a welfare system works, you can also see how happy people are, how many people are participating in social activities such as helping their communities. (Nohagen, Lars 2009:275) Autonomous vehicles maybe promote welfare by making people happier and more productive so that they can spend time on helping their society.

The public sector strives to simplify and improve society. This is connected to the infrastructure, public safety and well-being which are all important to the citizen and its government. The public sector stimulates growth and welfare so that the society works well and improves. The way society works has changed over the centuries, even just the last few decades. Today, infrastructure is a big part of what makes the society work. It is the highways, roads, tolls and other buildings that connect our house to our job, school and entertainments. These are all financed through tax whether it be in the form of income, sales tax to property tax. (Nohagen, Lars 2009:120) This relates back to how AV will impact society, and improving the infrastructure is a large social benefit.

2.3 Neoclassical economics

The neoclassical theory emergence came about in the late 1800s and early 1900s as a part of the above discussed theory of welfare in the fields of economics. Before neoclassic economics, most were interested in growth and allocation over a long period of time, where neoclassic economics focuses on determining price, outcomes and income.

As the market had worked without any major problems, while growth and improving welfare, the shift came to focus on the study the market and maximize its efficiency rather then discussions of production and distribution among different social groups. This meant that we went from a macro perspective to a micro perspective, so to understand how society worked as a whole. This means that the preferences of individuals and companies were more important than before. (Pålsson Syll 2007, s.198)

One of the founders to the new school of economies was Alfred Marshall. He believed that

> “The element of time is a chief cause of those difficulties in economic investigations which make it necessary for man with his limited powers to go step by step; breaking up a complex question, studying one bit at a time, and at last combining his partial solutions into a more or less complete solution of the whole riddle… The more the issue is thus narrowed, the more exactly can it be handled: but also the less closely does it correspond to real life. Each exact and firm handling of a narrow issue, however, helps towards treating broader issues, in which that narrow issue is contained, more exactly than would otherwise have been possible.” -Alfred Marshell (Marshell, Alfred 1920:V.V. 10)

This is a way to understand economics, and allows us to carry out a theoretical experiment with a variable and a constant. The consequences are that this model will make it less based in reality, but it will be easier understood and orderly. (Marshell, Alfred 1920:V.V.10) The fundamental assumptions of a neoclassic economists are: rational preferences maximize utility and profits, and act on the basis of relevant information (E. Roy Weintraub (2014). This paper is based upon these neoclassical assumptions.

The goal was to build a coherent economic theory that assumed that we had rational individuals and companies who always strived to maximize their needs and their net income. With the goal of maximizing needs and net income, Marshell created a demand curve for the market as an entirety. With this he was he was also able to make a supply curve which is the foundation of the well-known and utilized supply and demand curve. (Pålsson Syll 2007, s. 210f) This meant that Marshell could create a prize theory, and if the market had worked as his theory predicted, the resource allocation would have worked to 100% and we would not have any need for any public interference in the form of taxation. However in reality, an unregulated market does not lead to an optimal resource allocation. (Pålsson Syll 2007, s. 214)

In addition to its many benefits, the supply and demand curve allow one to determine if there will be an excess, and according to Marshell, excess can be used as an indicator of welfare, assuming that the marginal utility was constant. The consumers excess or surplus demonstrated that there was money left that could be used for other services and products which is good for the society as a whole. (Pålsson Syll 2007, s. 214) This surplus of money in our case can be used on autonomous vehicles but its also important to note that an excess is an indicator that the government as a whole is successful and it's citizens are generally happier during times of economic excess.

3 Methodology and Data Sources

This section will talk about Cost Benefit Analysis, both its stages and the exante and exposit analyses. It will also go through how present value and shadow prices are calculated, and at the end it will determine what resources were used for the analyses.

3.1 CBA

To investigate the impact of AV in the future, a cost benefit analysis will be used. This analysis will best be able to look at the socioeconomic benefits and value the various costs in the most appropriate manner. There are many different ways to calculate an economic cost where the basis is socioeconomic.

Cost Benefit Analysis (CBA) investigates, in this case, socioeconomic costs and benefits and is then used to determine if the scenario is profitable. CBA's core is from the welfare structure, which demands one to account for efficiency, time, quality and market failures. (Salas, 2012:20) CBA not only includes the analysis of identifying cost and benefits in the privet sector, but it also looks at values and effects that are not in monetary terms. This is important because even effects without monetary terms could be a cost or a benefit to the society. (Salas, 2012:15)

CBA is used as a tool to analytically resolve if a project is using the resources in an efficient and cost beneficially way. It helps to provide an overhead view of a project both immediately financially and over time. (Salas, 2012:15)

As an example, quality of life has a big impact of the society. It can change the way we feel about work or our family. CBA helps us to understand the effects of AV, and those effects can be calculated into monetary terms. It is important to keep the external negative effects to a minimum, and to make sure there is a profit financially and in terms of socioeconomics. When we analyze the cost and benefits of projects we can discover and identify vulnerabilities that can be either benefits or costs. It s important that we calculate the cost of projects out of a socioeconomic perspective so that decision makers don't miss monetary effects that are not always shown in your simple economic calculations. (Salas, 2012:32)

In this paper we will look at the socioeconomic cost on a nation wide level. With that we are also looking at the cost of an exante project because AV are not readily available in today's market.

EX-ANTE & EX-POST CBA

Cost Benefit Analysis can take shape at different times: ex-ante, before an event, or ex-post, after an event. Here we will look at it on an exante basis, because autonomous vehicles are not yet fully integrated into society yet. The driving argument in this paper is to focus on the effects of the coming AV revolution, which has not yet completely arrived. By analyzing an exante event, we benefit by supplying vital information to the decision makers and politicians, as well as consumers. They will have more complete information of the real value of the coming of AV's, from how to write legislature, to inform the buyer's market. Additionally, exante CBA also allows us to understand the future cost and the revenue. The negative side of an exante study is that it is a prediction of a future time and cannot be perfectly true because the future can always change. For instance, it cannot show resource allocations because the analysis is done before the vehicles are being made for production. (Boardman, 2001:3) Regardless, CBA is a tool currently used throughout out the US government and of particular relevance, by the department of transportation (DOT). The tool will provide the basis for much of the calculation in determining the cost and benefit to society of AVs. (Salas, 2012:81) (DOT)

THE STAGES OF A COST BENEFIT ANALYSIS

To be able to come to calculate the present value result there are three stages that needs to be performed. The first stage is identification. This means identifying all of the projects activities and thereby their costs and benefits. It is usually easier to identify the costs of a project, however, due to the overwhelming benefits in this circumstance, it seems difficult to find significant socioeconomic costs. (Salas 2012:37)

Stage two is to quantify. As it implies, the second stage will quantify physicals items into hours, distances, numbers, and counts. This stage allows us to put a monetary amount to each item within the analysis. (Salas 2012:35)

Stage three is evaluation. This is the last step, but one of the most important. In this stage we use the monetary amounts calculated in stage two and determine the overall effect. (Salas 2012:42)

3.2 Present Value method, and Shadow Prices

The goal of CBA is to describe the socioeconomic cost and benefit as accurately as possible. To obtain the economic viability of a project is to weight the costs and benefits (economic) against each other. In order to do this, revenue and expense items should be valued in a measure, which is equal for all items, and this is usually done in monetary terms. They will then be discounted at a rate that is selected. When discounting is used the chosen discount rate used to convert income and costs to present value, so that these can be compared accurately. Discounting thus eliminates income and expenses added up to present value. Once this is done, it is possible to determine if a specific project is economically viable or beneficial. The cost and benefits typically come from data sources representing past figures. These will be calculated into the present value in a present value method (Salas, 2012:34). The formula is defined in Table 2.

Table 2

Present value method calculation
$PV = C/(1+i)^n$ C= Costs, I= Effective Interests, n= period

In a case where the market fails to put a price on an item there is a need for a shadow price to be calculated. This calculation derives prices to reflect the cost that had existed in case the goods had been priced in the market. (Salas, 2012:34) However, this is very time consuming. (Brent, 2006:112)

Using these methods and adjustments it will be determined if AV is a net cost or benefit to society. (Salas, 2012:34)

3.3 Sensitivity Analysis

To better appraise the project, especially, when it is predicting future events that are in a distant future, it is useful to use a sensitivity analysis where we will minimize the uncertainty of the dynamic economic reality. Sensitivity analyses also present the reader with different results depending upon the model used, so that he can better understand the project and potential outcomes. The future is unreliable and this is an important factor to highlight. When performing a sensitivity analysis, it is common to use interest rates and tax rates as scenarios when performing a sensitivity analysis. These are only a few examples of what variables can be used to account for the dynamics of the real economy within which this market will function. It is useful for testing the robustness of results in the thesis. (Sales, 2012:42)

3.4 Data Collection

This thesis, explained earlier, is largely supported by a research publication from KPMG and Car called Self-driving Cars: The Next Revolution (KPMG and Car 2012). This publication served as a starting off point to further pursue the sources cited within the document, and then move on to additional sources. These additional sources were found via Google scholar and Google by simply using keywords such as “Autonomous Vehicles” “self-driving cars”. It is important that the sources are authentic, trust-worthy, representative, meaningful and validated. Because of this, each source was carefully reviewed and only standardized sources concerning the automotive industry were used (Bryman 2011:489).

Additionally, official US government websites, publications and research papers will be used heavily, which is an excellent source of nationwide data. It should be mention that it is quantity of statistics we are looking for and in this case not quality statistics. (Bryman 2011:488).

Data from the US department of transportation (DOT) and the National Highway Traffic Safety Administration (NHTSA), which is part of the US DOT, will be used. US DOT's mission is to "Serve the United States by ensuring a fast, safe, efficient, accessible and convenient transportation system that meets our vital national interests and enhances the quality of life of the American people, today and into the future." (DOT 2013) These sources will contribute with vital statistics about crashes and deaths on American roads. These sources are easily available online via their websites. Besides using DOT and NHTSA the paper will also use RITA, Research and Innovation Technology Administration, which is part of DOT to get research statistics; this data will be validated and up-to-date.

4 Results

This chapter will identify the different effects, quantify and evaluate the items into dollar amounts. The thesis will mainly look at two aspects: the safety and productivity of AV's. The paper is assuming that AV's are at level 4 of the previously described NHTSA scale using 2012 data.

The following chapters will Identify, which is the first step of the CBA. The second stage is to Quantify and the third stage is to Evaluate, which makes it possible to calculate so that we are able to compare and evaluate the items in the same term, monetary terms.

The following is a summarized identification of both cost and benefits in Table 3. For each item the total cost will be calculated.

Cost	Benefit
Additional consumer cost per AV	Fewer accidents

	Few deaths
	Less traffic congestion
	Higher productivity

Table 3. Summary of costs and benefits to be analyzed.

4.2 Costs

Here we will summarize the cost of the having autonomous vehicles on the road. We will identify the cost and quantify it. At the end of the paragraph there is small discussion on what more cost could be associated with the autonomous vehicles but have been taken out of the thesis.

4.2.1 Additional cost per vehicle

There are not many costs attributed to AV's in the future, but the main cost attributed to these vehicles is the cost to consumer. Not surprisingly, this initial large cost is predicted to decrease over time, as with any budding technology. The estimated additional cost when the product is introduced is somewhere between $25,000 to $50,000 and would likely not fall to the $10,000 mark for at least 10 years. (ENO 2013) According to (Hensely, 2009: 88) the $10,000 price mark could come as soon as 5-7 years after mass market introduction of AV. This is calculated on the same basis as electric vehicles. The introductory price is unaffordable to most Americans where the current top selling vehicles range from $16,000 to $27,000 in total. (Boesler, 2012)

In a recent study by J.D Power and Associates revealed that 37% of people said they were 'definitely' purchasing a car with AV capability but this response dropped to 20% when asked if they would pay an extra $3000 (KPMG and Car 2012). This $3000 is the price increase Erik Coelingh (ENO 2013), a Volvo Senior Engineer for AV Capabilities, believes the AV cars will have on the price tag, although consumers known as early adaptors (those that purchase new technology early in its lifetime will have a much higher price tag.

This paper will assume an increase in the average price tag by $10,000, which is a fair estimate of semi-early adaptors and mass production. For comparison, as of December 2013 adding technology package, witch includes AV features like lane departure warning, lane keep aid, collision warning with full auto break, pedestrian detection with full auto break, City Safety (which avoids or mitigates a collisions at low speeds) adds $2,400 to the base price of $35,300 for Volvo's new V60 Drive-E (Volvo Car Corporation 2013). Additionally, to add similar packages to an Audi there is a $5,600 additional charge. In addition to the AV features mentioned on Volvo's S60, this vehicle comes with an infrared camera. This $5600 is added to a $57,900 price tag on the Audi A6 (Audi of America 2013).

There are about 230 millions vehicles on the US roads today (RITA 2013) carrying 312 million Americans (RITA 2012). In 2012, 14.5 million new vehicles were sold (Autodata 2013). This number will be used to calculate the estimated cost per year for AVs.

To summarize, the cost will be an additional $10,000 per car, with 14.5 million new cars sales, if we have assumed that the market has become completely overtaken by the AV. This results in an additional $145 billion in cost to the consumers (Table 3).
14,500,000x10,000= 145,000,0000.

Potential new AVs each year Units	Additional cost $	Total $
14,500,000	10,000	145,000,000,000

Table 4. Total cost of AV to consumers.

4.2.1 Why not more Costs?

There are many costs associated with AV's, one of which is the cost of implementing the vehicles. This analysis is from the perspective of costs to society, and so the large cost of implementation of the vehicles, which is absorbed by the private companies developing the vehicles, is not taken into consideration here. There are more potential cost such as loss of jobs, such as EMT's Police, taxi/ bus drivers. This is however very hard to estimate, and it is also possible that their jobs will be transformed to something else, or the AV market will provide a large increase in jobs, and so the net effect on jobs is unknown at this time. In the discussion, this will be further elaborated upon.

4.3 Benefits

In the following chapter we will go over the different benefits, where we will identify and quantify the benefits.

4.3.1 Fewer accidents

With LIDAR and other intelligent technology systems that mimic human behaviors the so-called converged solution AV will be able to avoid accidents. There are an estimated 2.36 million people injured in motor vehicle traffic related crashes in 2012 (NHTSA 2013a). It is worth noting this is the first increase of motor vehicle accidents since 2005 (NHTSA 2013a). Included in these accidents are passenger vehicles, large trucks, buses, and motorcycle occupants, as well as pedestrians, cyclists and other non-occupants (NHTSA 2013a). The total crashes per year in United States are 5.5 million (AAA 2011), with 93% being driver error as the primary cause of accidents (NHTSA 2013a). Even when vehicle malfunction is attributed to the crash, there are still human errors such as not paying attention or speeding that were also found to be contributing factors to crashes. To say the least, AV has a great potential to reduce accidents and crashes. AVs will be able to overcome many of the human errors attributed to accidents, but with any technology there are obstacles to overcome such as what do to in a situation where poor weather will challenge the sensors and impact road surface and change driving conditions. However, if we consider other current forms of AV transportation such as trains and airplanes, the fatality rate during transit is only about 1 percent (KPMG and Car 2012), a stark decrease compared to motor vehicles. With that being said, the roadways will not likely be entirely AV.

There will likely still be vehicles with manual override, putting the control back into human hands, and reintroducing human error.

A motor vehicle accident which results in an injury results in an estimated cost of $126,000. This takes into account the physical accident, costs to the victims, as well as the loss of wages and time of those stuck in traffic due to the accident. Federal, state and local municipalities pay for about 9% of the cost of motor vehicle accidents, and most of the cost is paid by private insurances, which is about 50 percent. 25 percent of the cost of accidents is paid by individual crash victims, while uninvolved motorist delayed in traffic, charities and healthcare pays the rest of the 14%. (NHTSA 2013 n,d.)

Crashes vs. Congestions projected a cost of injury at $126,000 (AAA 2011). Using 2.36 million people injured in motor vehicle crashes (NHTSA 2013a), the total savings if it is assumed that the injury rate goes down to zero with complete AV takeover of the roadways, a total of about $297 billion will be saved (Table 4).

2,360,000x126,000 = 297,360,000,000

Accidents each year	Cost per accident $	Total $
2,360,000	126,000	297,360,000,000

Table 5. Savings due to elimination of injuries due to motor vehicle accidents.

4.3.2 Fewer deaths

With 93% percent of accidents being contributed to human error, realistically AV’s could ultimately eliminate about 31,000 (93% of 33,000) of the 33,000 deaths that happen each year (NHTSA 2013a). The goal must always be to protect human life. Both the NHTSA and car companies like Volvo and Nissan have pledged that their goal for 2020 is that there will be no deaths and no serious injuries - a big testament for the future (NHTSA n.d., Volvo Car Corporation 2013c, Nissan 2013). AVs will be a big part of this goal.

There is a general moral benefit to eliminating motor vehicle fatalities, but additionally the monetary benefit is the economic impact of fewer deaths. Fewer fatalities mean more working years for these citizens, and therefore more taxes being paid, more income to the government, and the quality of life will be higher. It is important to note that a death in traffic impacts more than the people involved in the accident, as it is related to more parts of life. Crashes vs. Congestion was used to place a monetary value on the life lost to a traffic fatality (AAA 2011). Their research determined that each life is worth approximately 6 million in United States.

By using 31,000 (92% of 33,000) fatalities per year in motor vehicles, and the loss of $6,000,000, the total savings would be $186 billion (Table 5).
31,000x6,000,000 = 186,000,000,000

Deaths a year	Cost of a life $	Total $
31,000	6,000,000	186,000,000,000

Table 6. Cost of fatalities caused by motor vehicle accidents.

4.3.3 Less congestions

Twenty-five percent of congestion comes from accidents, and so fewer accidents means less congestion (DOT 2013). Congestion has only worsened year to year. In 1993 travelers spent an extra 40 hours per year in traffic, versus today where commuters and travelers spend an extra 47 hours per year in traffic congestion (DOT 2013).

The AV technology aims to make cars better at handling congestions, with systems that allow the car to read the traffic ahead of the vehicle, and control speed. Many of these systems we already have today. For example adaptive cruise control (ACC) keeps an even distance from the vehicle in front of you, automatically controlling the cars speed in traffic. There is research being done in

Europe called Safe Road Trains of the Environment (SARTRE n,d.), which is funded by the European Commission and is working with Volvo Cars and Volvo Technology of Sweden. It aims to put cars in large caravan lines so that they will be able to drive at higher speeds. They will do so semi-autonomously by following a professional truck driver, but at a closer proximity, allowing them to save on fuel and as a result, creating more space on highways (SARTRE n,d.).

Most traffic congestions come from traffic incidents and bottlenecks in traffic. Essentially all of the sources of congestions (figure 1) should be able to be avoided even with taking weather into consideration.

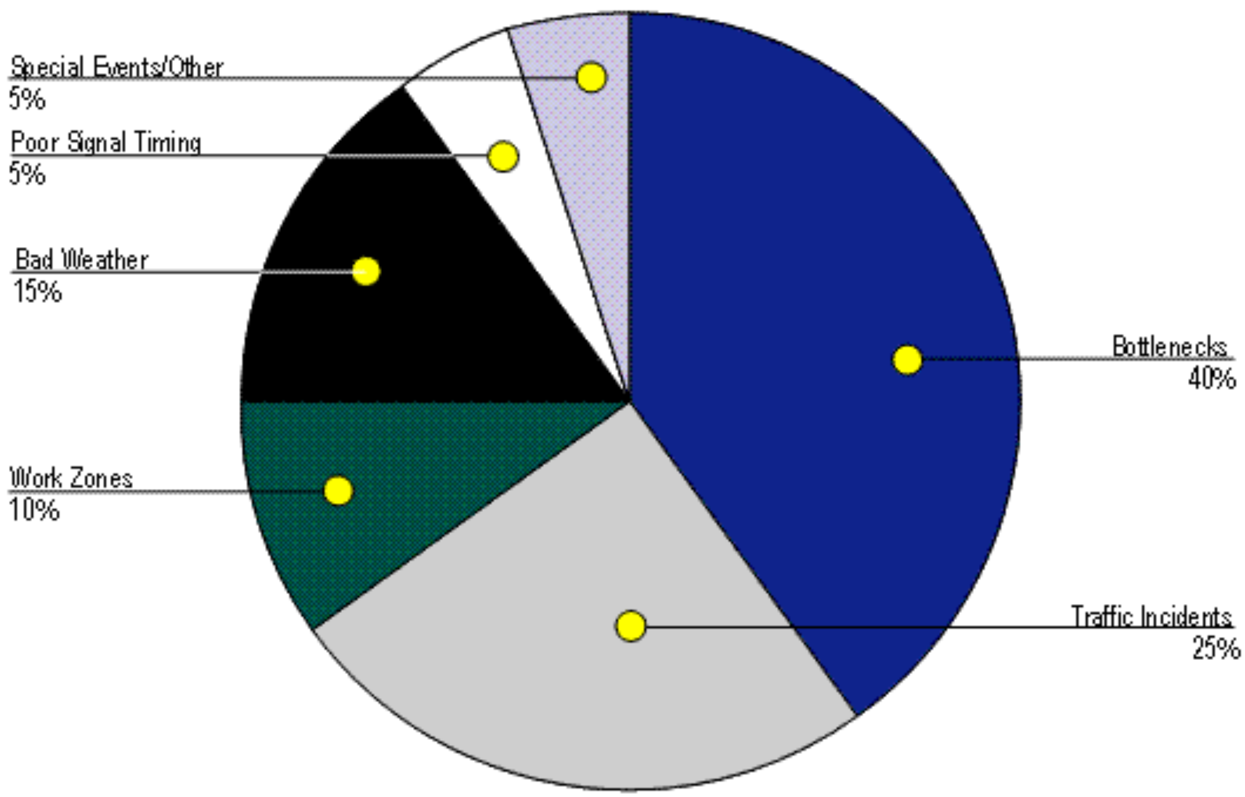

Figure 1. Source of congestions. (DOT)

There are circumstances where the cars' computer would be able to take a detour to avoid such events or keep a slower but steady pace during bad weather so to not hold up traffic. According to ENOs study, *Preparing a Nation For Autonomous Vehicles,* research shows potential for reduction in traffic congestion due to AV's that could increase fuel economy and speeds during congestion up to 39% and 15% respectively. By enabling vehicles to drive closer together, like in the SARTRE program, depending on market penetration of AVs, could lead up to a 90% increase in highway effective capacities (ENO 2013).

Urban Mobility Report 2012 (INRIX 2012) reported an increase of congestion cost for 2011 to an astonishing $121 billion. This number will be used as the savings attributed to preventing traffic congestion.

Cost of Congestions $		Total $
121,000,000,000		121,000,000,000

Table 7. Total savings attributed to eliminating traffic congestion with AV.

4.3.4 Higher productivity

Within this analysis productivity is defined as time spent driving rather than completing other tasks such as reading emails, being on phone calls, texting, working, reading the paper, putting make up on, or any other task that could be performed if you did not have to concentrate on the road. With AV's, you can now spend the time more freely. This not only adds to quality of life, it could also lead to more productivity in work and with roughly 80 percent of the work force spending an average of 50 minutes commuting to work and home, there is a lot of productivity being lost (KPMG and Car 2012).

It should be emphasized that whatever your occupation, student, employed, or retired, there are always ways for you to be more productive. If you're a doctor you can review your day's schedule. As a retail manager you can make the day's schedule. If your a student you can read that chapter you didn't have time to read the night before. The retired would have more independence and would be able to feel more secure at driving.

This is a difficult item to analyze and quantify because the use of free time could differ between various people - some can be relaxing and some could be working - both are acceptable. One way to put a monetary number on the productivity that is spent is to take the average wage for an American, which in 2012 was $44,321.67 (SSA n,d.). Assuming the average American works 49 weeks a year (2 weeks of vacation and about 7 days off for holidays,), and each work week consists of 40 hours, this yields 49 weeks/year x 40 hours/week = 1960 hours a year. Dividing $44,321.67 salary by 1,960 hours gives us an hourly wage of about $22. If we spend driving an estimated 1 hour extra commuting every day, five days a week for 49 weeks a year, that is 245 hours that we could be spending at work, which equals to 245 hours x $22/hour = $5390. $5390 lost of potential productivity per person in each vehicle. This number does not account for traffic and only demonstrates a scenario where everyone that drives to work was able to work an additional hour each day, over a year they would earn an additional $5,390. Now, if we further assume that someone traveling to work at any given point during the day taking them an extra hour. The total potential use for each car on the road in the United States earnings if AVs had complete market penetration would be $1.3 trillion ($1,239,700,000,000) (Table 7). 230,000,000x5,390= 1,239,700,000,000

Cars on the Road	Potential Wage that could be earned $	Total $
230,000,000	5,390	1,239,700,000,000

Table 8. Potential earnings if each vehicle driver was able to work one additional hour per day.

*note: using 49 weeks most Americans get an average of 12 days paid leave. (USDL) To calculate for sick days and personal I added a week.

Summary of Data

The following table summarized the results described previously:

Item	$ Cost	$ Benefit	Total
Additional cost per AV	-145,000,000,000		
Fewer accidents		297,360,000,000	
Few deaths		186,000,000,000	
Less congestions		121,000,000,000	
Higher productivity		1,239,700,000,000	
Total			1,699,060,000,000
Without higher productivity			459,360,000,000

Tabel 9. The total cost and benefit.

All in billions: 297+186+121+1,239 -145 = $1,699 Billion
Without higher productivity: 297+186+121-145= $459 Billion

The potential benefit for the society without the higher productivity benefit, because its subject to change depending on job and if its a personal benefit or a work benefit its also uses a different numb of vehicles, is a savings of $459,360,000,000; this is with full market penetration. *The benefit is three times the cost.* This means that for every dollar spent you get three dollar back. We could potentially save almost half a trillion dollar a year by having autonomous vehicles on our roads.

Sensitivity Analysis

A major issue for AV's is the problem of product implementation. Although most Americans desire the technology, in its current state, it is far from being affordable. Although this is the case of our present, this analysis considers this issue from a future vantage point. ENO and KPMG predict that in the year 2021 we will be 4-5 years out from the initial launch of AV's which is to happen in 2018.

If we consider the viewpoint of this paper to be set in 2021, there is variable potential for market penetration. In the outlook of not having a full market share when it is first mass marketed, three scenarios will be considered with three different market penetrations: 10%, 40%, and 80%. This will account for unpredictable and unforeseen factors such as implementation problems, technology trends, and provide a more realistic look at affordability. The *higher productivity benefit* described previously has also been subtracted from the total benefit because it inflated the total to appreciate any difference in market share. We are not accounting for an increase in sales or increase in deaths.

Market Share	Total Cost	Total Benefit	Total
10%	14,500,000,000	45,936,000,000	31,436,000,000
40%	58,000,000,000	183,744,000,000	125,744,000,000
80%	116,000,000,000	367,488,000,000	251,488,000,000

Table 10. The Sensitivity Analysis showing the trend.

10% of 145 billion = $14.5 billion
40% of 145 billion = $58 billion
80% of 145 billion = $116 Billion

The variable market share percentages provide several different scenarios, and a prediction for the changes that will undergo as AV take over larger and larger shares of the market. This also gives us a more realistic look of how it will be introduced to the market. With just a 10 percent market share, there is a net benefit of billions of dollars in United States of America alone. Even though we don't have the future number of cars or costs the difference should not change so say we sold more cars there would be more deaths are more traffic, which would keep the benefit about the same level.

Discussion

There are a few things to discuss; the first being the cost. The cost of $10,000 for each additional vehicle is similar to what you would pay today for a technology packages on most luxury cars in United States. This cost will have to come down though, before we will see a full penetration in the market, which is mentioned in the research. There is also the issue of availability and market penetration. This will take some time as we will not see a 100% penetration by 2021, but we should see at least 5% to maybe even 10%. With the savings that have been described and the increased quality of life, politicians, decision makes and private companies should all be interested in promoting this market and technology advancement. We are able to make cars that can drive themselves, now the problem is the infrastructure and legislation.

There are more costs that we could possible have looked at, but without significant data, many costs were not able to be included in this analysis. For instance, a cost could have been steel; if we build cars that are not going to crash we will not need to build as strong cars as we do today. This would in it self cost jobs at steel mills. With fewer accidents we would potentially need less hospitals. The EMT's would not be needed as much either and would lose jobs here as well. Police are always needed but we would now no longer need them controlling traffic violations and assisting in crashes with the possibility of cars not going over the speed limit or driving illegally on the road, so we could potentially lose a big part of the police force. Some would call this making our government more lean, however it could come at a cost as well as a saving depending on the perspective. These are just a few of the foreseeable and unforeseeable consequences.

There are major difficulties that the government and car makers needs to over come before Level 4 AV's will be on the road. These difficulties include additional cost per AV. Currently the additional cost could be as high as $10,000 and this would not be affordable for the average automotive customer. Who will be liable incase a collision occurs, is another problem. Would it be the manufacturers fault, the company that programmed the car, or the human occupant/driver? What if the car decides to drive into another car? It's a strange feeling to let go of controls to a 4000 lbs. machine, how will we over come this? What about different weather situations like snow? What will happen will the car be able to be put in a manual mode? Security is another big problem that might exist, if maps and GPS drive the cars could someone spy on a certain car? Or even worse some one hacks into the operating system and takes control of the car? Who will have access to this data and what will that company do with it?

There are also more benefits to the society then listed, such as environmental impact. With the cars taking the human error of driving away we will be able to pollute less by using cars in an efficient way both to save on fuel expenses but also to be able to travel longer distances without refueling. There will potentially be less mechanical failures because of how the car is used which will save on ownership cost of the car.

If we are able to make autonomous vehicles we will be able to sooner or later eliminate public transportation workers, taxis and truck drivers. Though, we believe this is going to take longer because we might be able to trust the car with two or four people but talking about a train driving itself without supervision having 70 people on board is another issue that will need to be addressed.

Conclusion

This study examined the cost and benefit that autonomous vehicles would have on the society in the United States of America when they come to be mass-produced for ownership by the private citizen. It demonstrates the effects that occur when its market share is influential enough to make an impact on society. According to the research that has been done by KPMG and other institutions, autonomous vehicles will be on the road by 2018. The study shows that the benefit of having autonomous vehicles is astounding: the death rate would almost be eliminated, we would never hear about accidents happening, and traffic congestion would be a distant memory.

Additionally, with autonomous vehicles driving themselves, in the car we as people will have more free time do to what we want while transporting ourselves. The quality of life would rise significantly, and not only for the people who have cars but also for people who do not drive.

There will likely not be a smooth transition to autonomous vehicles over time because cost and implication problems will accrue. Looking at the sensitivity analysis and with even just a 10 percent market penetration, the US would see cost savings in the billions each year. This shows that significant investment on the part of the transportation agencies and safety agencies, as well as the automotive industries is well worth it. The additional cost to each vehicle being predicted to be $10,000 makes the cars unaffordable for many in the beginning, but the savings that could be generated by lower insurances, better fuel economy, faster transportation and less cost of ownership could balance it out until the price shrinks to a more comfortable level.

One shortcoming of this paper is that the analysis is concerning future events, and using statistics relative to today leads to inherent inaccuracy. Unpredictable costs and benefits are bound to arise, as well as variable fluctuations in the automotive market itself. The number of cars on the road grows each year, and so in 2021 this trend will only continue. If 2007 was an indicator of the death rates and accidents, these numbers will continue to rise as well, and increasing autonomous features in automobiles is one method to slow the death and accident toll (NHTSA n,d.). Additionally, with new technology come new opportunities. The new businesses that will potentially arise from these developing technologies are additional unknown benefits to society and the economy.

The reality is that Autonomous Vehicles will be here sooner than we think. With the government spending millions of taxpayers' money on research and private companies spending a small fortune on developing them for both private and military uses, there is a need to have a better understanding of what it will give back. With this paper, it has been shown that the benefits are huge in both monetary benefits and raises the quality of life significantly for both driving and non-driving people. More research can be done on the environmental impact of Autonomous Vehicles as well as the ownership costs.

Final Words

Year 2014 may be the breakthrough for autonomous vehicles. With every day passing there is more and more information available about the benefits and technology improvements. What will the future actually hold with car companies that want to build cars that don't get into accidents? Is this truly a social benefit, and even though it has the potential to bring in new business models there are businesses that will fail, which ones are they and what can we do to make the transform and woken in this new market that will be built?

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