Project Epsilon

Team Carrozzeria:
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Abstract

This document provides a complete and thorough description of all research and development on the Project Epsilon autonomous vehicle. It describes the engineering team and circumstances leading to the project, as well as the current state of development. Additionally, it outlines all aspects of the design problem, alternate solutions currently in production, and the overall plans for the project moving forward. Together, it provides a comprehensive overview of every aspect of the project for investors, fellow developers, or any other interested parties.

Introduction

Project Epsilon began as a simple idea among a few friends for a fun hobby project. However, after completing some research and deciding to pursue it as our senior design project, the scope of the project increased significantly. Now, the development has included many hours of problem-based research, with a complex solution to several different problems with the American transportation system.

The Idea

When we first thought of creating a self-driving car, it was just an offhand idea for a fun project. Then, we realized that it was something that we could actually accomplish using our combined skills to address different parts of the problem. So we started to look into how we could possibly create some sort of autonomous vehicle within our time and cost constraints. After some research and brainstorming, we decided that a small, line-sensing model car could be achieved relatively simply. While it would require a significant amount of code, we felt that it was a manageable first step for the project. After seeing how this initial prototype fared, we would consider our ultimate goal, a nearly autonomous go-kart.

The Team

The project team consists of six high school seniors: Harrison Jain, Raymond Rainville, Damanbir Sahi, Mishael Scott, Raymond Soya, and Stephen Zacks. We call ourselves Team Carrozzeria, making use of the Italian word for a coachmaker or body shop. All of us have been in Red Bank Regional's Academy of Engineering for four years, taking at least two engineering electives per year; these courses have included Digital Electronics, Honors Computer Integrated Manufacturing, and AP Computer Science A, among others. Additionally, we have pursued many advanced placement science and math classes, such as Multivariable Calculus and AP Physics C. We felt that this project would utilize all our previous knowledge and skills while helping us develop new skills in the process of creating an innovative solution to many significant transportation problems.

Harrison Jain acts as the Project Manager of the team, so he is in charge of keeping everything organized, from documentation to code development platforms. Additionally, he communicates with all members of the team to make sure the entire team is as efficient and effective as possible. In terms of development work, he acts as the Director of Hardware-Software Integration. This job includes both programming and construction attributes, focusing on the interaction between the code and physical design. For example, in the initial phases, he is in charge of motor control, which requires interacting with both the construction team and the programming team.

Raymond Rainville acts as the Design Director and Analyst for the project, focusing on researching and sketching potential designs for the prototypes. At the same time, he is crucial in developing the overall vision for the final product. For example, when designing the prototype suspension, he also researches go-kart suspensions. As a result, his prototype designs are able to accurately model specific elements of later prototypes and the final design. Additionally, after the designs are completed and tested, Raymond is in charge of analyzing their success using the test data. If the design is successful, he will make sure to incorporate it in later designs. Otherwise, he researches alternate designs for the part.

Damanbir Sahi is the Head of Programming and Software Development, leading all development relating to code. He is especially involved in the autonomous algorithms, researching and testing a variety of different strategies for vision detection. Utilizing his strong background in Java, he is tasked with finding and augmenting open source software for self-driving capabilities to make our design as autonomous as possible. Additionally, he must communicate the software developments with the rest of the team so they can properly implement related processes such as motor and steering control.

Mishael Scott acts as the team's Head of Prototyping and Construction, using his knowledge of materials and mechanics to create the physical design for the project. He is in charge of building the frames, suspensions, and drivetrains of each prototype while communicating with other team members to ensure smooth integration. Mishael is crucial in making sure that the designs are realized to their full potential and tested properly. Additionally, along with the two Raymonds, he must document the success of construction and testing in order to properly iterate through different designs and, ultimately, to select the most successful one.

Raymond Soya plays an important role as the project's Lead Researcher, looking into similar designs by competitors and other project groups as well as regulations related to autonomous vehicles. His job is crucial in allowing us to gain inspiration from and build upon others' designs while creating our own. Additionally, his comprehensive research into regulations helps us make sure our design would be able to be implemented on road-going vehicles in the future. Raymond also acts as the Design Assistant. Along with Mishael and the other Raymond, he works on the construction of prototypes, including the design and the physical building process.

Stephen Zacks serves as the project's Financial Director, assessing the budget for each phase as well as the overall economic viability of the project. He also researches potential clients and customers to assist the team in making important design decisions. Stephen also acts as the Assistant Software Developer, which requires close collaboration with Damanbir. He is heavily involved in researching and implementing line-sensing algorithms but also contributes to the motor and steering control software. Overall, he helps provide direction to the project through his widespread influence on all aspects of the design.

Together, our team is able to address all facets of our design solution by combining our variety of skills. While we each have specialties, maintaining continuity throughout the team will be crucial to effectively fulfil our design goals. By accomplishing both our individual assignments and combining them cohesively, we will be able to provide an effective solution to our design problems.

The Development

In order to complete our project, we started by outlining where and when we would work on it. Since our senior capstone course, Honors Engineering Design and Development, was structured as a yearlong project, that was our first development setting. However, we knew that an autonomous car was a large undertaking that would require a significant amount of work outside of class. Therefore, we started initial programming and prototype design over the summer, working as individuals or pairs on small aspects of the design like motor control.

Once the school year began, we started to address the problem in accordance with a more formal engineering design process. Therefore, we spent several months completing research and brainstorming regarding our specific design problem. By documenting our work in our team Google drive and our engineering notebooks, we kept a careful record of any research or design work done. We completed individual work and then combined our findings into more general documents, such as our design brief. Ultimately, all of this research is summarized within this project proposal.

Moving forward, we are focused on prototyping and code development. These will be done both within our class setting and outside of school, with frequent team meetings to organize each group's work. In terms of construction, everything from sketches to prototype tests will continue to be documented in Google Drive and our engineering notebooks. We will store our code in a private GitHub repository so that all members of the team can work on the code together with careful version control. Therefore, we will be able to work on all aspects of the design at any time, regardless of what team members are present.

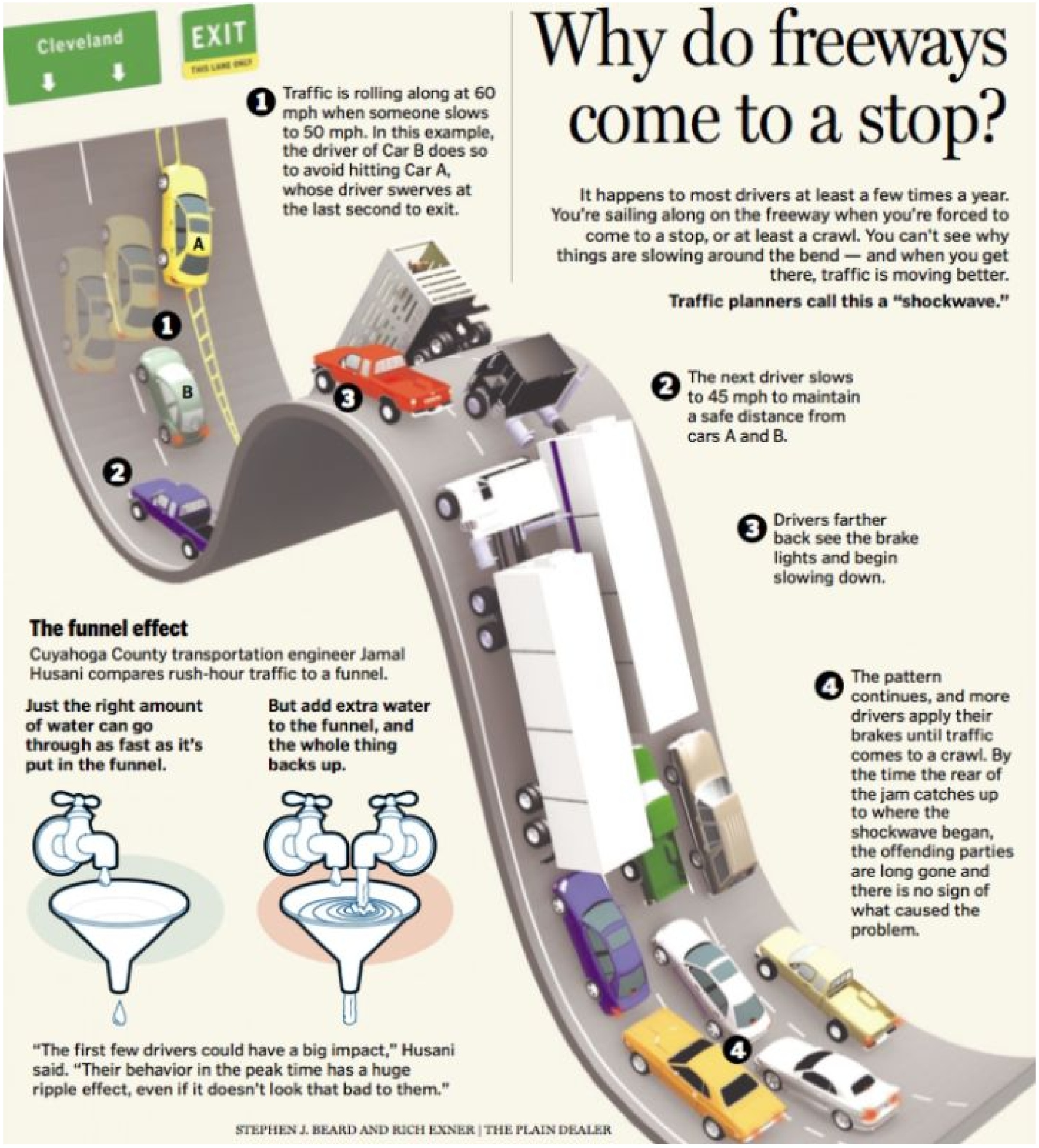
Justification

There are a variety of problems relating to transportation in the United States, specifically automobile transportation. From the safety to the efficiency of travel, there are many ways in which car travel can be improved. When viewing the problem inspiring our project, we divided the issues into three parts: traffic on the road, distracted driving, and disabled/impaired driving. With human drivers, there are always some elements of error while driving, which, compounded together, can lead to significant traffic and make automobile transportation very inefficient.

On top of these slowdowns, driving a car can be very dangerous due to distracted drivers. Alcohol has been known to dangerously inhibit driving for years, but cell phone usage has also contributed to the increasingly hazardous conditions on the road. Finally, the current form of automobile transportation is inaccessible for many people due to physical handicaps, restricting their ability to interact with society significantly. Together these problems make cars a dangerous, ineffective form of transportation, something we have set out to solve with Project Epsilon.

Traffic

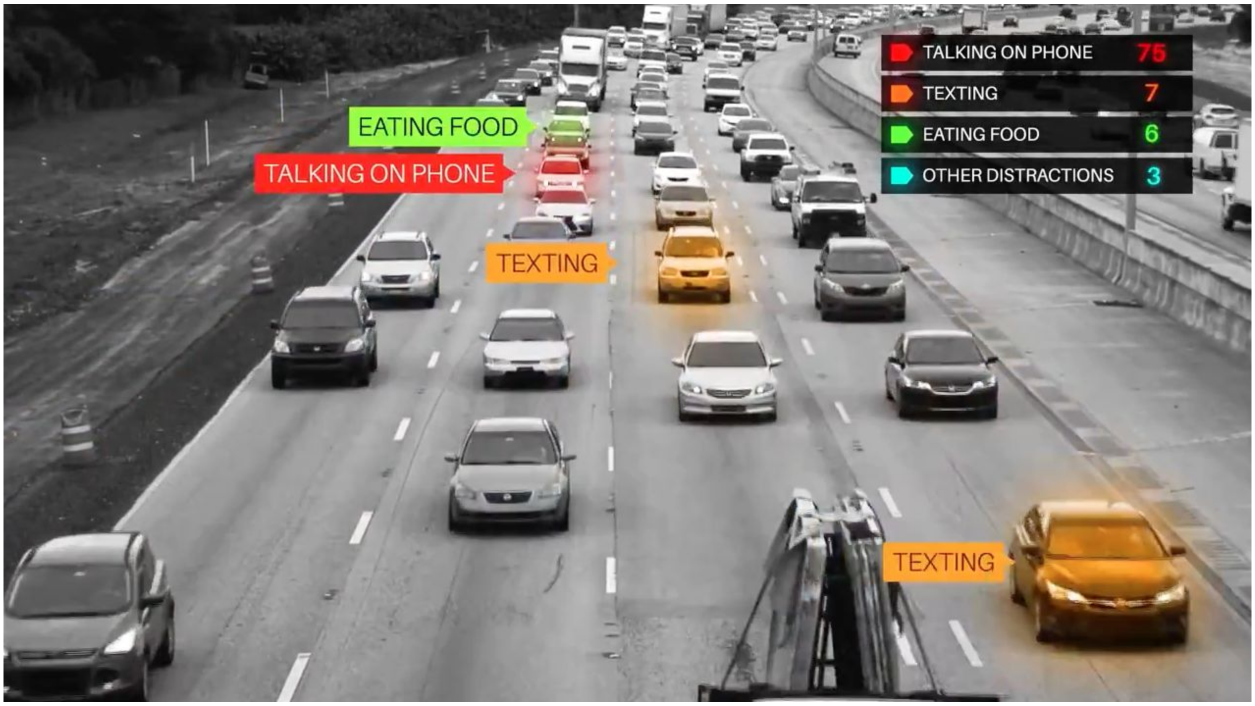
One of the paramount issues with everyday driving is the abundance of traffic. As of 2017, there were 253 million cars and trucks on U.S. roads and counting, a 1.5% increase from 2016.[1] With this many cars, traffic is a major problem that is only increasing. While it is sometimes caused by crashes or construction, most traffic is caused by small human errors while driving. When there are many people going in the same direction on a road and one person slows down unnecessarily, the entire flow of traffic is disrupted. Therefore, traffic is something inherent with human driving; however, this nature also implies that this problem has a clear cause and can be fixed.



Human error compounds and creates large backups of traffic, similar to water pouring through a funnel.[2]

Traffic significantly hinders automobile transportation overall, as it slows all progress on a given road. Since cars are one of the primary methods of transportation in the United States, traffic inhibits both travel and business. This makes it a crucial problem in American society. With a lessening of road traffic, the economy will be more productive, more efficient, and more prosperous. Therefore, persistent and increasing automobile traffic is a substantial issue that should be solved in order to improve the effectiveness of car travel overall.

Distracted Driving

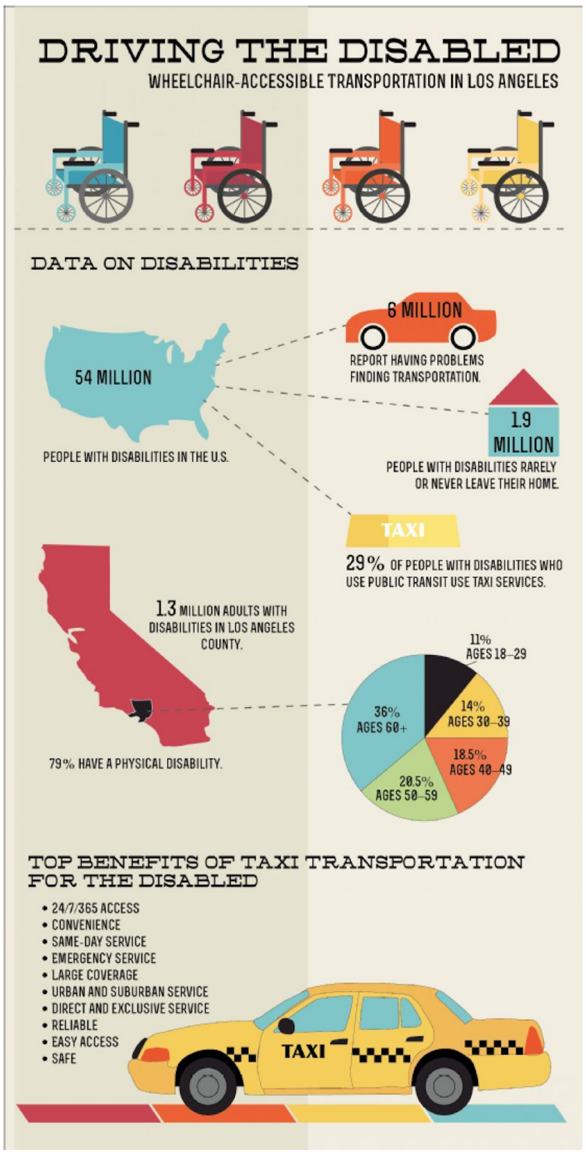


There are a great variety of distractions present on the average highway.[3]

Distracted driving comes in various forms and is therefore something that has many causes. Traditionally, drunk driving has been the most prominent form of distracted driving, causing countless accidents and many deaths. Despite years of campaigns describing its dangers, drunk driving is still a massive problem, with one person dying from an alcohol-related crash every 51 minutes. Additionally, it is a very widespread issue, with 111 million self-reported episodes of alcohol-impaired driving for 210 million licensed drivers in the U.S. However, only 1.1 million drivers were arrested for driving under the influence of alcohol or narcotics in 2015, demonstrating how current law procedures fail to catch many dangerous instances of drunk driving.[4] Therefore, the problem, while slightly diminished, is still an enormous issue on American roads, with the costs of deaths and damages from alcohol-related crashes estimated at about $44 billion.[5]

A new and increasingly prominent form of distracted driving has come with the advent of smartphones, as millions of people are constantly checking their cell phones for calls, text messages, and social media updates. Despite the clear and dangerous distraction, this obsession with phones has pervaded everyday driving. In fact, based on driving analytics company Zendrive's study of 3 million drivers and 5.6 billion miles of driving, drivers use their phones on 88 percent of their journeys.[6] Furthermore, they found that the average driver spends 3.5 minutes on the phone for each hour of driving. This underlines the ultimate danger of cell phone usage while driving: the benign nature makes drivers oblivious to the danger. And this problem cannot be isolated to a single group or demographic; it plagues everyone on the road. Most people think that the quick interactions with their phone are not dangerous, yet it only takes a two-second distraction to increase crash risk by 20 percent, a fact that leads to the NHTSA estimated 3,500 deaths from cell phone-related crashes in 2015.[6]

Whether it is due to alcohol abuse or cell phone usage, distracted driving is dangerous to everyone on the road, regardless of the attentiveness or skill of the other drivers. Losing focus on the road leads to swerving, unpredictable speed changes, and other inadvertent movements of the car. As a result, a distracted driver puts all the cars around them in danger, disrupting the natural and anticipated flow of traffic. Ultimately, the inherent danger of distracted driving, along with its increasing prominence, makes it a crucial problem to solve in order to preserve the safety of all drivers on the road.



Disabled Driving

While driving is an essential part of American society, many people are unable to drive due to various mental and physical disabilities, or even just elderly age. Many people with mental disabilities are unable to properly operate a vehicle due to processing difficulties. They cannot properly judge road conditions or operate a car's controls, making it impossible for them to drive. Therefore, they are unable to obtain a driver's license and must rely on alternate forms of transportation.

People with physical disabilities are often unable to utilize the typical controls for a vehicle; however, the National Health Interview Survey on Disability (NHIS-D), which polls the over 35 million disabled Americans, found that less than 2 percent of drivers said they used special equipment on their car to drive.[7] This small number is reflective of how difficult it is to find suitable equipment in cars, requiring expensive, bespoke components. Therefore, many people with physical disabilities decide not to drive at all, even though they would be perfectly fit to drive with the right vehicle.

Disabilities affect many people in the U.S.[8]

Like disabled Americans, many elderly people do not feel comfortable driving, whether it is due to physical ailments like deteriorating eyesight or inability to perceive and process road conditions quickly enough. There are few ways to get around these issues, and many elderly people give up driving altogether. Even if they do not choose to stop driving, many people fail license renewal tests after a certain age. Some are unable to pass sight or hearing tests, while others are prohibited from driving based on other medical conditions such as joint ailments or medications being taken.

Together, disabled and elderly people constitute a large portion of the American population, but many in both categories are unable to operate a car. They are left without the ability to drive on the road, separating them from the primary form of American transportation. As a result, their lives are further complicated and they are unnecessarily restricted by their disability or age. While public transportation and other services are available, this ultimately robs these demographics of their independence, damaging the efficiency and prosperity of American society overall.

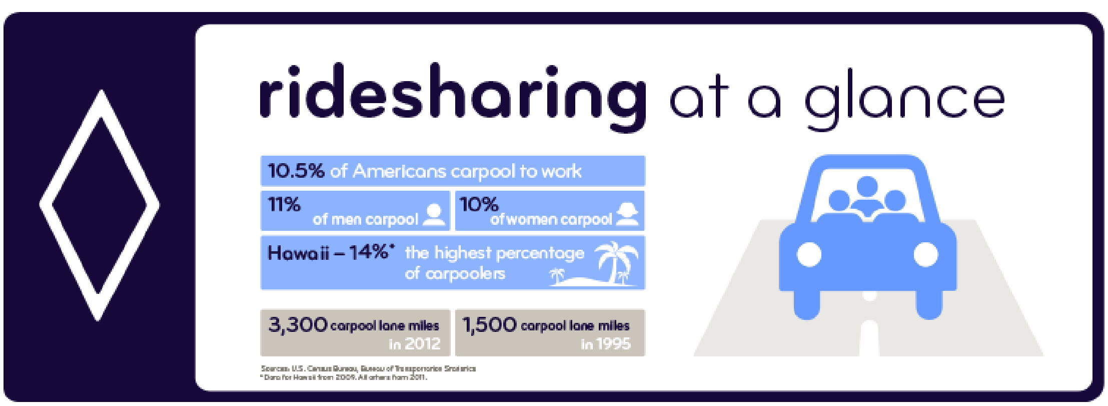
Alternate Solutions

In order to ensure that our solution would solve our design problems to the fullest extent, we had to analyze the failed and or current attempts of others. Currently, large ride-sharing platforms, such as Uber, have put a focus on lowering accidents involving an intoxicated driver. Along with this, they provide easy access to reliable transportation right from your phone. Public transportation allows for cheap transportation, giving every citizen the ability to travel. However, it is not as convenient for every situation. Self-driving has also proven to be a viable option for alternate transport, offering low effort transportation to any consumer. In observing alternate solutions we have gained a deeper knowledge of the problem and how we should proceed.

Ride-Sharing

The concept of ridesharing is most certainly not new. The idea of carpooling to work or school is very common for those trying to save money or the environment, but it requires that all of the parties involved were traveling to the same place. However, the modern form of ridesharing comes on every smartphone in the form of Uber and Lyft.

These services combine the properties of GPS navigation and a social network. By having a form of transport instantly accessible through a nearly essential device in the modern world, these companies have created a massive network for transportation. They don't even have to recruit their drivers. With a crowdsourced fleet of employees, Uber and Lyft are effectively the evolution of taxicabs.[9] There is almost always a driver within five minutes of your location and hailing is as easy as pushing a button. However, they are not perfect and must be analyzed to see their true benefits.



Many Americans utilize the benefits of ridesharing for their transportation needs.[10]

Uber, the current leader in this new industry, is available in all but a few locations in the US. However, after taking a 25% cut of every ride fee, Uber still lost 2.5 billion dollars in 2016.[11] Meanwhile, Lyft attempts to be the friendlier version of the service, encouraging its passengers to sit in the front seat with their driver and maybe strike up a conversation. But Lyft also suffered heavy losses in 2016: 600 million dollars.[12] Business Insider reported that as long as you drive less than roughly 9500 miles per year, it is more cost effective to use Uber and not buy a car at all.[13] However, with heavy losses such as these, it does not seem likely that these cheap prices will stick around.

On the positive side, these services solve a number of problems with everyday driving. Ridesharing removes unneeded cars from the road, effectively reducing road congestion. Driving under the influence can easily be avoided with these services because a designated driver is only moments away. It also allows a solution for those who are disabled and or elderly who cannot drive themselves. It is very effective in these categories, but without being profitable, it seems to fall flat. Requiring the user to rely on a stranger and difficulty coordinating a ride are the most common complaints about these services. More importantly, they do not remove the chances for human error on the road.

Public Transportation

Public transportation has been an option for commuters for many years. The system was first introduced in France in 1662 when the first public busing system and infrastructure were created.[14] It has given many citizens a somewhat reliable means of transport while keeping a low cost. In 2016 alone, Americans took 10.4 billion trips on public transportation.[15] Despite its age and popularity, public transportation suffers many drawbacks.

Public transportation is a large machine with many moving parts. Something is bound to break down at any given moment. Over 6,800 organizations make up the US public transportation service. This is a 61 billion dollar industry employing over 400,000 people.[15] It would be reasonable to think that with all of this funding and manpower that the system would work flawlessly; however, this is not the case. The largest obstacles they face are over and underuse. In a period of overuse, a vehicle may meet max capacity and end up turning away commuters in need. During underuse, the system is no longer financially viable.

Public transportation does effectively reduce the number of vehicles on the road; however, in order to eliminate traffic, everyone would need to use the system.[16] Since this is an unrealistic expectation, public transportation vehicles end up getting stuck in traffic and causing a larger issue due to their increased average size. Along with being slower than the average individual form of transport, these systems are less flexible. A public transportation schedule is a necessity for the regular user, causing them to often arrange their day around when the next bus or train will be departing.

One benefit it does provide for regular users is cost. An average bus in New York City costs 3 dollars (the most expensive bus is in Copenhagen, Denmark where it costs the equivalent of 4.6 US Dollars).[17] If a citizen were to use public transportation instead of owning a vehicle, they would save an average $9,242 annually.[15] This makes it an extremely attractive option for those trying to save money on travel.

While public transportation gives a cheap mode of transport to every citizen, its beneficial effects are far outweighed by its downfalls. Without a more comprehensive form of implementation, its ability to reduce road congestion is not substantial. It is still slower and less adjustable than individual transportation. This is less convenient overall, leading to the conclusion that the system could be improved for a far more effective execution.

Autonomous Driving

Autonomous driving has become much more popular in recent years with multiple companies focusing on adding this feature to their flagship vehicles. Now that it has been brought to the public's attention, it has been defined by varying levels of autonomy:

- **Level 0** - full human control
- **Level 1** - one specific function can be performed by the car; i.e. accelerating, braking, turning
- **Level 2** - one system involving acceleration and steering is automated; i.e. cruise control with lane centering capabilities
- **Level 3** - safety critical functions are fully automated; the driver can be completely passive but may be required to intervene.
- **Level 4** - full autonomy and capable of handling all situations in the Operational Design Domain
- **Level 5** - fully autonomous and capable of handling any situation that a human driver may encounter[18]

Currently, the highest level achieved is level 3. Level 4 has not been publicly tested, but some companies claim that they are close to making a big step in autonomous technology. Companies like Uber and Tesla boast they will obtain level 4 or 5 autonomy in the next 5 years. Due to road laws, all road legal cars with autonomous capability still require an alert driver at the wheel, which effectively defeats the purpose. The two aforementioned companies are at the front of the pack in development of this cutting-edge technology; however, they use two different forms of detection.

Tesla's level 3 cars utilize a radar, a forward-looking camera, and 12 long range ultrasonic sensors to give a 360°, 16ft radius scan of the surrounding environment. These sensors give the car the capability to do simple actions safely, such as change lanes.[19] It could be subject to failure if the sensors are obstructed or damaged. The radar detects moving objects and their relative speeds to the car to ensure a lane shift does not happen just as a car will be occupying the same space. The forward facing camera confirms the data received through the radar.

This mode is activated via the cruise control lever. The car is capable of steering within the lane, changing lanes, and adjusting speed (accelerating to the flow of traffic and braking to avoid crashing). Self-parking is also available.

Tesla's self-driving systems monitor both road lanes and potential obstructions.[20]

However, it does have certain limitations. This system does not include mapping (the self-driving is not connected to a GPS). The driver must keep his/her hands on the wheel in case of emergency, and if the driver does take his/her hands off, the car will only continue in its self-driving mode for 3 minutes before alerting the driver and coming to a safe stop.

Uber uses a more common method of self-driving: Light Detection and Ranging. LiDAR is a system used to create very accurate 3D models of a space. An emitter shoots 1.4 million lasers per second to collect information which then bounce off the surroundings and return to receptors to give information to the car. These devices are mounted on top of Uber's self-driving vehicles along with 2 miniature LiDARs for the front and back of the car. In addition to these, 20 cameras are placed around the sides of the car to enhance the images of the environment.[21]

The most intriguing development in Uber's vehicle is the GPS integration. GPS antennae ensure reliable pathing. This car can drive while following traffic laws from point A to B, using only an address input on a phone. However, there have been some crashes and violations which raised concerns.

Overall, self-driving provides a comprehensive solution to almost every problem on the road. Especially with the possibility of communication between self-driving vehicles, the future of transportation is automated. The biggest positives are that it is a very attainable technological advancement, and it requires very little new infrastructure for implementation.

Solution Overview

When we finished outlining all aspects of our problems and general requirements for the final design, we set out to create our solution. First, we conceived many different ideas to solve various aspects of our problem. After narrowing the design concepts down to four, we evaluated several aspects of each, ultimately deciding on an autonomous car. We determined that self-driving cars would effectively address all aspects of our design problem in an easily implemented, cost-effective manner. An effective autonomous vehicle would be able to provide a simple, inexpensive form of transportation that would not require any human interaction to travel between locations, and our solution will be developed with this goal in mind. This level of full autonomy has yet to be successfully reached by any car manufacturer, making it a problem still worth pursuing. Furthermore, while the United States government has yet to provide full legislation on autonomous cars, we researched all current laws relating to our solution.

Brainstorming

One of the most important parts of our design process was creating ideas to solve our complex, widespread set of transportation problems. We began by listing out any idea that came to mind, without consideration of practicality or effectiveness. Then, out of our many potential solutions, we selected the four most promising to evaluation further: autonomous cars, underground tunnels, smart traffic lights, and personalized automobile control.

As one of the fastest-growing segments of transportation, we had already looked into autonomous cars. However, at this point the solutions are only partial and are also relatively costly, making further development a worthy effort. A fully autonomous car that could utilize cameras or radar to maneuver a car, read traffic lights, and provide efficient transportation was judged to be a very viable solution. Since they would require no human control at all, autonomous cars would allow anyone, whether they were drunk, distracted, or disabled, to travel between locations. Additionally, their efficiency would help alleviate traffic on public roads. Therefore, along with their low cost and easy implementation, autonomous cars were one of the most promising ideas, with the only real downside being public opposition to autonomy.

Another solution judged to be viable was underground tunnels, which would contain some sort of rail or cart system to provide vehicle movement without any human interaction. They would be dug underneath traditional infrastructure and real estate, allowing vehicles to travel very quickly without disrupting any traditional traffic flow. Additionally, because there would be some system to move the cars, vehicle operators would not have to interact while they were in the tunnels. Therefore, they could provide safe travel for both disabled and distracted drivers. However, the tunnels would not solve the problem of short distance town driving, where tunnels would be impractical. Furthermore, they would be very expensive to build and would require government support for construction.

A slightly simpler solution to transportation problems would be smart traffic lights, which could judge oncoming traffic when considering light timing. The technology needed to create them exists, and intelligent programming would definitely make travel more efficient for everyone. Additionally, while their implementation would be more expensive and complicated than it initially appears, their integration with existing roads is certainly plausible. However, smart traffic lights would not provide any sort of control of the vehicle, making them useless in solving distracted and disabled driving. Therefore, while being an interesting solution to part of our problem, they were not a frontrunner for the ultimate solution.

Like smart traffic lights, personalized automobile control is a simple and specific solution to a part of the design problem. Implementing specialized controls, such as alternate pedals or wheels, to accommodate for various driving hindrances would greatly improve the driving experience for disabled or elderly drivers. It would allow some people to drive who could not reach or effectively operate traditional controls, providing the desired increase in transportation freedom. However, it would not fundamentally change the nature of automobiles, making it ineffective at decreasing traffic. Furthermore, it would still require human interaction, providing no solution to distracted driving. Nevertheless, its simplicity and low cost made it a solution worth considering.

Decision Matrix

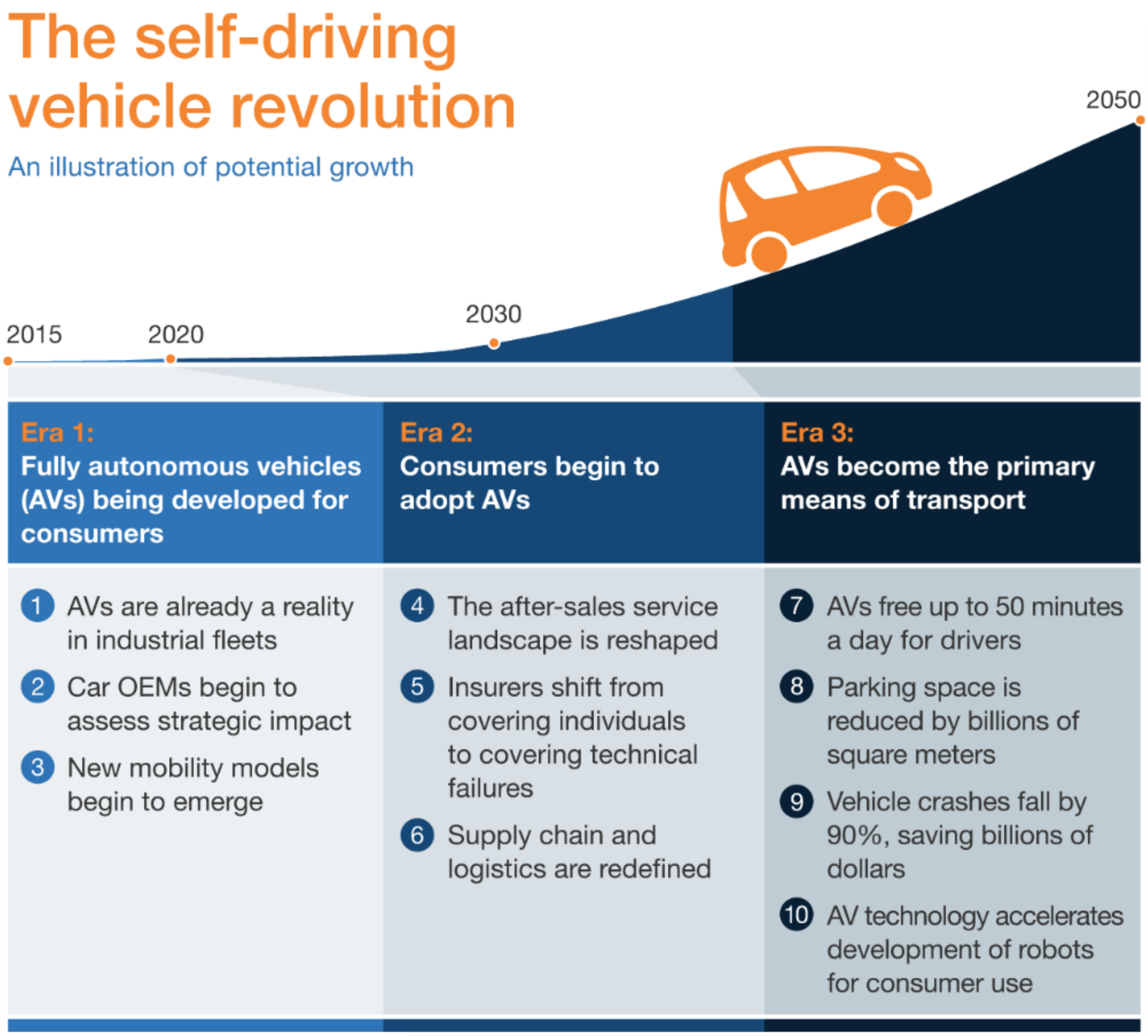
Solutions were judged in four categories on a scale 1-5, with 5 being the best and 1 the worst. Based on the sum total of all four categories, autonomous cars were the best solution to our problem, earning high marks for plausibility, effectiveness, and cost, while still being relatively easy to implement using current infrastructure. Underground tunnels were too high in cost and too difficult to implement, while not even being overly effective. Smart traffic lights and personalized automobile control were better solutions, but smart traffic lights are too expensive for states to implement easily, and personalized automobile controls were only effective for a small part of the overall transportation problem.

- **Plausibility** - how realistic the solution is
- **Effectiveness** - to what extent the solution will solve the problem
- **Cost** - how expensive development of the solution will be
- **Implementation** - how easily the solution will be applied

Our Solution

After deciding on autonomous cars as our solution, we set out to outline what exactly our design would accomplish. To start, we looked back at our research on current autonomous technology. While many manufacturers had claimed Level 3 autonomy, this still requires human interaction. Therefore, it is merely a technology demonstration and a driving aid, providing limited relaxation to drivers. However, because of the required human control, they do not provide any solution to distracted or disabled driving. Additionally, current self-driving features such as autonomous cruise control systems are still mostly reserved for luxury vehicles due to their high cost. Our solution aims to solve these main problems through its artificial intelligence and low production cost.

In terms of capabilities, we aim to create a level 2 or 3 autonomous vehicle. Although this is a daunting task with limited resources, we have determined that line following, signal identifying, braking, and any type of turning are fully achievable. By completing these objectives, our solution will not be on pace to compete with current autonomous driving technology, but it will be very cheap for its capabilities. While our solution will not solve distracted or disabled driving due to some required human interaction, the simplicity of our design will allow for an easier transition to complex level 4 and 5 autonomous capabilities. Moving further, implementation of communication between vehicles would effectively create a new form of transportation in which every vehicle could move from point A to B with maximum efficiency and minimum idle time.



Over time, self-driving vehicles are projected to overtake most automobile transportation.[22]

Such a large task would be expected to have a large cost, however, our solution will be produced with very few expenses to ensure a cheap selling price. Currently, the cheapest production car with autonomous driving is roughly thirty-seven thousand dollars. Our software will cost less than five hundred dollars to develop and will therefore add very little cost for a car to gain access to Project Epsilon's full potential. This will bring accessible self-driving to the public. More importantly, it will contribute to the path towards universal autonomous transportation, which will revolutionize the car industry and create safer roads for the entire world.

Design Requirements

In order to solve all our problems, we organized the general accomplishments that our solution should achieve. Along with these we have kept in mind the realistic limitations that will come into play while developing our solution. After outlining these requirements, we were able to effectively outline our basic design.

Criteria

- Minimal driver input
- Safe transportation
- More efficient travel speeds

To begin designing our solution, we outlined several goals and milestones it must meet in terms of design. It must be able to address each of our problems to some degree to create an overall safer and more efficient form of transportation.

As the main design problems include distracted and disabled drivers who cannot operate a car themselves, our ultimate solution must involve limited input from the user. It must provide simple transportation for the customer, allowing them to travel between locations without actually controlling themselves, as much of the target audience is unable to do so.

One of the paramount concerns of the solution is to create something safe for all its users. Each of our problems increases danger on the public roads, so our solution must overcome and improve the safety conditions. While modern automotive transportation includes the constant threat of a crash or other dangerous event, our solution will provide a sense of comfort and security to its users.

The final qualification for judging our solution is the efficiency of its transportation. To solve the problem of traffic, it must improve travel times compared to current automobiles. This way, it will not only provide an increase in safety and accessibility; it will also make travel quicker and simpler for everyone.

Constraints

- Development funding
- Tools and processing power
- Road regulations
- Cost for consumer

Realistically, our solution will encounter problems during the design process. To ensure efficiency, we have tried to predict the largest obstacles that we will face.

Development funding is an obvious limitation. We lack the funding for a research and development phase or advanced equipment, which in turn affects the final product's capabilities. Consequently, we do not have the ability to develop essential modern technological advancements to aid our process. We are limited to our own tools such as coding environments and basic processors.

One of the most important considerations to be made during the development of our solution is road regulations. If our product is to be on the road with other drivers, it has to undergo intense, safety testing. To be considered road legal, our solution must meet many different qualifications. On top of these conditions, one of our main goals is to keep our solution in a moderate price range so that it can be attainable by the average citizen.

Market Evaluation

In order to gain an understanding of our market, we first had to analyze the magnitude of the problems we are trying to solve. Once this is clarified, we are able to determine our target market.

According to surveys of the US population, roughly 47% say that traffic is bad in their area, which leaves much room for improvement. More than two-thirds of the population that commutes to work have to adjust their route on a regular basis to avoid traffic.[23] This is both inconvenient and time-consuming. On a more alarming side of the problem, 1.3 million people die in road crashes each year.[24] A large percentage of these accidents are caused by cell phone usage. Drivers in the United States use their phones on 88% of trips, and only two seconds of distraction increases the chance of a crash by 20%.[6] On top of this, 210 million drivers in the US[4], which is roughly two-thirds of the adult population, have admitted to driving under the influence. All of these statistics in combination show the great danger of everyday driving. Lastly, 45% of US adults who have not driven have some kind of impairment or health issue.[7]

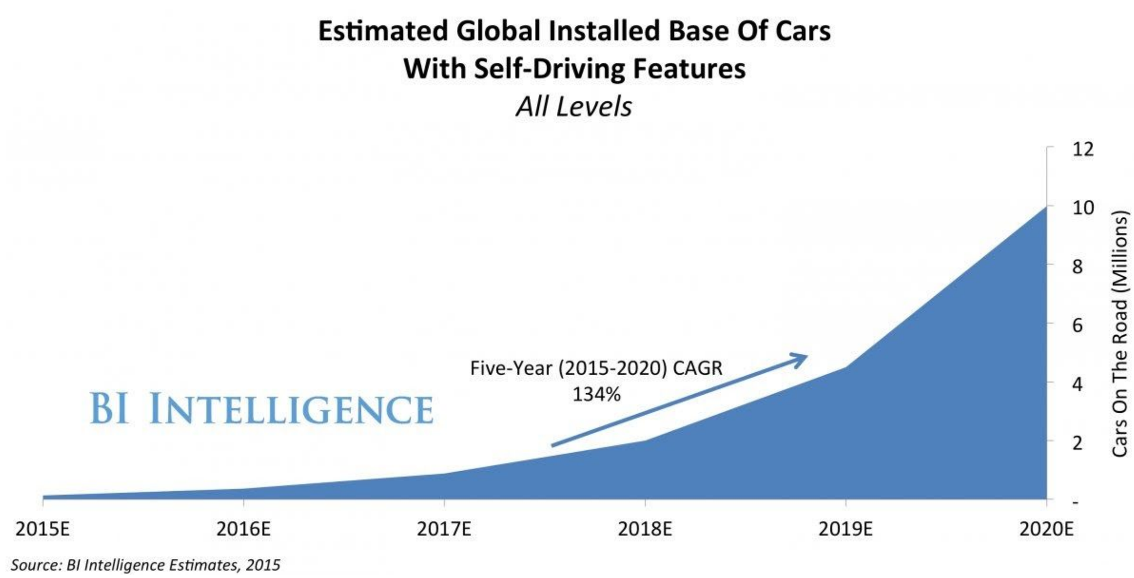
Based on these problems and the general public's response to them, the issues of traffic, distracted driving, and impaired driving are definitely prominent in society. This indicates that the target market for our product is quite general. In theory, anyone who drives is a target consumer.

Another important part of analyzing our market is noting any competitors. These include but are not limited to:

- **Tesla** - Model S, X, 3[20]
- **Uber/Volvo** - XC90[21]
- **Audi** - A8[25]
- **Porsche** - Panamera[26]

In comparison to these competitors, we are admittedly less advanced. However, with much room for improvement in the self-driving market, this is no reason to stop development. We are trying to develop a cheaper version of the software to sell to manufacturers. This will allow for a lower market price so that autonomous vehicles will be more accessible.

The final part of our market evaluation was to identify our users and buyers and calculate the available market. This is ultimately determined by our future business plan, but mapping out the possible paths ensures that we will not encounter any unforeseen obstacles. Our users, as I said before, would be everyday drivers, including the disabled and elderly, or it could be any type of commuter. After considering our different business paths, we determined our possible buyers to be car manufacturers, transportation services, government corporations, or individuals. It is most likely that we will sell software and hardware to manufacturers for them to implement as they please and then distribute. However, it is also possible that we could sell it to taxi services, or the government for implementation into public transport. Our last option is to sell directly to the end user, cutting out any middleman, but this would make it much more difficult to develop because it would have to be simple for an average person to set up.



As the usage of autonomous vehicles increases, the market for self-driving cars will increase exponentially.[27]

Keeping this in mind, and remembering that our target is the everyday driver, we calculated the total available market for our product. According to the AAA, the average person spends $8,469 per year to drive a car.[28] As of 2016, the Department of Motor Vehicles has reported 210 million eligible drivers in the United States.[4] This brings us to the calculation of the available market:

$$\$8{,}469 \times 210E6 = \$1.77 \text{ Trillion}$$

Knowing this, we can see that the market for our product is quite large, but we have to keep in mind that many competitors already exist, and the pursuit for the self-driving car is only expanding. Our aim is for affordable, autonomous driving, which puts our solution at an advantage. As of right now, most self-driving capable cars are high-end vehicles. If we can successfully keep our costs low and sell our technology for a reasonable price, our product will be far more accessible to the public than previous attempts.

Regulations

Regulations and rules for autonomous vehicles has become an increasing public concern within the last year. As technology continues to advance it has become clear that state and municipal governments must get involved. In 2017, 33 states introduced legislation. However, the state of New Jersey is yet to introduce legislation. Not only have the state governments become involved, but also the federal government.[29] In 2017 the House passed the SELF-DRIVE Act, the first-of-its-kind legislation that ensures safety and innovative development, testing, and deployment of autonomous vehicles.[30] The newly passed legislation improves the National Highway Traffic Safety Administration's ability to adapt to developing technologies and also clarifies federal and state roles in regards to autonomous vehicles.

It is team Carrozzeria's goal to abide by all laws and regulations regarding the development, testing, and deployment of our self-driving vehicle. As mentioned before, the state we are currently working in, New Jersey, as of now has no legislation regarding autonomous vehicles. Therefore, the team abides by the regulations of the SELF-DRIVE Act that are applicable to the team and continues to wait for new federal and state regulations.

Project Development

In order to make our project as flexible and effective as possible, we divided our development into several phases, each of which has a specific focus. Therefore, we would have distinct benchmarks to meet at various points in the design process. Also, we could break the complex design problem of an autonomous car into smaller, more manageable pieces. Finally, the different phases will allow us to expand and contract the project according to our progress, with the ability for different team members to work on different phases simultaneously.

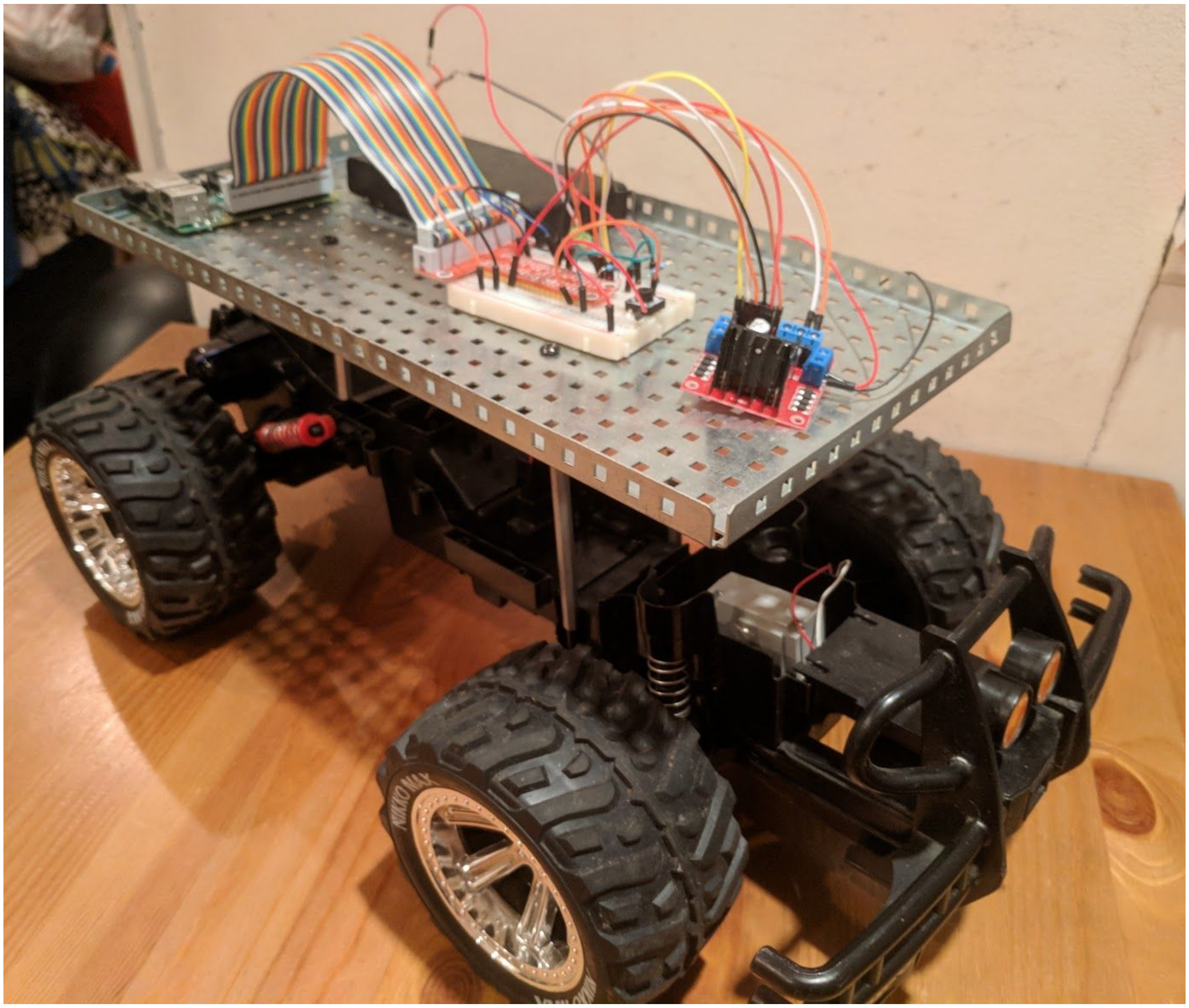
Phase 0: Research

To create a thorough solution to our design problem and to fulfill the requirements of our engineering class, we created the Phase 0, which is focused exclusively on research and project organization. This phase has included outlining and justifying our design problem, investigating alternate solutions currently in production, and brainstorming ideas for our ultimate solution. It was completed shortly before the creation of this proposal and presented the team with a comprehensive overview of everything our design needed to accomplish, all of which is summarized within this document.

Phase 1: RC Prototype

After completing research, our initial task was to create a workable prototype for testing code. For simplicity and time savings, we took an old remote control car and stripped off the plastic body. Additionally, we cut out the main circuitry so we could replace it with our own design. However, we maintained the RC car's basic suspension, drivetrain, motor, and steering mechanism. This allowed us to utilize the already functioning physical design with our electronics and code. Finally, to give us more flexibility in the wiring design, we added a metal plate on top of the car for holding our control circuit.

Our first challenge regarding this phase was to gain motor control with our own circuit. By doing so, we would form the foundation of our autonomous control circuit. Because of its open source background and its large library of resources, we decided to use a Raspberry Pi for our core processing. Initially, we used a Raspberry Pi 2 Model B, but we have recently upgraded to the Raspberry Pi 3 Model B due to its additional processing power. To integrate with our Java line-sensing code, we utilized the Pi4j library to control the Pi's GPIO ports.[31] Additionally, we are using an L298N motor driver in conjunction with the Raspberry Pi to gain sufficient amperage and voltage to drive the motor. Together, the Pi and the motor driver are able to control the speed and direction of both the drive DC motor and the steering stepper motor.



Prototype 1 utilizes a remote control vehicle as a base and integrates our circuit control board.

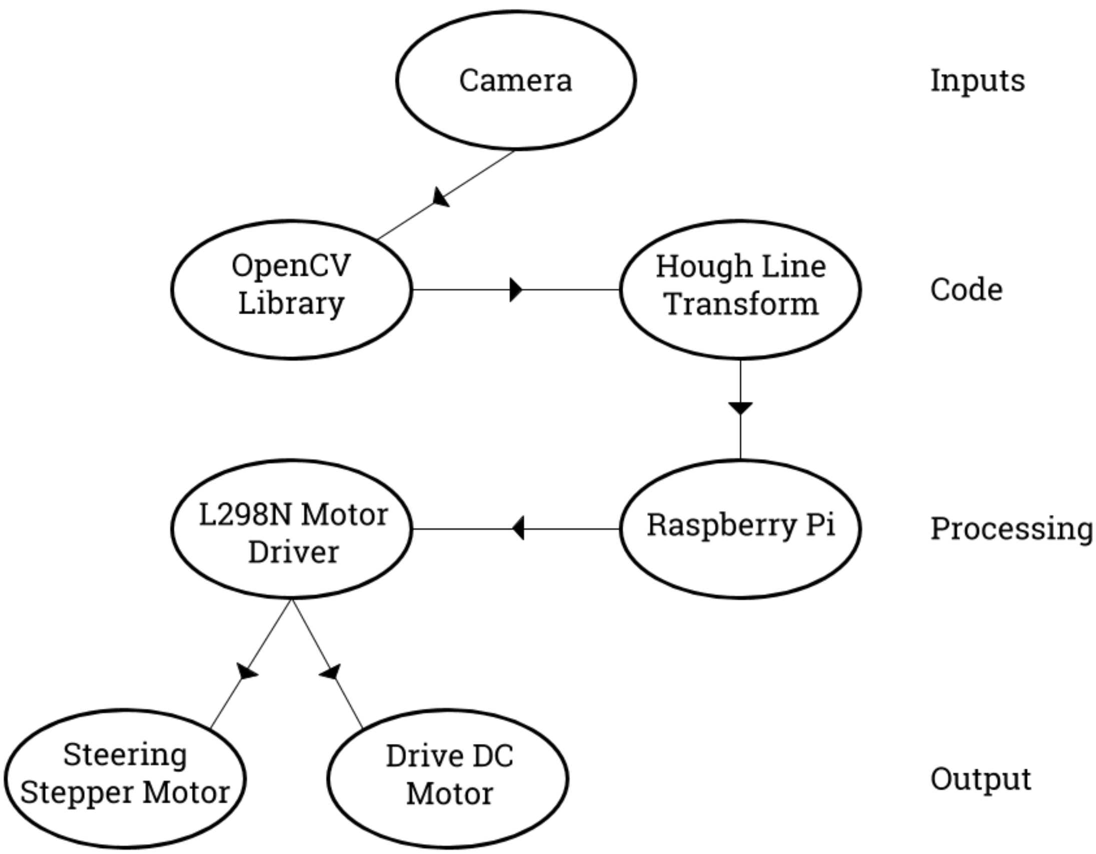
Along with obtaining basic motor and steering control, Phase 1 includes creating and testing our autonomous algorithms. The first step in the code was to make a basic line-sensing program that could take video input and determine the surrounding lane lines. For this purpose, we used OpenCV in order to detect the lanes on a road.[32] Using OpenCV we isolated the colors to only black-and-white and then used the Hough Line transform to detect lanes. After this, we will set out to combine this line-sensing with our control circuit in order to make the prototype drive in the center of the defined lanes. As a result, this prototype will be able to take in camera input, process it, and steer according to the surrounding lanes.

The black-and-white video used for processing and determining lane lines.

The lane and centerline output as the program is running.

This phase was actually begun very early on in our design process, before Phase 0 was complete. The very first work on the project was done on the line-sensing programs, and basic motor control and steering control was achieved using the control circuit. However, this phase was temporarily on pause as more thorough research and pre-design work were completed. Now, we hope to achieve a more nuanced and precise form of motor and steering control using a more efficient circuit design. Additionally, we will continue to refine our line-sensing algorithms to provide further autonomous capabilities.

In addition to serving as a development platform for our code and circuitry, this prototype could be used as a sort of "pacebot" for our school's track team. Since it can follow lines, it should be able to trace a runner's path along a track for a given distance. By adding an element of speed control, the car could race off against athletes so that they can pace themselves to achieve certain speeds and race times. This practical use of the Phase 1 prototype is something definitely worth pursuing, if only as a fun and useful testing mechanism for our line-sensing code.

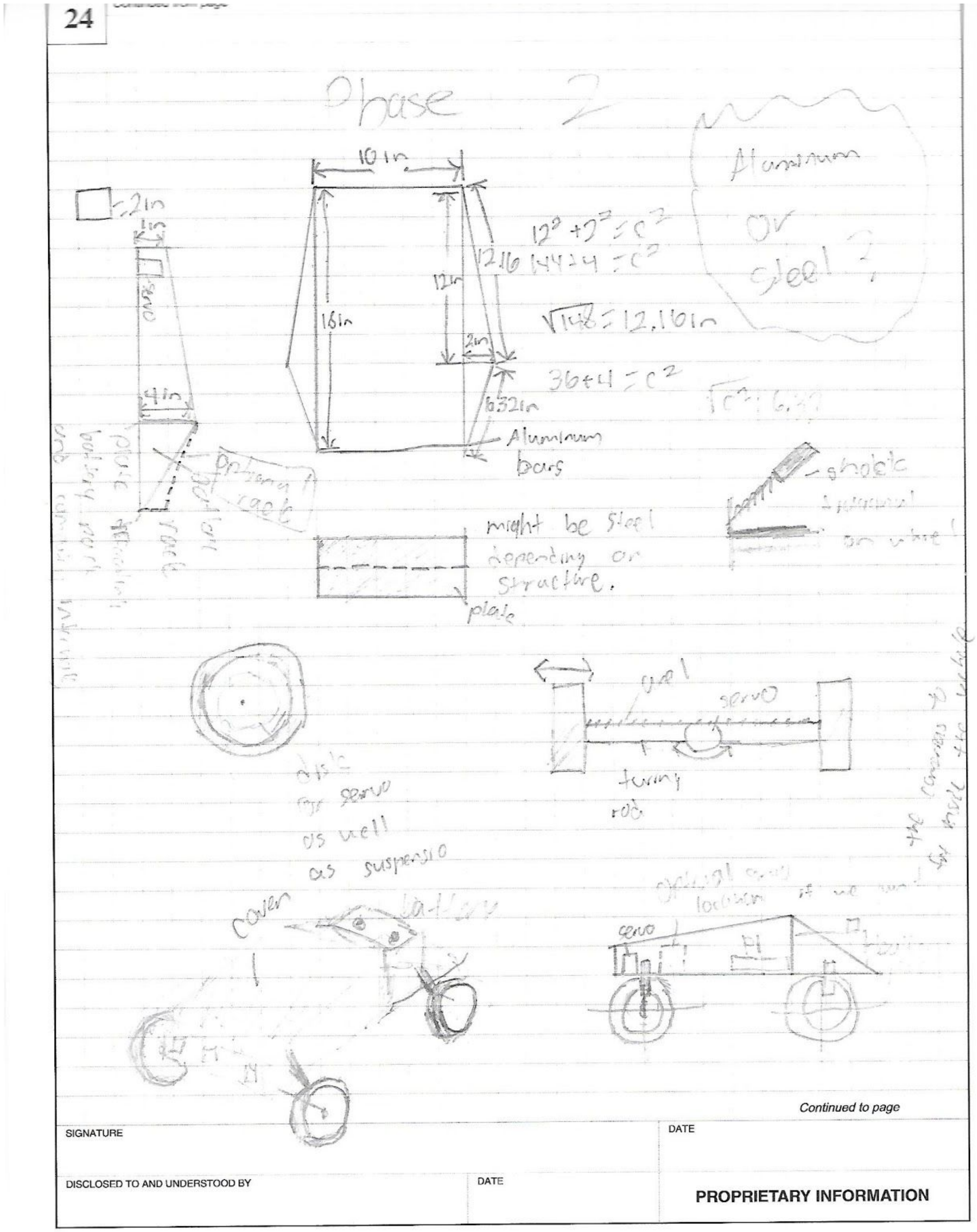


Our design is centered around taking inputs, applying them to our coding algorithms, processing them with our computing chips, and outputting driving and steering control.

Phase 2: Bespoke Prototype

To further test the autonomous capabilities of our design, we deemed it necessary to create a second prototype that our construction team would build from the ground up. This prototype would allow us to create something to the optimal specifications for our line-sensing algorithms, with a bespoke area for circuitry. Additionally, we can choose the motor driver and steering servo that would allow the speeds and turning radius desired of our design. In terms of practical applications, this prototype would be even more effective as a pacebot, as we could create a faster, more agile design.

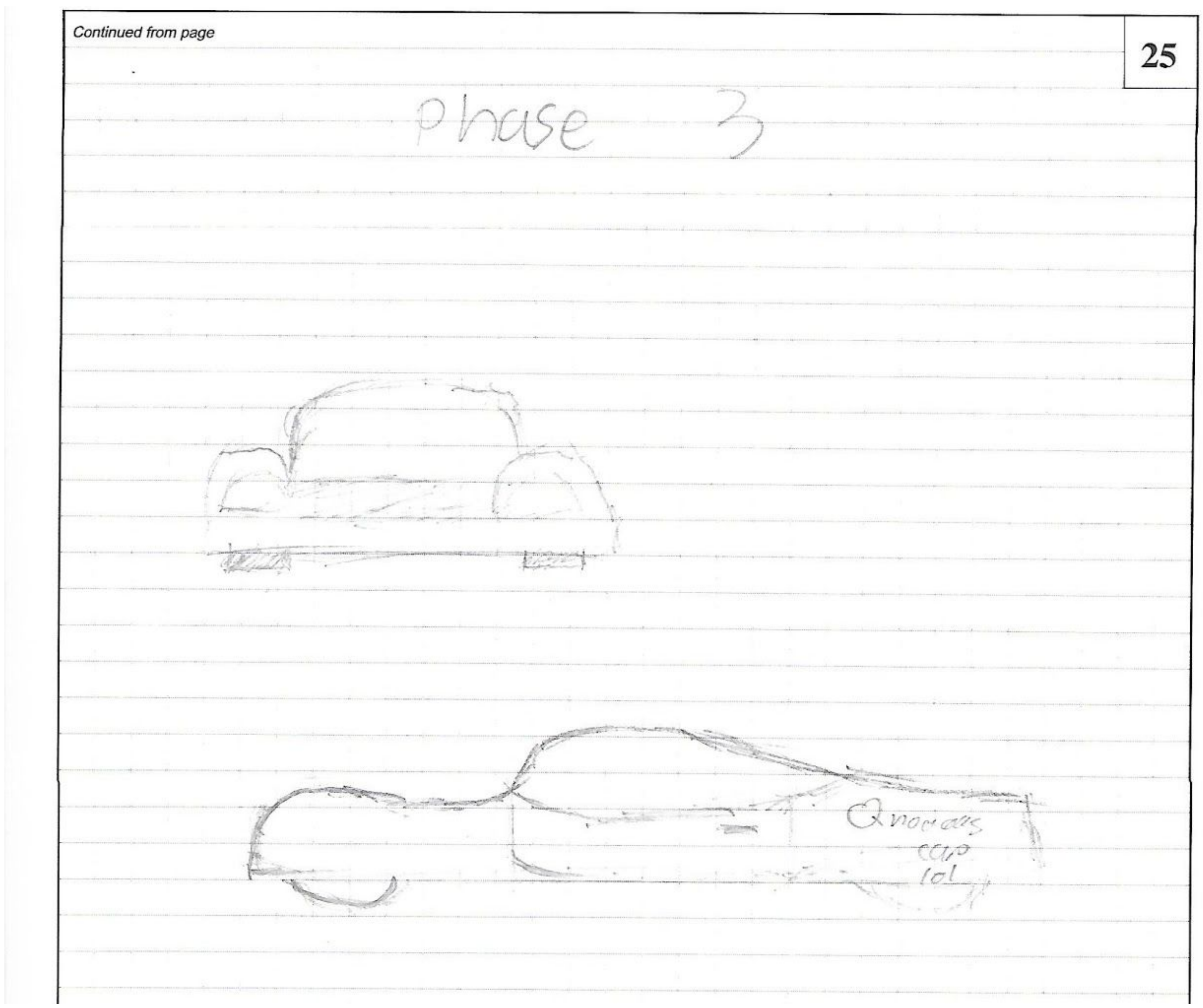
This phase is especially crucial for the construction team, as they can test every design element they would want to implement on a full-size go-kart. The goal is that everything built in Phase 2 would be scalable to the Phase 3 design. At this point, the team has created a preliminary design for this prototype, and construction is beginning now. In terms of circuitry, the same design as the RC car will be used, with small modifications based on the specifications of the chosen motor. The code used for this phase will also be the same as in Phase 1, with the possible addition of some signal identification.



Prototype 2’s design utilizes an aluminum frame with an integrated platform in the base for the circuitry.

Phase 3: Go-Kart

Our ultimate hope for the project is to create a highly functioning autonomous go-kart that would be nearly ready to drive on the road without human control. This would accomplish all of our design goals and effectively solve our design problems. However, as building a go-kart is far more expensive and time-consuming than our Phase 1 and Phase 2 prototypes, this phase is not the initial focus. If we were to reach this phase, the emphasis would be on creating a fairly comfortable and powerful design, while implementing new autonomous algorithms that would make it safer on public roads. At this point, Phase 3 is still a bit undefined, but if the initial phases progress quickly and effectively, we will outline more specific goals for our go-kart.



While we do not have a specific design yet, we hope to make the full-sized go-kart more similar to a full-sized car.

Conclusion

Despite its humble origins as a high school project, we hope that Project Epsilon will be able to move autonomous technology forward in some way. It may only end up demonstrating how self-driving transportation can be accomplished with limited resources, but even this achievement is valuable in a future of transportation increasingly dominated by autonomy. The prototypes could be useful as pacebots for the track team, and they could serve as the basis for future designs. Ultimately, we hope our small contribution to autonomy will help people realize that self-driving is not some space-age technology. Instead, they will realize that autonomous cars are something both achievable and useful, something that will move us towards a safer, more efficient future.

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