ELEC 390: Principless of Design and Development

Proposal for Project DMW

Duck Moving Vehicle

Team: 2

The Quaxi Company

Jacob Chisholm (21jc138)

Hendrix Gryspeerdt (21hgg3)

Luke Strickland (21laps1)

Matthew Szalawiga (21mps6)

Date of Submission: January 27, 2025

Prepared For: Eric Godden

Statement of Originality

The members of Team 2, listed on the page above, declare that the work presented in this document is our own. Any information, materials, data or content presented that is not solely ours has been properly acknowledged and cited in accordance with the IEEE format.

The use of AI and large language models (LLMs) has been limited to the acceptable uses as outlined in the ELEC 390 course syllabus.

Signed,

Jacob Chisholm   Luke Strickland

Matthew Szalawiga   Hendrix Gryspeerd

Contribution Table

Section	Content	Write-Up	Editing
Executive Summary	Matthew, Luke, Hendrix, Jacob	Hendrix	Matthew, Luke, Hendrix, Jacob
Introduction	Luke	Luke	Matthew, Luke, Hendrix, Jacob
Technical Specifications	Jacob	Jacob	Jacob , Luke, Hendrix, Jacob
Technologies and Tools	Luke	Luke	Matthew, Luke, Hendrix, Jacob
Algorithms	Hendrix, Jacob	Hendrix, Jacob	Luke, Hendrix, Jacob
Data Sources	Hendrix	Hendrix	Matthew, Luke, Hendrix, Jacob
System Integration	Jacob	Jacob	Matthew, Luke, Hendrix, Jacob
Ethical and Risk Considerations	Matthew, Hendrix	Matthew	Matthew, Luke, Hendrix, Jacob
Project Management	Hendrix	Hendrix	Matthew, Luke, Hendrix, Jacob
Expected Outcomes	Matthew	Matthew	Matthew, Luke, Hendrix, Jacob
Conclusions	Matthew, Luke	Matthew, Luke	Matthew, Luke, Hendrix, Jacob

Executive Summary

The objective of this project is to develop an autonomous taxi using a modified PiCarX [1] capable of operating effectively in the model environment of Quackston [2]. The company name for the competition is "The Quaxi Company". To operate effectively car must be capable of autonomously navigating from location to location across the town while fulfilling ride requests by picking up and dropping off toy duck passengers and following road rules [3].

The end goal of the project is to have the autonomous taxi compete in a competition in Quackston on March 24-25, 2025. The performance of the taxi during competition will be measured by a reputation score ranging from -100 to +100 and cash flow in dollars. Scores will be accumulated over a fixed period of time driving in the environment. Trip completions and good driving behavior contribute positively to scores and bad driving, by breaking road rules, will contribute negatively to scores. Between trips, the taxi will have to communicate wirelessly to a competition computer to accept fares and earn rewards. During trips, the taxi will have to maintain a toy duck as a vehicle passenger. The aim is to achieve a high cash flow while maintaining high reputation score. Performing the driving task well will lead to high scores in both of those metrics.

To achieve this goal, the hardware suite of the PiCarX will be combined with a software solution. There will be a high-level route planning algorithm that has access to a map of the road network and a list of requested rides. The cameras and sensors will be combined with a computer vision solution to perceive other vehicles, pedestrians, road markings and road signs. A restraint system will be developed and mounted on the vehicle to keep the passenger secure while driving. The route planner and computer vision information will be combined into an integrated vehicle control system to ultimately navigate the environment without the use of human control.

This project will expose the team to multiple technical, economic, and ethical challenges. The technical and economic challenges are apparent in the task of completing rides and collecting fares as rewards. Although the environment is artificial, ethics based decisions will have to be made about the operation of the vehicle in adverse conditions such as in avoiding collisions with other vehicles or pedestrians on the road. Confronting these challenges in a controlled environment will lead the team to consider solutions to implementing autonomous driving networks in the real world without the risk of life or death consequences associated with real world driving.

Contents

List of Figures

List of Tables

1 Introduction

1.1 Background Information

1.1.1 Autonomous Driving

Autonomous driving refers to vehicles capable of navigating and operating without any human input. These vehicles rely on advanced technology to perform tasks traditionally done by the driver, such as steering, braking, and decision-making. To achieve this, autonomous vehicles (AVs) utilize a suite of sensors, such as cameras, LIDAR, radar, and ultrasonic sensors, which create a complete view of the car's surroundings. These sensors gather much more information than a human is able to. An onboard computer processes this data in real-time, enabling the vehicle to make decisions and self-drive.

The Society of Automotive Engineers (SAE) has established six levels of autonomous driving, ranging from Level 0 to Level 5. Levels 0 to 2 focus on driver assistance features, where the driver must remain fully engaged and supervise the system.

- Level 0: Provides warnings and momentary assistance, such as collision alerts.
- Level 1: Offers either steering or braking/acceleration support such as adaptive cruise control.
- Level 2: Delivers both steering and braking/acceleration support but still requires constant driver oversight.

In Levels 3 to 5, the vehicle assumes greater responsibility, requiring little to no human intervention.

- Level 3: Can autonomously drive under specific conditions but requires the driver to take over when requested.
- Level 4: Operates independently under limited conditions without needing driver intervention.
- Level 5: Achieves full self-driving in all conditions and environments. [4]

As of today, the highest level of autonomous driving achieved commercially is Level 4. Companies like Waymo have deployed autonomous taxis that operate under specific conditions without requiring human intervention [5]. Meanwhile, Tesla's vehicles are classified as Level 2, as their Autopilot system still requires drivers to remain ready to take over at any moment.

1.1.2 Significance and Challenges

Autonomous driving has the potential to significantly impact safety, accessibility, and efficiency.

- Safety: AVs reduce the number of accidents caused by human error. Studies show that SAE Level 4 self-driving cars are approximately 36 percent less likely to be involved in moderate-injury crashes and 90 percent less likely to be involved in fatal accidents [6]
- Efficiency: Self driving cars are more fuel/ power efficient. They are able to drive in such a way that is 15-20 percent more efficient, industry experts call this 'eco driving' [7]
- Accessibility: Self-driving cars offer more options to individuals unable to drive, such as the elderly or those with disabilities.

With ongoing technological advancements, autonomous driving has shown immense promise for shaping the future of transportation safety, accessibility, and efficiency.

The field of AVs faces numerous ethical and technical challenges. Public acceptance is a significant one, as many people are hesitant to even consider the idea of AVs. Additionally, predicting the behaviors of other vehicles on the road requires advanced algorithms and advanced decision-making systems. Another major challenge is enabling AVs to operate safely in varying conditions, such as during a snowstorm when sensors may become obstructed. Ethical concerns can also pose a challenge, such as addressing moral dilemmas where AVs might need to prioritize lives in the event of a crash, raising questions about whose life should take precedence, if at all. Also, legal liability is a critical issue, as determining fault in cases where an AV commits a road violation or causes an accident remains an unresolved and contentious matter. Clearly there are a lot of challenges in the field of AVs.

1.1.3 Context

The town of Quackston, a rubber duck community, is embracing the future of transportation by adopting autonomous taxis. To support this initiative, Quackston has invited multiple companies to test their AVs on its roads. Our company, The Quaxi Company, is proposing a plan for our AV, WhatsUpDuck, which aims to revolutionize transportation in Quackston. Our primary goal is to efficiently transport ducks to their destinations while maximizing cash flow and maintaining a strong reputation for safety and reliability. Additionally, we are committed to developing a Level 4 SAE AV tailored for Quackston's specific conditions.

1.2 Problem Statement

The current state of fully AVs in 2025 face challenges in safely navigating complex urban environments while complying with traffic laws and maintaining passenger safety. Furthermore, existing AVs lack accessibility features, which causes barriers for passengers with varying physical abilities and lack efficiency in passenger loading and unloading. This project aims to address these gaps by developing an autonomous vehicle system that integrates technologies, such as computer vision and machine learning, to enable safe urban navigation while incorporating innovative accessibility solutions to promote inclusivity and efficiency.

1.3 Objectives

There are three primary objectives of our group for this project:

1. Develop an autonomous vehicle capable of safely navigating through urban environments while adhering to all road rules.
2. Design a duck lift to accommodate passengers with varying levels of physical ability, thereby enhancing accessibility and significantly reducing loading times.
3. Place in the top 10 in the competition at the end of the semester.

1.4 Scope

The boundaries are being defined for the project to ensure it aligns with the competition guidelines while focusing on the teams goals for our autonomous vehicle system. The project will aim to achieve SAE Level 3/4 self-driving capabilities, enabling the AV to navigate urban environments with minimal human intervention while following the road rules. The project will include a detection system to verify passenger presence. The AV will locate pickup points and perform optimal path planning to that point. Additionally, the AV will detect and respond to lane lines, ducks, other vehicles, and traffic signs, and dynamically update its route based on real-time conditions. These features will ensure that the vehicle meets both competition requirements and the teams own design objectives.

At the same time, there are limits intentionally set on what the project will address to maintain feasibility. The project will not address loading duck passengers onto the lowered lifting platform, it will be done by a team member, as this falls outside the autonomous functionality we aim to achieve. We will not implement a fully end-to-end AI system; instead, a hybrid approach combining AI with hardcoded logic will be used for driving. Finally, optimizing the cost of the vehicle will not be a focus, the teams priority is to develop a fully functional prototype that meets performance requirements and not cost constraints. By defining these boundaries, we can concentrate our efforts on creating a reliable AV within the scope of the competition.

2 Technical Specifications and Design Overview

The design of the system is heavily guided by the competition objectives, with a strong emphasis on speed and safety. This section outlines several of the design requirements and performance metrics that will be used to evaluate the final design.

2.1 Functional Requirements

As an autonomous taxi, it is expected to operate continuously within the specified area, repeating the same basic sequence of events. This event sequence, shown below in Figure 1, details a small portion of the overall responsibilities of the autonomous system. However, it portrays an accurate depiction of the higher-level responsibilities the vehicle will be responsible for.

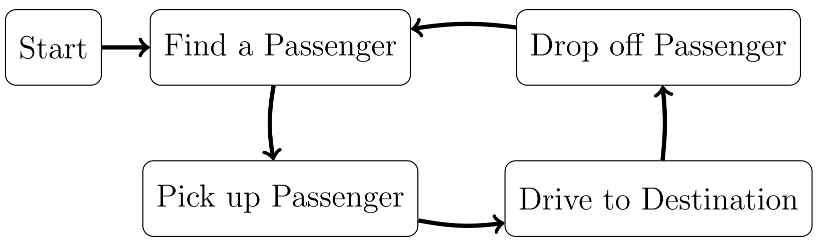

Figure 1: Basic Functional Diagram

2.1.1 Locating Passengers

Before the vehicle can continue with any other stage in its event sequence, it must be able to locate passengers and collect fares. Presently available fairs will be posted within the Vehicle Positioning and Fare System (VPFS). However, according to the road rules [4], not all fares are equal. All trips start with a base fair of \$10, increasing by either \$5 or \$10 per meter traveled. Furthermore, depending on the type of fare, the reputation reward may increase or decrease, along with the loading and unloading time.

The difficulty of finding a passenger is further compounded when factoring in the locations of pickups, destinations, and pending fares. Fares that require traveling through certain zones introduce an added risk to the vehicle due to damaged or dangerous roads. On the contrary, traveling through zones with a high population density increases the risk of collision with a pedestrian. However, these zones offer a higher availability of fares, decreasing the time spent driving without a passenger.

Given this information, a complex algorithm must be developed to determine which fares provide the most value at the least incurred cost.

2.1.2 Picking up and Dropping off Passengers

The Cabin and Restraint Equipment (CARE) is a critical component of the autonomous vehicle. It is responsible for handling the physical pickup and drop off of the passengers and ensuring their safety during the ride. A well-designed CARE system decreases the loading and unloading time, increasing the amount of fares that can be collected over a fixed period of time.

The CARE system must also adhere to several safety regulations. This includes providing a mechanism to secure passengers inside the vehicle and detect when they have safely exited. However, during the competition, passengers will be manually loaded into the vehicle, thus the loading requirements are optional.

2.1.3 Driving to the Destination

Upon entering this stage of the event sequence, the autonomous vehicle must plan and execute a safe route from the pickup to the drop-off location. This includes employing an algorithm to find the best route between the two points. When considering routes, both speed and safety must be considered as fares are calculated using a straight line distance from the pickup to the drop-off point. Furthermore, through choosing to take the fastest route between two points, more fares can be collected within a fixed time interval, increasing profits.

While driving, all road regulations must be followed. This includes staying on the right side of the road, following First Come First Served (FCFS) at intersections, and several others. However, the most important regulations that must be followed are the ones that involve the safety of town residents. The autonomous vehicle must be able to avoid collisions both with other vehicles and with pedestrians. Additionally, the autonomous vehicle must avoid situations that have potential to cause accidents, such as speeding in residential zones or following other vehicles too closely.

To accomplish the above goals, the vehicle must be able to detect and reason about road signs such as speed limits and stop signs. The vehicle must also be able determine its location and the location of other vehicles to make safe decisions when approaching and proceeding through intersections.

2.2 Performance Requirements

The performance requirements of the autonomous vehicle are critical when determining its overall functionality and effectiveness during the competition. The requirements listed below define several qualitative and quantitative benchmarks for measuring the performance of the system. To fully assess the autonomous vehicle, performance requirements have been separated into three categories: Software performance, detection requirements, and driving performance.

2.2.1 Software Performance

When measuring the software performance of the autonomous vehicle, it is important to consider the hardware being used. In this competition, a Raspberry Pi 4 has been provided as the main source of computational power. Thus, the first critical metric for the software system is its effective use of resources. The entire software stack must use less than 1Gb of RAM, and be able to run on the Raspberry Pi processor. Furthermore, as an autonomous vehicle, the software must be able to operate in real-time. Therefore, the software system should be able to recognize and react to non-emergency situations in less than 2 seconds and emergency situations in less than 500 milliseconds.

2.2.2 Detection Requirements

As an autonomous vehicle, the detection system must be able to correctly identify the location of road markers and obstacles. To ensure the safety of bystanders and the vehicle, the vision system must be able to do so with a greater than 90% accuracy, erring on the side of caution. Furthermore, to meet real time requirements, the vision system must be able to detect objects within 250 milliseconds of them appearing.

2.2.3 Driving Performance

After concluding the requirements of the software and detection systems, the overall driving performance of the vehicle must be considered. To ensure safe operation, the vehicle must slow to 20% or less of its maximum speed when approaching hazard zones such as stop signs, merge lanes, and intersections. The vehicle must stay within the borders of the lane at all times, with less than a 20% deviation from the center-line. Additionally, when entering intersections, the vehicle must stop on or before the intersection stop line. When stopping or reducing speed, the brake lights must be illuminated. Finally, when following other cars, a minimum separation distance of one full car length must be maintained.

2.3 High-Level Design Description

To accomplish the requirements laid out above, a basic description of the system architecture has been curated. This description describes the control flow of information from the cars sensors to its drivetrain. To best understand this description, Figure 2 has been created. This diagram shows the control flow of information, with information sources placed at the top of the diagram and outputs placed at the bottom.

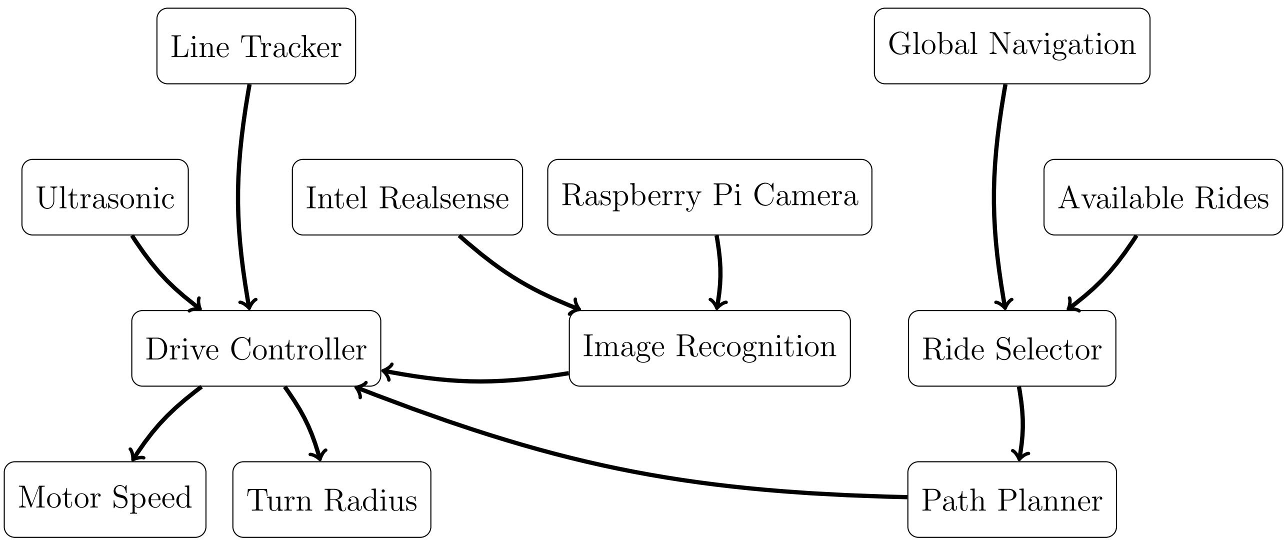

Figure 2: System Information Control Diagram

As seen Figure 2, information is first processed by higher level controllers, such as the image recognition system and ride selector. Once the information is gathered, it is passed to the drive controller in the form of "events." Events can take the form of hazards or information. Changes in road conditions, information about other vehicles, and changes in routes are all forms of events. Once an event is triggered by a higher level system, it prompts a response from the drive controller.

3 Methodology

3.1 Technologies and Tools

The tools and technologies needed for this project are separated into software and hardware in table 1. They cover the design and production phases for 3D printing, and PCB making, as well as all other aspects that the team will cover in this project.

3.2 Algorithms

This section briefly describes some of the algorithms that will be used to develop the autonomous vehicle.

First, ride selection will use a gravitational weighting algorithm. In this algorithm, potential fares vote on the destinations closest to them. The ride with the highest number of fares with start locations near its destination will be selected, reducing the time spent without a passenger. After ride selection, path generation will use the A-Star algorithm for its efficiency in solving shortest-path problems on weighted graphs. Using a well-tuned heuristic, A-Star can find the shortest route that avoids hazardous zones.

Finally, the Canny and Hough transform will be used to identify road lines and markings while driving.

The aforementioned algorithms will be used along with several others, including an acceleration tracker and vehicle speed monitoring for brake light activation, image recognition for road signs, and a PID controller for traction control.

3.3 Data Sources

There are two major types of data sources that will be needed, offline and online sources. The offline sources will be used for training any machine learning models and for any hard-coded information about the environment such as the road map or road rules. Online data sources will include things such as the state of the car and anything measured by the vehicle's sensors.

3.3.1 Offline Data Sources

Offline Data Sources include information about the following items:

- Reward System: Cash and Reputation rewards/penalties
  - Road Rules and associated infraction penalties
  - Fare types and properties
  - Achievements for reputation increases
- Vehicle Positioning and Fare System Data Format
- Traffic Signs
  - Stop Sign
  - No Entry Sign
  - Yield Sign
  - One-Way Sign
- Road Data
  - Map Coordinate System (road network)
  - Road Markings: Lanes, Intersections, One-Way Arrows, Pedestrian Crossings
  - Road Zones: Pedestrian, Risk, Common Pickup Zones, Traffic Circle
- Virtual 3D Test Environment
- (Derived State, Vehicle Sensor State) pairs
- Ducks/Pedestrians: Images, Dimensions
- Vehicles: Images, Dimensions, Top Speeds, Braking Speeds

For the hard coded data such as the reward system, road rules, VPFS API data format, and road map, this data will be obtained through course resources such as the SharePoint site [4], and integrated into the algorithms to control the autonomous car. Pre-processing the road network will involve converting the measurements and specifications into a weighted directed graph that can be used for route planning. The 3D model is also suspected to be provided later in the course, however, with the maps of the road and dimensions of ducks and cars this environment could be created.

For dynamic data such as images of road signs, vehicles, ducks, and other road obstructions, a variety of data sources is required. For road signs, there are multiple data sets available on the internet on sites such as Kaggle [8] which can be used. For live images of vehicles and toy ducks, much of this data will have to be collected by the team using the vehicle's sensors. More data regarding the PiCarX such as the top speeds and braking speeds will have to be tested to obtain accurate numbers relative to the road surfaces specific to the competition.

3.3.2 Online Data Sources

The list of online data sources is as follows:

- Current Cash amount 1D, and Reputation score 1D
- Vehicle Control State: velocity 2D (rectangular or direction and magnitude), acceleration 2D (rectangular or direction and magnitude), steering/turn angle 1D, controllable camera angles for head camera 2D, duck lift angle 1D, lights on/off (brake, turn signal left/right, head lights, taxi status light), horn on/off, API calls to VPFS
- Vehicle Sensor State: Head Camera Module tensor (video/static), ultrasonic range detector 1D, Grayscale Line Tracking Module 3D, Intel Realsense Depth Camera tensor (image video & depth)
- Global Vehicle Positioning and Fare System (VPFS) Data: Our Vehicle position and orientation angle 3D, other vehicle positions and orientations $n \times 3$D, Match API, Fares API with added pickup and drop off delays
- Vehicle Derived State (from sensors and APIs): position 2D, position/gap relative to road edges/markings, currently selected fare, path/routing plan (sequence of waypoints and routes between them)
- Environment Derived State: Locations and velocities of other vehicles and pedestrians (typically those within line of sight or a close distance to our vehicle).

Much of this online (real-time) data will be processed by the control systems on the PiCarX. The signals may be normalized for use in machine learning algorithms. Sensors available to obtain this data are listed in table 1. This real-time data can be saved for later review to inspect to diagnose issues and measure improvements.

3.4 System Integration

As described in Figure 2, the system will consist of several discrete controllers. High-level controllers, such as image recognition will be written in Python whereas lower-level controllers, such as the drive controller will be written in C. Through the combination of these languages, both speed and efficiency can be achieved. Inter-process communication will be achieved through ZeroMQ, a lightweight message-passing library.

4 Ethical and Risk Considerations

To provide the best autonomous taxi service our company ethos is safety first, ethical use of AI, customer-centricity, and inclusivity, we prioritize the well-being of passengers while promoting fairness and accessibility. Ethical considerations such as transparency and fairness in decision-making guide our autonomous driving approach[9]. We aim to have our AI systems operate without bias, being open about how decisions are made, increasing trust with the passengers and stakeholders.

The decisions made by our algorithms directly affect key stakeholders, including the passengers and the company/investors. The particularly important decisions are driving-related, as they have to prioritize passenger safety above all else, ensuring a secure and reliable ride, while also not causing danger to others on the road. As an electric vehicle, our taxi contributes to sustainability efforts by reducing emissions.

For risk management, we utilize multiple sensors for the same functionality which provides backups in the case of hardware failure and provides the ability to cross-check data in the case of software and data issues, improving the reliability that the decisions made are reliable and accurate.

5 Project Management

The team roster is Jacob Chisholm, Hendrix Gryspeerdt, Luke Strickland (Computer Engineers), and Matthew Szalawiga (Electrical Engineer). Jacob has the highest level of experience with low level software for robotics and classical image processing techniques so he will be heading system integration and road marking recognition. Hendrix is more experienced working with AI datasets and AI image processing models and project management so his responsibilities will be centered around high-level system design, object detection, and project management. Luke has taken initiative and already begun building the duck passenger restraint system and will be the mechanical lead. Matthew has focused so far on the brake light system and ethical considerations of autonomous taxis and will manage the car's electrical system for drive capabilities. Matthew and Luke will also participate in work on system integration and testing as the project progresses.

For making decisions and managing conflict with this project, the process depends on the topic. Decisions made for particular technical issues will be left up to those who are working more closely with the problem while the rest of the team may be informed or consulted. Team wide decisions such as for deciding whether reports are written in LaTeXor Microsoft Word are discussed as a group and decided by majority opinion. Other more nuanced decisions will be made by listing out all the relevant details for the whole team to consider, the team then meets to weigh the benefits of each option and comes to an agreement.

The key milestones for this project in chronological order are listed in the table 2. The milestones and dates were determined using the Critical Path Method after a comprehensive project work breakdown diagram that is too large to fit into this document (see Figures 3 to 7). The ability to traverse the traffic circle on the map is an optional milestone that can be dropped if there is not enough time to implement that capability. Similar optional milestones include some capabilities of road sign detection because if the road line detection is capable of fully recognizing intersections, then the car's position data can be combined with map information to determine the type of intersection.

The team will ensure the above milestones are completed by maintaining regular communication and meeting in person more than once per week to resolve any complex technical issues. Risks of timeline slippage will likely be related to unforeseen technical challenges that take additional time to address. To manage these risks complex driving tasks have been given priority over optimal ride selection and routing and the team will keep a dynamic check list in the project Git repository at the top of the README.md file that is updated daily. The project Logbook will be rotated from person to person each week depending on who is doing the most work on the project at that time. Each week during the Tuesday Lab Sessions, the team will reconvene to add in any undocumented contributions into the Logbook.

6 Expected Outcomes and Impact

Our goal is to develop a completely autonomous taxi that prioritizes ensuring passenger safety, reliability, and adherence to traffic laws. The team aims to place in the top 10 teams in the competition, finishing with a reputation score of at least 80% and a competitive cash flow.

As the project progresses, the teaching staff will be able to assess the new course scope providing an opportunity to identify which areas need improvement. The challenges that are encountered during the project will offer insights into potential changes in the course structure and content, allowing future students to be better equipped for real-world engineering problems. This feedback loop helps refine and enhance the quality of the engineering education provided in this course.

This project is valuable to our education and future career paths, as working in teams is a fundamental aspect of engineering. Developing this project will allow us to learn essential ethics, project management, and technical skills, providing insight into the way to tackle projects in our future workplaces. Additionally, as artificial intelligence and machine learning become more prominent, exposure to these technologies during the project allows us to gain a solid foundation in these fields.

7 Conclusions

In conclusion, the challenges faced by fully autonomous vehicles in 2025, including safe navigation in an urban environment, following all traffic laws, and meeting accessibility barriers, highlight significant gaps in current technology. Our project seeks to address these issues by developing an AV that integrates technologies like computer vision and machine learning to ensure safe navigation while incorporating new accessibility features, such as a duck lift, to enhance inclusivity and efficiency.

Building on this, The Quaxi Company focuses on creating solutions that improve passenger experiences, system reliability, and performance in dynamic driving conditions. By utilizing advanced computer vision and path planning algorithms, we aim to achieve SAE Level 4 driving capabilities. The design adheres to the competition rules and real-world traffic laws, providing a reliable and safe solution that works towards the demands for sustainable and accessible transportation.

References

[1] "Robot Resources." [Online]. Available: https://queensuca.sharepoint.com/teams/CCT-938446/SitePages/Robot-Resources.aspx

[2] "Welcome to the Town of Quackston." [Online]. Available: https://queensuca.sharepoint.com/teams/CCT-938446/SitePages/The-Town.aspx

[3] "Rules and Scoring." [Online]. Available: https://queensuca.sharepoint.com/teams/CCT-938446/SitePages/Rules.aspx

[4] "ELEC 390 Principles of Design & Dev. W25 - Home." [Online]. Available: https://queensuca.sharepoint.com/teams/CCT-938446/SitePages/LearningTeamHome.aspx

[5] "Waymo - Self-Driving Cars - Autonomous Vehicles - Ride-Hail." [Online]. Available: https://waymo.com/

[6] "Autonomous Vehicles Are Great at Driving Straight - IEEE Spectrum." [Online]. Available: https://spectrum.ieee.org/autonomous-vehicles-great-at-straights

[7] M. Igini, "Environmental Pros and Cons of Self-Driving Cars," May 2022. [Online]. Available: https://earth.org/pros-and-cons-of-self-driving-cars/

[8] "Find Open Datasets and Machine Learning Projects | Kaggle." [Online]. Available: https://www.kaggle.com/datasets

[9] K. Miller, "Designing Ethical Self-Driving Cars." [Online]. Available: https://hai.stanford.edu/news/designing-ethical-self-driving-cars

[10] "ELEC 390 Lecture 1 Slide Deck."

[11] "ELEC 390 Competition Information."

8 Appendix

8.1 Tools and Technologies Table

Table 1: Tools and Technologies

Category	**Tool/Technology**	**Description/Use**
Software	LPFK software	Used for making PCBs with the LPFK S104 PCB machine.
	Bambu Studio	Used to slice 3D models for printing.
	Fusion 360	Used to create 3D models.
	Python & relevant libraries	Used for creating computer vision system.
	KiCad	Used to design PCBs.
Hardware	Intel Realsense Depth Camera D435	Used as an additional camera alongside lidar.
	PiCar-X	Provided
	Raspberry Pi	Provided
	Coral Edge TPU	Provided for AI and ML inference tasks.
	Grayscale Sensor	Provided
	Ultrasonic Sensor	Provided
	Raspberry Pi Camera	Provided
	LEDs	Provided
	LPFK S104 PCB Machine	Used to produce PCBs.
	Creality K1 3D Printer	Used to produce 3D-printed components.

8.2 Project Work Breakdown

The following figures are listed in order from left to right in the larger diagram.

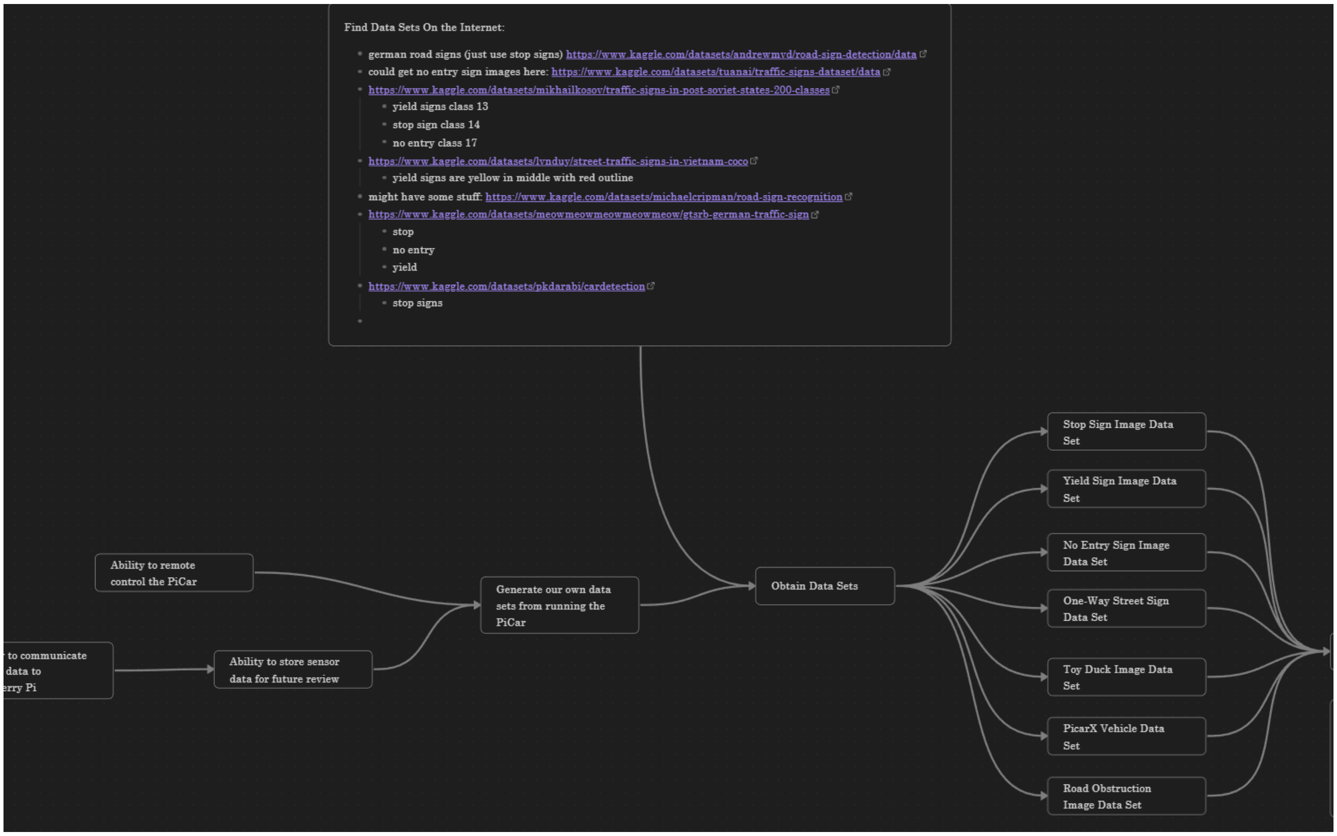

Figure 3: Data Collection

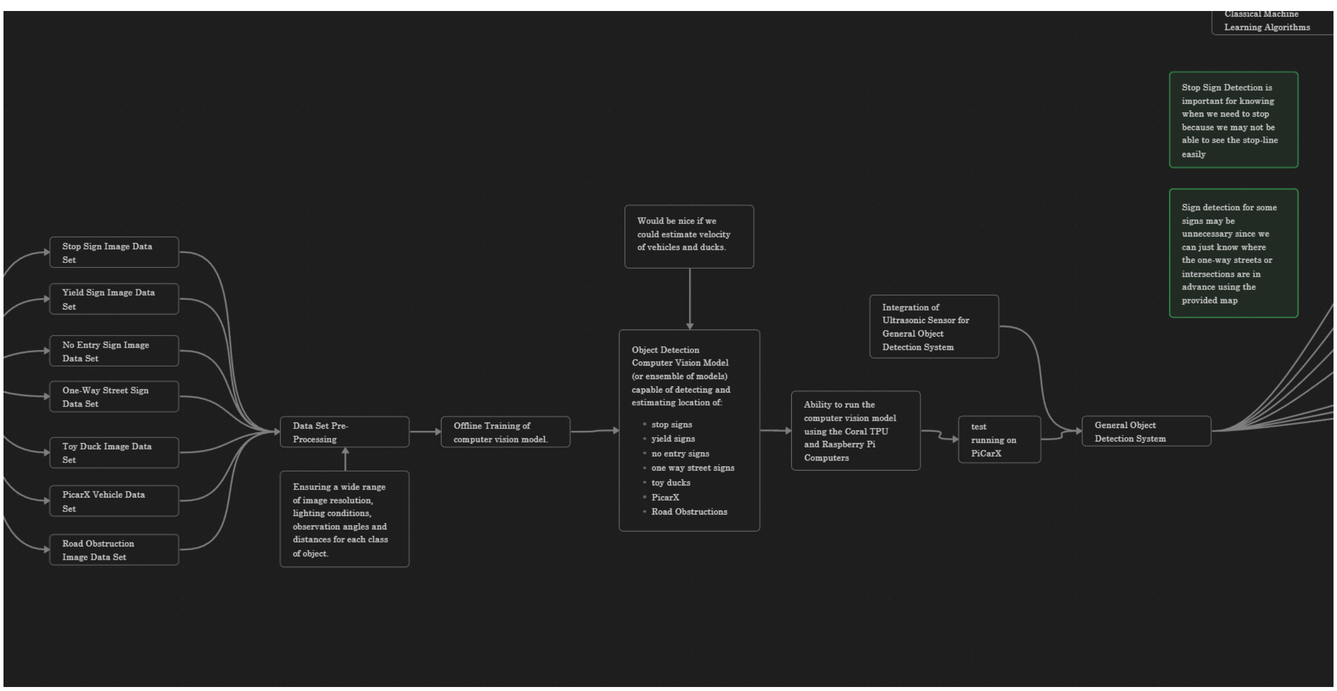

Figure 4: Integrating Road Data and Other Image Processing

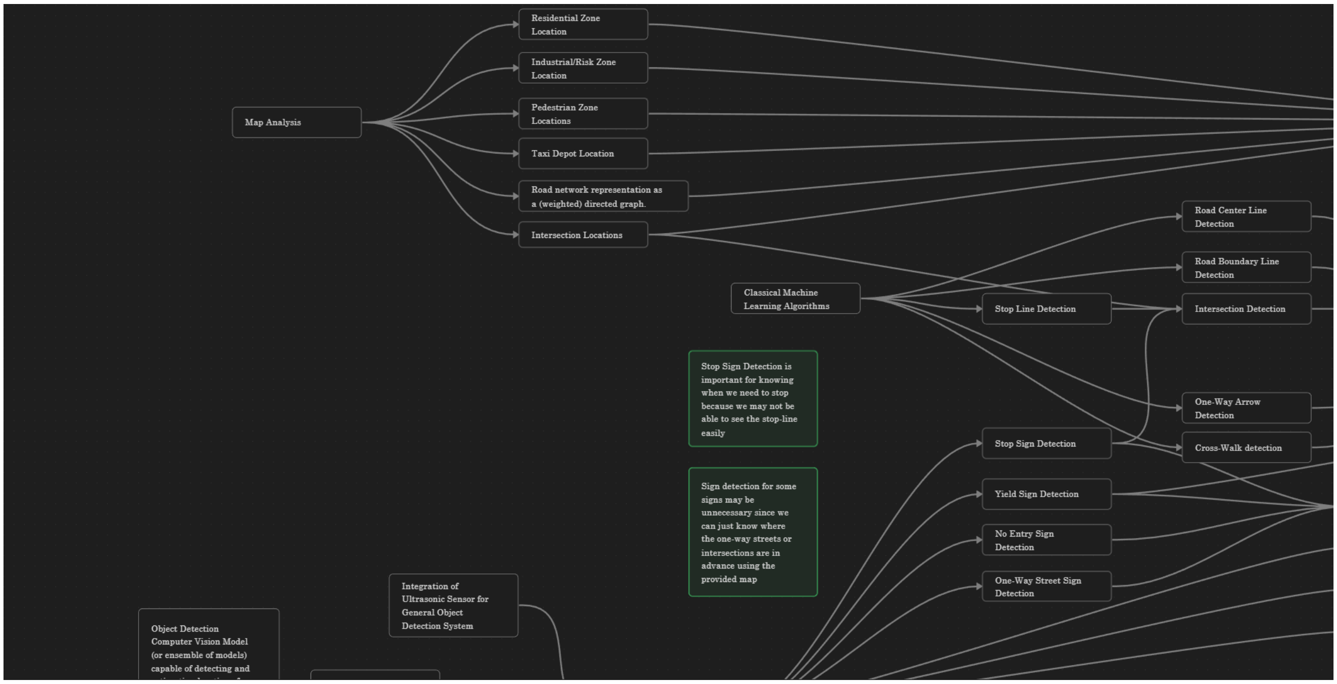

Figure 5: Object Detection Implementation

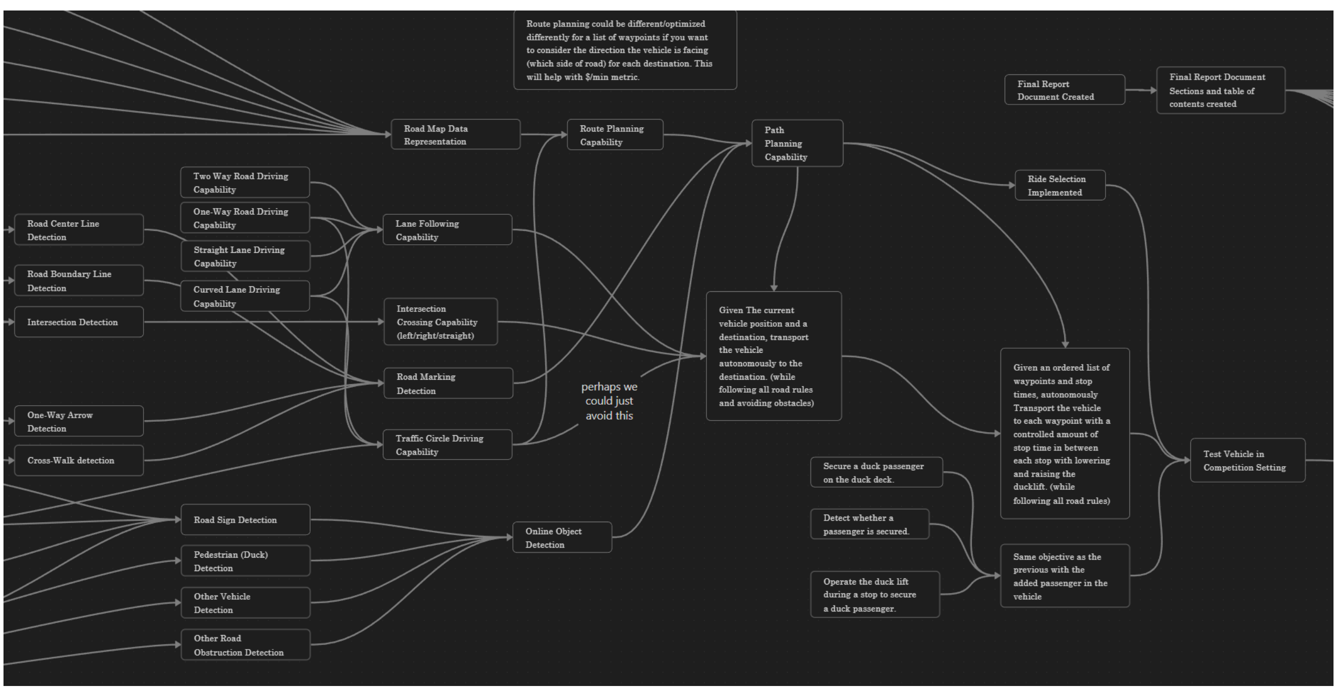

Figure 6: Middle of the Project

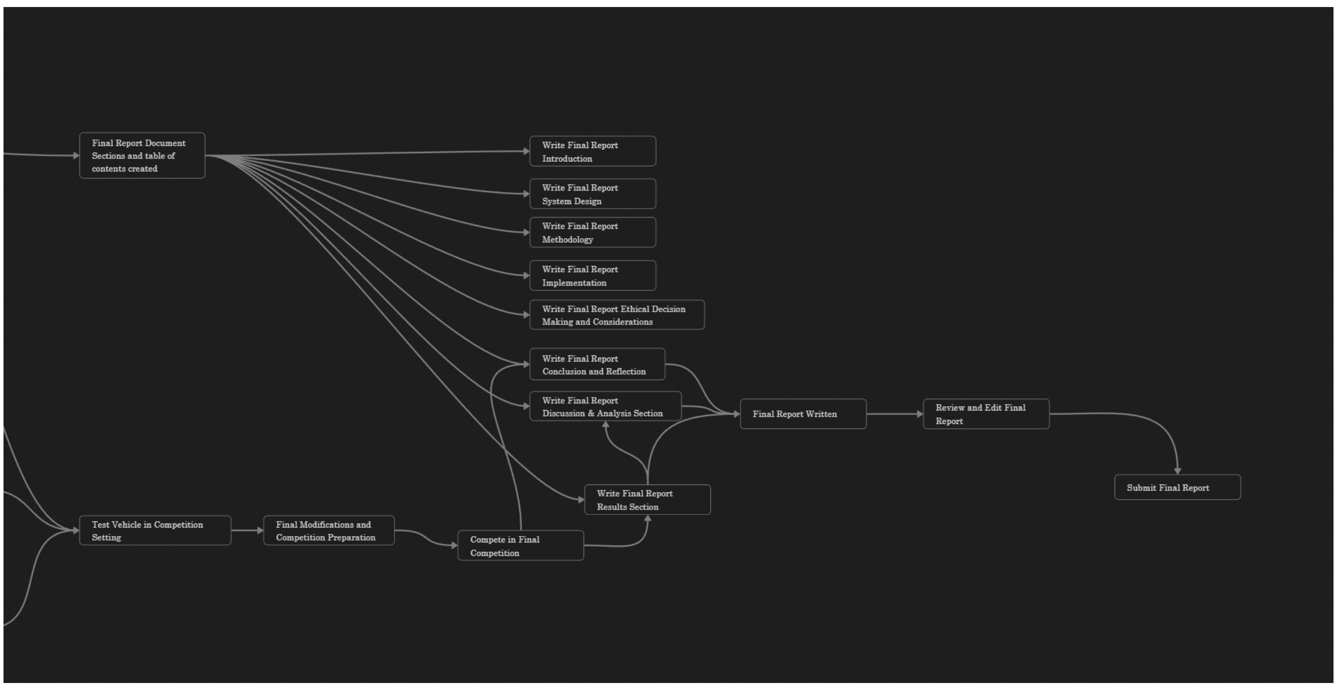

Figure 7: Final Stages of the Project

8.3 Project Timeline

Table 2: Project Timeline

Milestone	Date
PiCar can be Remote Controlled and Record Key Metrics	2025-02-01
Basic Autonomous Drive Controller Works	2025-02-02
Data Sets Obtained for Training Object Detection	2025-02-09
PiCar Can Drive Autonomously Along a Lane	2025-02-09
Road Map Integrated into Planning System	2025-02-19
Route Planning System Done	2025-02-19
Path Planning Based on Route Plan Works	2025-02-19
Object Detection Works	2025-02-19
Each Capability is Integrated as a Cohesive System within the PiCar	2025-02-19
PiCar Can Drive Autonomously Through an Intersection	2025-02-15
PiCar Can Drive Autonomously to any Destination in Quackston	2025-03-01
Optimized Ride Selection Algorithm Complete	2025-03-08
PiCar Duck Lift Cabin and Restraint Equipment System Complete	2025-03-09
Begin Writing Final Report	2025-03-10
Vehicle Tested in Competition Setting	2025-03-16
Compete in Final Competition	2025-03-24
Final Project Report Complete	2025-04-04