THE OHIO STATE UNIVERSITY

Final Design Report

Group M

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Opportunity Identification

INTRODUCTION

Currently, assured safe campus transportation is only available during certain hours of the day on certain days of the week and many of these available transportation systems are not optimal for students. Many students also have issues with the amount of wait time they are forced to endure which could potentially lead to uncomfortable/possibly dangerous situations. Bus stops often don't provide safe environments for students waiting for a ride

It is necessary and important to provide inexpensive, safe transport for all students at all times. This transportation method would provide direct routes for on and around campus travel. Many students would be more encouraged to explore unfamiliar surroundings (businesses, attractions, etc). Providing a reliable, safe, accessible transportation system for OSU students living on campus and in the neighborhoods slightly east of campus during all hours of the day, every day of the week will benefit the OSU community.

PROBLEM DEFINITION

PAINS:

1. Assured safe campus transportation is only available during certain hours
2. Not all available transportation systems are desirable for students
3. Current methods leave too much wait time for uncomfortable/possibly dangerous situations
4. Bus stops don't provide a safe environment for students waiting for a ride

GAINS:

1. Provides safe transport for all students at all times
2. Direct routes provided for on and around campus travel
3. Encourages students to be more comfortable exploring unfamiliar surroundings(businesses, attractions, etc)
4. Inexpensive, guaranteed transportation services

PERSONA

Rae Addams
19, Female
Single
Occupation/Salary - student, office assistant makes minimum wage
Hobbies - rides her bike, plays volleyball and piano
Commuting Habits - lives on campus, has friends and older sister off campus who she regularly visits
Commuting Needs - get to and from her family/friend's houses, meet them at restaurants, go to attractions off campus on weekends, occasionally out late from meeting them

NEEDS CHART

Ranked	Need	Brief Description
5	Safe for students	The entire purpose of this transportation system is to ensure that students have a method of traveling off campus which they feel entirely safe using.
4	Always available	Students are traveling at all hours of the day, it is necessary that they also have safe transportation any time they are traveling.
4	Inexpensive	College students are generally living on small budgets, having a cost efficient method in place is necessary.
3	Quickest Route	Getting to class on time is important for students, so less time wait is important.
3	Reliable	Having a transportation vehicle that doesn't break down or harm students while in use adds to general sense of safety.
2	Eco Friendly	Public/private transportation systems should lessen negative environmental impacts.
1	Student Only	Being limited to only be used by students gives a sense of security to users. This also regulates users and keeps the system more available for targeted users.
2	Multiple Seating	Ensures that multiples students or groups can travel together and decreases wait time.

PAIRWISE COMPARISON

	Safe for students	Always available	inexpensive	quickest route	Eco friendly	Student only	Reliable	Multiple seating	Total	Normalized	Original
Safe for students		1	1	1	1	1	1	1	7	4.375	5
Always available	0		1	0	1	1	0	1	4	2.5	4
inexpensive	0	0		1	1	1	0	1	4	2.5	4
quickest route	0	1	0		1	0	0	0	2	1.25	3
Eco friendly	0	0	0	0		1	0	0	1	0.625	3
Student only	0	0	0	1	0		0	0	1	0.625	2
Reliable	0	1	1	1	1	1		1	6	3.75	1
Mutiple seating	0	0	0	1	1	1	0		3	1.875	2

MARKET ANALYSIS

STAKEHOLDERS

Some of the people negatively affected by the vehicle solution would be people driving down high street or through the neighborhoods East of High Street. This is because there will be more cars on the road, thus causing more of a traffic jam during rush hour. This includes those who live in the target areas and do not go to Ohio State University. Some of the people positively affected by the vehicle solution would be store owners on high street and professors. With users having more of a motivation to get to further places, local stores may see an increase in business and classrooms will be filled more on a daily basis.

MARKET SIZE

The system is looking to accommodate at least 20,000 users as that is about how many people live around campus in the Columbus area. With this large of a population size, not everyone will use the service to its fullest extent, but it will make positive impacts on those who do.

CURRENT ALTERNATIVES

COTA is a public bussing system open for student use. Oftentimes there are potentially dangerous people riding on COTA buses, and students may feel unsafe while riding after hours. Bus stops are also not well lit so waiting for a bus can also be dangerous. Lyft and UBER are also ride sharing companies accessible by anyone. It is generally rather expensive for the user depending on the length of the ride. It can also be uncomfortable to ride with unfamiliar drivers. CABS is a network of buses which runs through Ohio State campus. Insufficient routes and timing of the buses is poorly executed especially during busy times. These buses are not alway

SECONDARY RESEARCH

Campus is, for many students, their first time away from home, and college is a time when students mature. However, 179,000 students from around the country were surveyed, and 14% of those student's felt uncomfortable walking alone especially late at night [2]. To make matters worse, 70% of campus crimes are burglaries, and 8% are sexual offences (Samsel). These statistics show students are uncomfortable traveling alone and learning to rely on themselves.

There are two typical American college town models, one in which the campus is located near a highway or near a town [3]. There is always a higher risk for younger people living in unfamiliar areas and this includes OSU. 2,174 safety-related incidents were reported that involved students on/near campus or other Ohio State affiliated property in 2017 [4]. Of the 2,795 colleges and universities that contributed data, 2,784 of them reported less incidents than OSU.

According to Ohio State University research, only 77% of students know where and how to report crimes [1]. With the number of students living on the Columbus campus having increased by 30% since the fall of 2016, when the new residence halls were finished, this is incredibly concerning. Obviously, this has increased the number of people on campus, therefore making crime more likely.

PRIMARY RESEARCH

INTERVIEW PLAN

How to find potential users:

- Ask friends from different areas
    - Live on different part of campus
    - Some may live off campus (ex: fraternity and sorority students)
- Ask students of different ages
    - Would be beneficial to include both older and younger students
    - Ask advisors
        - Provides an adult perspective
    - Ask a first year international student
        - Viewpoints of someone not familiar with the area of Columbus/campus

Viable interview location:

- Dorm building common areas
    - Lobbies, sitting areas, private conference rooms
- Outside (weather provided)
    - General seating areas
- Campus cafe

- A quieter (semi private) seating area that provides casual comfort

How to divide up interviewing:
- Each member of the group is to complete 2 interviews
- Members will decide which demographic of users to interview based on ease of finding a potential user comfortable with discussing their viewpoints

INTERVIEW RESULTS

Almost all of the students interviewed were familiar with the COTA and campus buses in some way, whether they used it to get to and from their homes or to travel throughout the general Columbus area. Many others were also rather familiar with private services such as Uber or Lyft. This highlighted the importance of these transportation systems and made it more evident how important it is for students to have access to transportation that doesn't involve owning a personal vehicle.

Another important factor was how many of the students were in agreement that they would utilize a system such as the one proposed. Almost every student who lived in/around the target neighborhood agreed that they would use a system such as the one proposed. Many of the female students also noted specifically that this would allow them to feel safer when traveling later in the day or during the night, especially when alone. The buses that run through the area are rather inefficient and can oftentimes be uncomfortable to use for students and can force individuals to wait long periods of time in dark, potentially dangerous areas, leaving them rather vulnerable and alone. They also noted that having a transportation system available only to students would aid in this feeling of general safety.

BUSINESS MODEL

VALUE PROPOSITION

After completing the interviews and research, people would use this system because it is safer than riding other forms of transportation such as a bus. This is due to the fact that the drivers have strict background checks and are university employees as well as the fact that users would not have to wait in potentially dangerous situations alone. The company is also intended towards providing transportation that is less expensive compared to competitors..

INITIAL USER IDENTIFICATION

The primary population of end users are to be students living off campus in houses and apartments and students living on campus in residence halls on the Columbus campus. In the future, the population may potentially increase as the project continues its expansion throughout Ohio State's main campus and eventually Ohio. This would not change the vehicle design, but rather require the company to have more active vehicles throughout the day to meet demands.

ITS Design Concepts

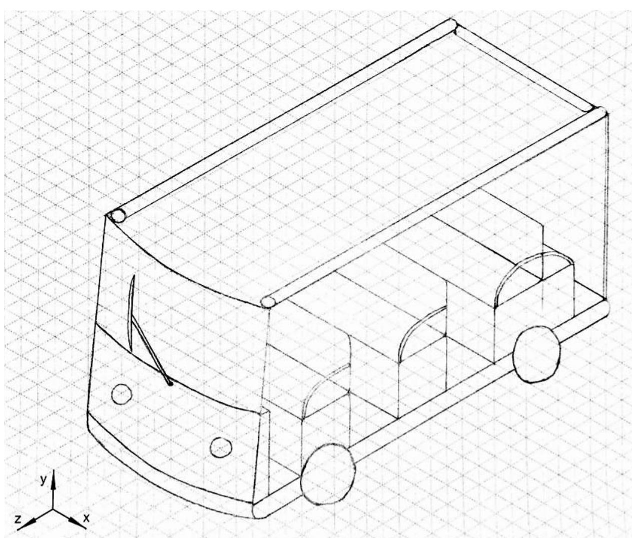
BRAINSTORMING

This process began with listing important requirements of the potential solution vehicle. Once this was complete, different concept were generated to meet these requirement. Each concept was then presented via sketches and a short summary explanation of the system. A meeting was held to discuss and pick one of the concepts that were most suited for the defined task. A final sketch was then developed for one solution vehicle which optimized the best aspects of each preliminary concept sketch.

The multiple brainstorming sessions allowed the team to specify what needs are primary for the project and what aspects of the vehicle will optimize these primary needs. Developing initial lists of requirements assured that all of the conceptualized solution vehicles would correspond accurately with the problem definition. Sketching allowed concepts to be visualized in a manner that highlighted important aspects of the potential solution vehicle.

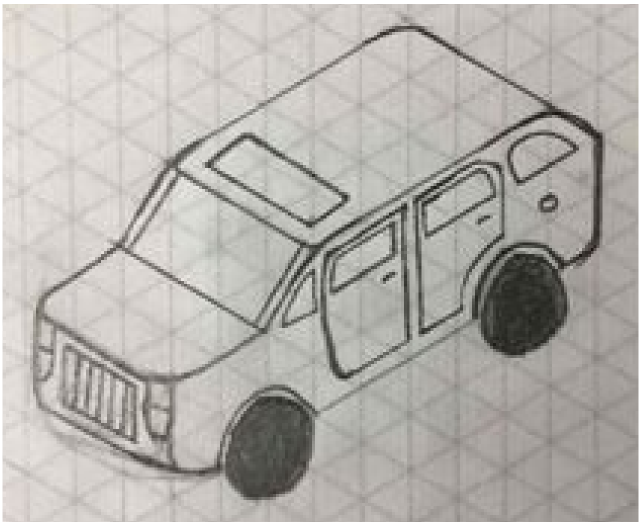
CONCEPT DESIGN SKETCHES

Solution 1



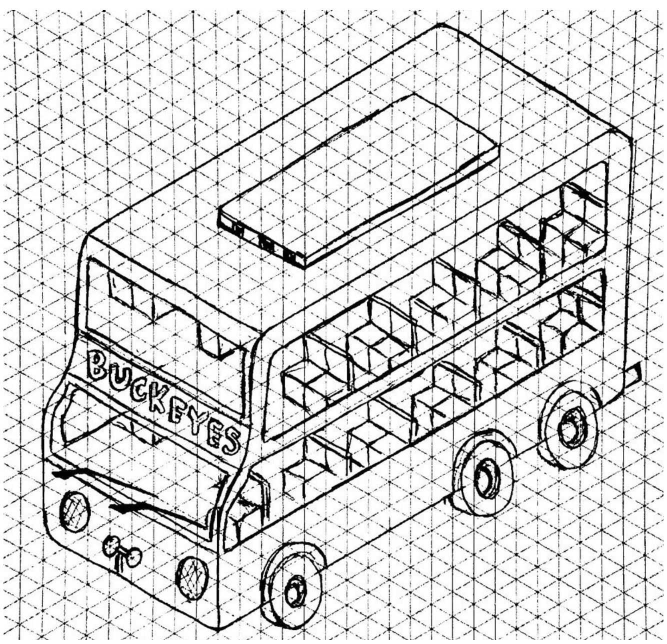
This solution is a large, modified golf cart which can hold up to 8 people including the driver. There is one extra seat in the back which is wheelchair accessible. The vehicle has three rolls of thick, waterproof plastic that act as makeshift doors which can be unrolled to protect passengers from any nonoptimal weather such as during raining and snowing days. This vehicle is intended for use in the project’s target neighborhood. Its thin design allows it to travel through the narrow streets easily while still reaching regulated speed limits. The vehicle is open so as to ensure that the passengers feel comfortable with any potential stranger who is driving or they are riding with. The vehicle is also designed with multiple seats to cut down on wait time.

Solution 2



This solution is a vehicle similar to a Range Rover in general shape and size. It is large enough to fit four students other than the driver and has a trunk which can be used for extra storage. The vehicle is structured enough so the students feel safe inside, however, the windows are large and very transparent to ensure that passengers are comfortable riding with an unfamiliar driver. Ideally, the vehicle will be designed as an electric car to preserve the environment, however, this depends on the cost of development and upkeep.

Solution 3



This solution is to replace the current buses with a double-decker bus form. This double-decker bus can load more passenger per route so it will reduce wait times and allow people to feel more comfortable around strangers because they have room to spread out. The cost would also be relatively low to individual students because this service is already included in student fees. Instead of simply running the same routes as COTA, this system would focus on the target neighborhood and travel down the main streets in the area.

USER REVIEW

After addressing potential users regarding preliminary brainstorming results, it was evident that users preferred a simple SUV type vehicle. Students were more interested in riding in a vehicle that “fit in” with other cars. This was preferred because it made the vehicles less obvious and contributed to an overall sense of safety. It was also crucial that the vehicle had storage space for any larger items or bags and had enough space for groups of 3-4 students to travel together.

UPDATED NEEDS

After further research and feedback from potential users, the only aspects which were ranked differently regarding the needs classifications were the "multiple seating" and "eco friendly" sections. Students require more seats available to them because they tend to travel in larger groups so it is necessary that the solution vehicle is able to accomodate all passengers in a larger group. It was also determined that while an environmentally friendly vehicle is important in a general sense, it may not be the most practical to focus on this due to the budget of the project and of the students paying for the system. The users solidified that safety and and budget awareness were crucial focal points to ensure the success of the final implemented system.

Rank	Need	Brief Description
5	Safe for students	The entire purpose of the transportation system is to ensure that students have a method of traveling off campus which they feel safe using.
4	Always available	It is important to students that their transportation methods are always available to them to decrease their wait time.
4	Inexpensive	College students are generally restricted on small budgets, having a cost effective method in place is necessary to accommodate this.
3	Quickest Route	Getting to class, work or events on time is important for students, so less time wait is crucial to be successful.
3	Reliable	Having a transportation vehicle that doesn't break down while in use adds to general sense of safety and encourages student use.
1	Eco Friendly	In order to ensure that the vehicle is inexpensive for students to use, it may be necessary to sacrifice some of the environmentally friendly technology in order to preserve a lower budget.
2	Student Only	Being limited to only be used by students gives a sense of security to users. This also regulates users and keeps the system more available. However students do have guests from outside of the university and this must be considered.
4	Multiple Seating	Further research has shown that people travel in larger groups rather than alone on the weekends. In order to transport everyone comfortably, more seating is required.

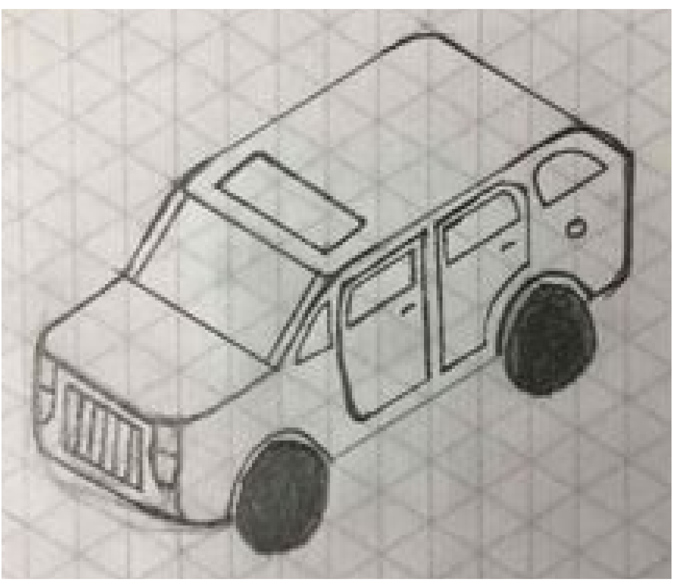
CONCEPT SELECTION

PUGH SCORING MATRIX

The Pugh Scoring Matrix intended to highlight the most successful aspects of each potential solution vehicle which aided in determining how to apply the user needs successfully onto the the final system vehicle. This ensured that (in the creation of the final product) the initial user needs are not lost

		Reference	UBER	**Concept 1**	Logan	**Concept 2**	Zoe	**Concept 3**	Amanda	**Concept 4**	Aidil
Needs	Weights	Rating	W. Score	Rating	W. Score	Rating	W. Score	Rating	W. Score	Rating	W. Score
Safe for students	4.375	4	17.5	4	17.5	4	17.5	4	17.5	3	13.125
Inexpensive	2.5	2	5	2	5	4	10	3.5	8.75	2	5
Efficient	1.25	3	3.75	3	3.75	4	5	4	5	3	3.75
Multiple Seating	1.875	4	7.5	2	3.75	4	7.5	3.5	6.56	5	9.375
Reliable	3.75	4	15	4	15	3	11.25	3.5	13.13	4	15
Appropriate Street Size	3.25	3	9.75	4	13	4	13	4	13	3	9.75
Eco Friendly	0.65	2	1.3	4	2.6	3	1.95	2.5	1.63	3	1.95
Disability Accesible	2.25	1	2.25	2	4.5	2	4.5	2.5	5.63	4	9
Simple to Clean	1.25	1	1.25	3	3.75	4	5	3	3.75	2	2.5
Comfortable	1.5	3	4.5	3	4.5	1	1.5	3	4.5	2	3
	Total		67.8		73.35		77.2		79.44		72.45
	Rank				**3**		**2**		**1**		**4**

FINAL SELECTED CONCEPT



When comparing each of the four concept designs, this vehicle was ranked the highest due to the versatility it offers for a college campus. This vehicle would be able to comfortably seat a large group of people while providing plenty of extra trunk space for storage. The vehicle allows students to feel safe as riders due to the stability of the vehicle itself. The vehicle would also have ideal gas mileage to lower expenses and keep costs down. The design is sized properly to ensure it can travel through the narrow streets of the target neighborhood.

USER FEEDBACK

When presented with the final concept, most users agreed with the final selected design. The reservations which were brought up by the users were mainly regarding seating and ease of maneuverability. The users commented on potentially producing a vehicle which would be able to seat six passengers. This feedback suggests that further tweaking of the vehicle may be required, however, the general shape/design is appropriate for the defined problem.

VEHICLE DESIGN REQUIREMENTS

These tables serve as references from which scaled vehicle testing will be based upon. The requirements are all aspects of the actual vehicle which can be tested on a scaled version to determine which systems/designs will be appropriate to input into the full scale, final vehicle. Completing testing on a smaller scale will be beneficial regarding cost awareness for the overall project. These testing aspects can ensure that the final vehicle will utilize the most appropriate systems to ensure it is as reliable and efficient as possible.

VEHICLE REQUIREMENTS TABLE

Requirement	**Description**
Mass	Based on the mass of an average car (not too heavy for road limits).
Time to Dismantle	Time required to entirely dismantle the vehicle into its subassembly parts.
Stopping Precision	Time taken for the vehicle to fully stop at anytime.
Pause for Gate	Amount of time that the vehicle spends when stopped at a light or stop sign.
Battery Life (Energy Efficiency)	Amount of energy used while traveling.
Vehicle Width	Based on the width of the average vehicle or (preferably) smaller.
Number of Seats	Number of seats available in the vehicle for the passengers (not including the driver).
Stability (left/right)	The stability of the vehicle from left to right.

REQUIREMENTS SCORING MATRIX

Vehicle Requirements Correlation Matrix ----> User Needs	Mass	Dismantle Time	Stopping Precision	Pause for Gate	Energy Efficiency	Vehicle Width	Number of Seats	Stability (left/right)	weight
Student Safety	1		9	9	3	1		3	4.375
Readily Available		3					3		2.5
Comfortable			1	1		3	3	3	1.5
Inexpensive	9				9		3		2.5
Reliable		3	3	3	3			3	3.75
Eco-Friendly	3				3		3		0.65
Mutiple Seats	1					3	9		1.875
Street Size						9			3.25
Accessible									2.25
Importance	30.7	18.75	52.125	52.125	48.825	43.75	38.325	28.875	

SCALED REQUIREMENTS

	Unscaled	Scaled	Rounded	Points (100)
Requirement 1	10	9.8%	9.00%	9
Requirement 2	10	6.0%	6.00%	6
Requirement 3	10	16.6%	17.00%	17
Requirement 4	10	16.6%	17.00%	17
Requirement 5	10	15.6%	16.00%	16
Requirement 6	10	14.0%	14.00%	14
Requirement 7	10	12.2%	12.00%	12
Requirement 8	10	9.2%	9.00%	9
		100.0%	100.0%	

This correlation matrix aided in defining which of the vehicle requirements will need more focus when deciding between design tradeoffs. The requirements that are more heavily weighted will have priority over the aspects which are deemed less relevant to the vehicle's task. The matrix also aided in relating the user needs with the vehicle requirements, this way the user needs are still considered when completing testing and finalizing development. This correlation matrix ensures that the initial goals are still relevant while finalizing development.

Vehicle Design & Final Testing

INTRODUCTION TO VEHICLE DESIGN

Some of the first steps to be taken when going to create something are deciding what its limits are, what it needs to accomplish, and how it will accomplish them. Once that is complete, a model should be created so it is easier to catch and fix problems, alter the design, and make sure that all of the components are interacting well together before making a final, full-scale model. The scaled down model has to complete requirement tests, which also show what may need to be changed.

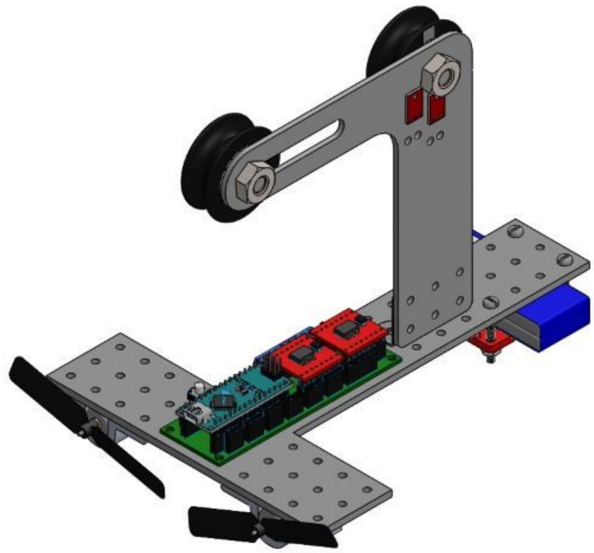
VEHICLE DESIGN REQUIREMENTS

These requirements are all aspects of the actual vehicle which are to be tested on a scaled version to determine which systems/designs are appropriate to input into the full scale, final vehicle. Completing testing on a smaller scale is beneficial regarding cost awareness for the overall project. These testing aspects ensure that the final vehicle utilizes the most appropriate systems to ensure it is as reliable and efficient as possible

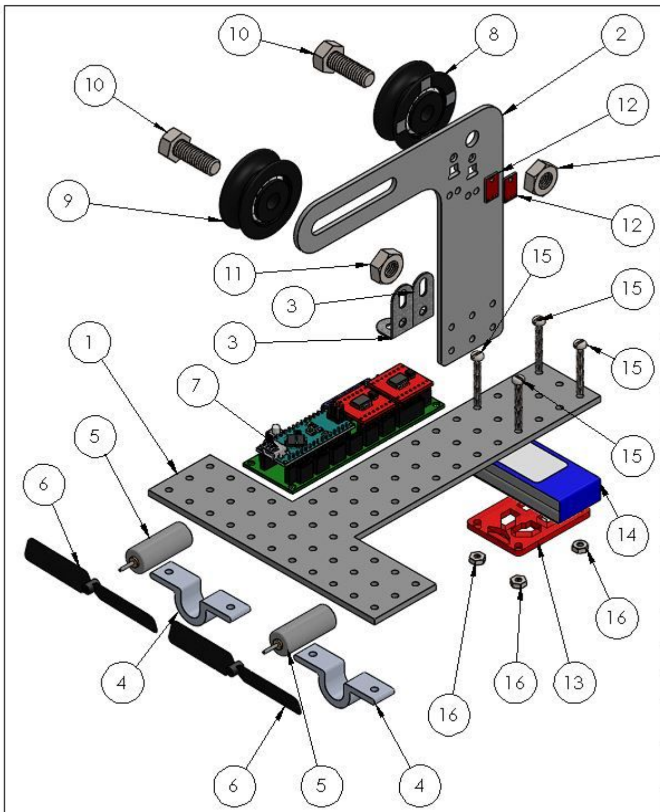
Vehicle Requirements	Range	Ideal	Scaled PV Requirements
Mass	4000 lbs - 5000 lbs	4500 lbs	125 grams
Time to Dismantle	300 sec. - 600 sec.	300 sec.	180 sec.
Stopping Precision	0 ft - 50 ft	20 ft	6 inches
Pause for Gate	0 sec. - 30 sec.	15 sec.	5 sec
Battery Life (Energy Efficiency)	20 mpg - 30 mpg	25 mpg	25 minutes
Vehicle Width	6ft - 12ft	6.5 ft	6 inches
Number of Seats	4 seats - 8 seats	6 seats	6 seats
Stability (left/right)	60/40 to 40/60	45/55 to 55/45	45/55 to 55/45

DETAILED DESIGN DRAWINGS

3D Assembly Drawing



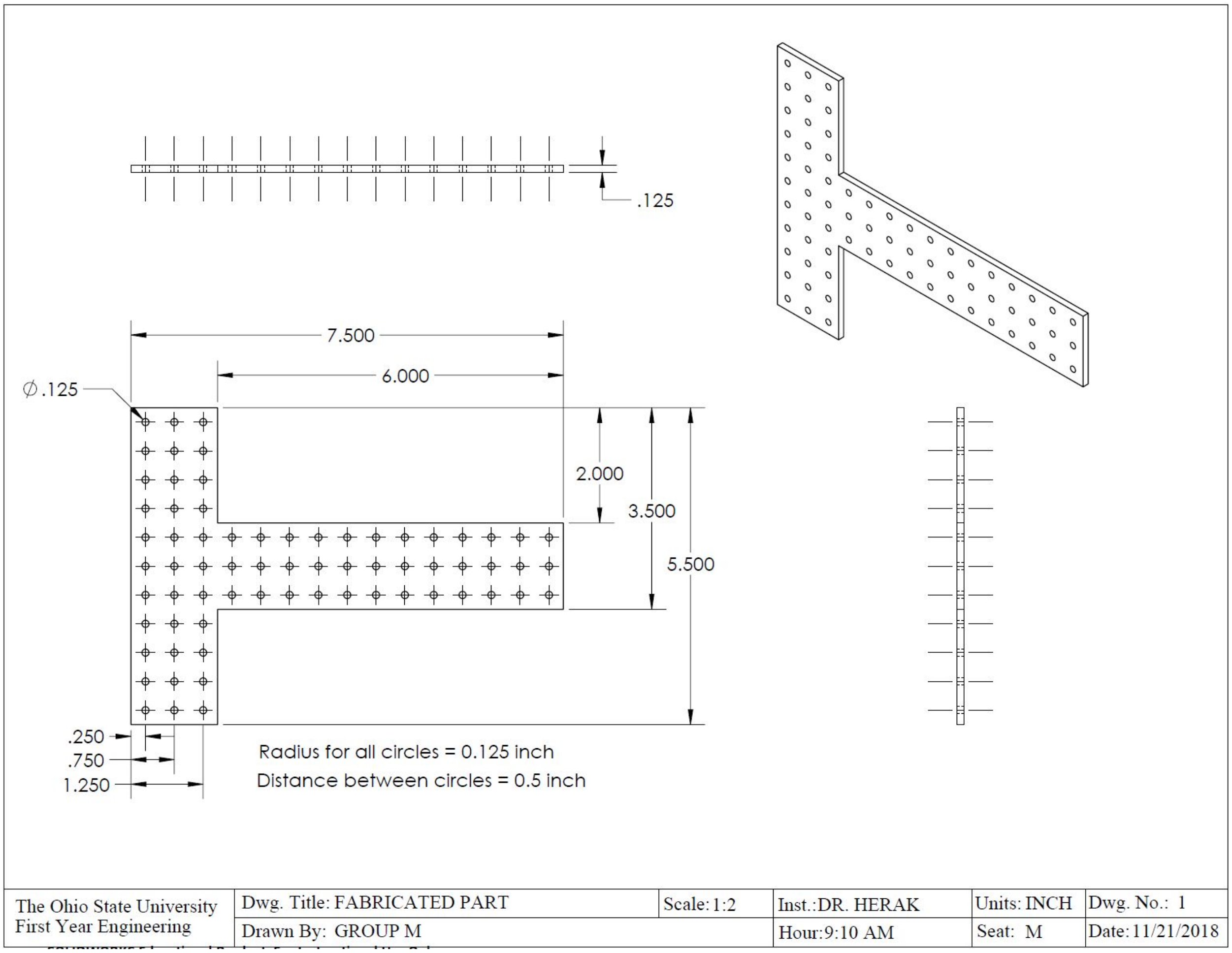
Exploded Assembly Drawing + Bill of Materials



ITEM NO.	PART	MATERIAL	QTY.
1	T-Shape Base	Plastic	1
2	Support Arm	Plastic	1
3	90-deg Bracket	Metal	2
4	Motor Mount Clip	Plastic	2
5	Motor	Metal	2
6	3 inch Propellor	Plastic	2
7	Arduino	Mixed	1
8	Wheel w/ reflective tape	Plastic	1
9	Wheel	Plastic	1
10	Wheel Bolt	Plastic	2
11	Wheel Nut	Plastic	2
12	Rotation Sensor	Mixed	2
13	Battery Clamp Plate	Plastic	1
14	Battery	Mixed	1
15	Screw	Plastic	4
16	Nut	Plastic	4

The Ohio State University First Year Engineering	Dwg. Title: VEHICLE EXPLODED ASSEMBLY	Scale: 1:2	Inst.: DR. HERAK	Units: INCH	Dwg. No.: 1
	Drawn By: GROUP M		Hour: 9:10	Seat: M	Date: 12/5/18

Detail Drawing for T-Shaped Base



VEHICLE METHODOLOGY TESTING

<u>MOTOR CONFIGURATION</u>

How motor polarity and number affects the total energy required to run the vehicle was tested to determine which configuration resulted in the most energy efficient vehicle. To encourage larger differences in energy use between configurations the vehicle towed a 1-caboose load. The scaled model traveled for 10 seconds at 35% power. After the completion of each run, the total energy used for the run was measured and recorded as shown in the table below.

It was assumed that having 2 motors facing backwards would require the least amount of total energy to complete the designated run (would be most energy efficient). After completing testing, it was determined that two motors facing forwards is the most energy efficient configuration. This layout will be utilized in the vehicle’s final configuration to improve energy efficiency.

Motor Configuration	Total Energy (Joules)
2 Motors Forward	88.1368
2 Motors Backwards	95.3091
1 Motor Forward, 1 Motor Backwards	95.5788

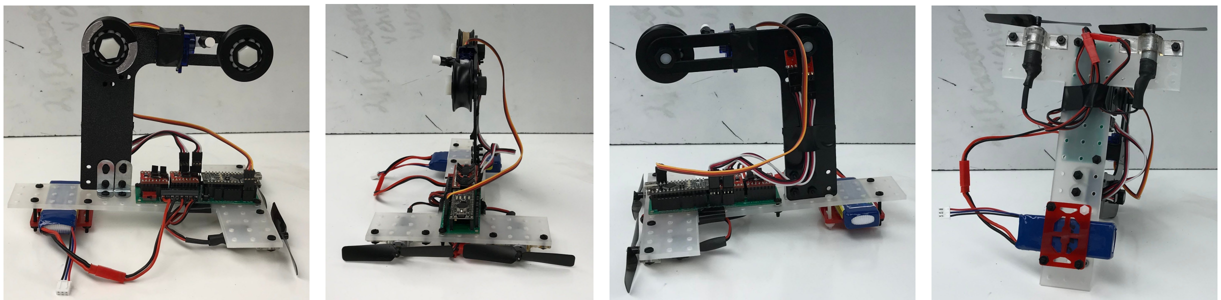
PROPELLOR CONFIGURATION

How propellor configuration and angles affects the total energy required to run the vehicle was tested to determine which configuration resulted in the most energy efficient vehicle. To encourage larger differences in energy requirements between configurations the vehicle towed a 1-caboose load. The AEV traveled for 10 seconds per run at 35% power. After the completion of each run, the total energy used for the run was measured and recorded.

It was suspected that the propellor configuration with two propellers flat on the outer edges of the vehicle would require the least amount of energy and would result in the most energy efficient configuration. Once testing and data collection was completed, this assumption was proven correct although many of the configurations resulted in somewhat similar energy requirements. The final vehicle will utilize this configuration to improve energy efficiency in the final vehicle.

Propeller Configurations	Total Energy (Joules)
2 On Outer Edges Flat	88.0956
1 90 Degree Up 1 90 Degree Down	88.2387
2 at 45 Degree Angle up	89.6864
2 at 45 Degree Angle Down	88.7420
1 45 Degree Up and 1 45 Degree Down	87.9412

From the test results, the final design for the vehicle is:



Images (in order): Right View, Front View, Left View, Bottom View.

As shown in the data, the T-shaped base with two motors forward was most energy efficient. This is because it is lighter than any other base configurations which had brackets and screws/washers as well as empty areas which added weight and bulk, also because it holds all of the required mountings for a successful design without having much empty space. The most efficient position for motor polarity (both forward facing) is visible in the image of the bottom view. To improve stopping accuracy, the servo arm was added (as seen in the right and front views) as a makeshift braking system between the wheels. The servo arm was extended and topped with a small rubber stopper to improve breaking accuracy which proved to be poor when completing initial stopping precision tests.

COMPANY RESEARCH

<u>GROUP N</u>

This group researched stopping precision (without a break mechanism i.e. rolling stops) using varying propellor configurations and shapes. The team has yet to be able to complete any entirely comprehensive results at this time because the custom propellor parts have yet to be completed, however, it has been determined so far that having wider tipped propellers increases their ability to encourage forward movement. The goal of this research is to develop a more efficient vehicle without having to add the extra weight of a breaking mechanism. The team intends to determine the best design to carry the highest load using the lowest power percentage.

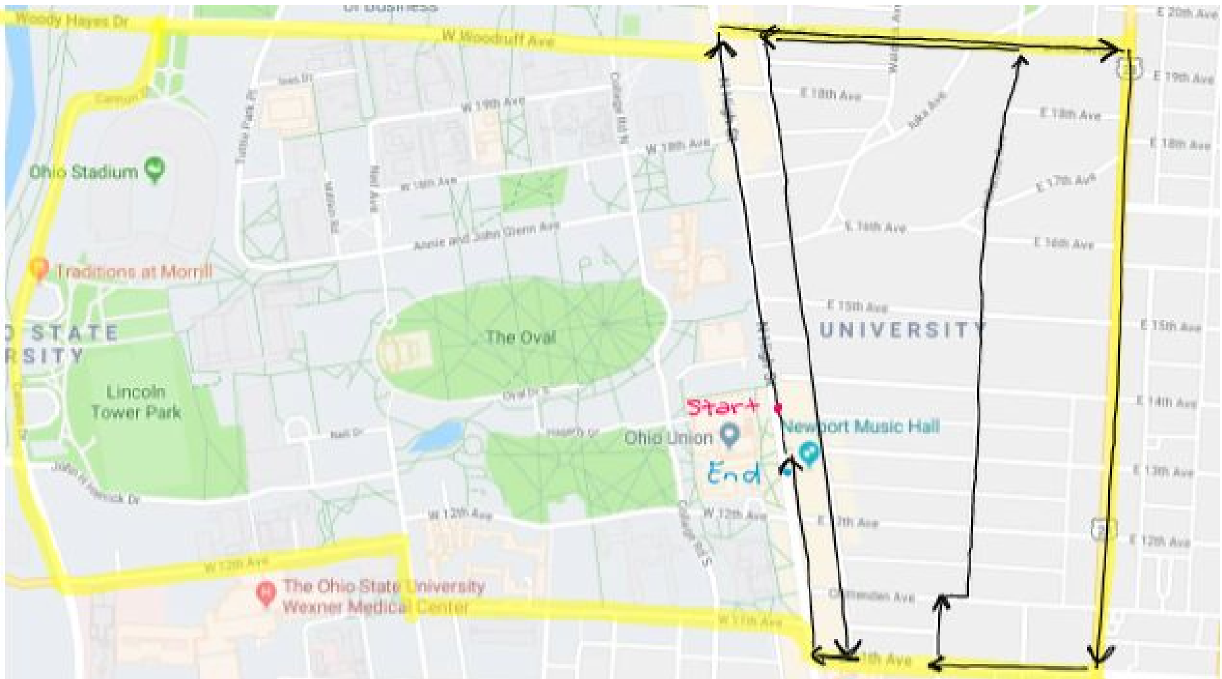
<u>GROUP R</u>

This team completed research regarding the percent of power required of the motors and propellers to move certain amounts of weight the same distance. The weight was increased by 100 gram increments to determine how much more power was required to move the vehicle and extra weight the same distance across the track. It was determined that 40% power with two propellers was required to move just the vehicle and 70% was required to move the vehicle and a caboose. With the addition of each 100 gram weight, the vehicle required about a 5% increase in power to travel the same distance.

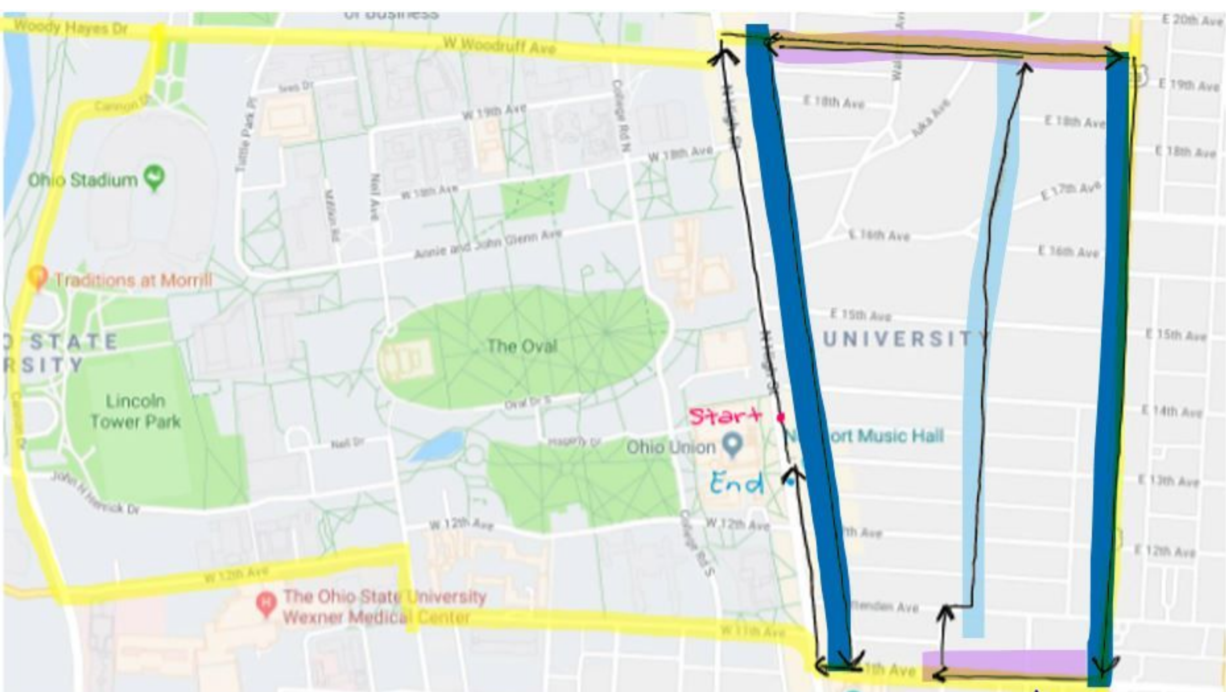
FINAL TEST PLAN

SIMULATED ENVIRONMENT

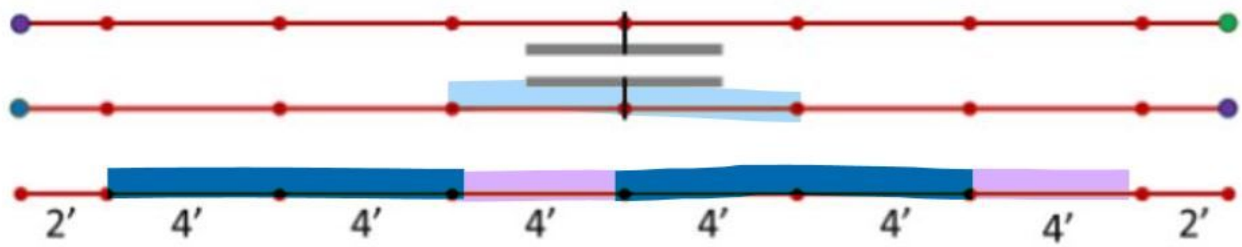
Actual Vehicle Route



Referenced Track Route



Scaled Route



Scale 1:
10 feet = 0.8 miles (Flat)
8 feet = 0.6 miles (Incline)

In order to simplify the simulation, the route was split into two model tracks including the straight track and the track with a slight incline. This was done to represent the varying types of routes the vehicle will take for the actual route. The planned actions are 5 short stops and an incline, the stops representing turns or stop signs and the incline representing the slight elevation on Indianola Avenue. From the route map, the dark blue routes are slightly larger than the purple segments, with the light blue representing the incline. The limitations to the simulation is straight tracks of length 28 feet and the size of the vehicle.

TESTING METHODS + MEASUREMENTS

Some of the requirements such as the mass and width were chosen based off what the average prototype looks like. Other requirements such as the battery life lasting more than 25 minutes was chosen based off of average battery life of small model vehicles. It was also decided that at least 4 seats (not including the driver) would be made available in the vehicle because this is the general assumption for most full-sized vehicles. For stopping precision and pause for gate requirements, it was assumed that these matters are more based on coding issues so, in order to have the code work the most efficiently, it was decided to have strict requirements. Finally, the time to dismantle the vehicle should take no longer than 3 minutes because the project is intended to encourage efficiency.

System Requirements	Test Runs	Testing Methods + <u>Measurements</u>
Mass	3	Measure the mass in grams of the vehicle as a whole (<u>use a scale to do so</u>). Ensure to measure all pieces of the vehicle.
Time to Dismantle	4	Each group member is required to dismantle the vehicle from fully assembled down to basic assembly parts within the time range required. <u>The time will be recorded with a stopwatch in seconds</u>.
Stopping Precision	5	Run the vehicle a distance of 50 inches and have it stop as close as possible to the 50 inch mark. <u>Measure with a ruler (in inches) the distance of the final resting point of the vehicle from the 50 inch mark</u>.
Pause for Gate	4	Run the vehicle for 10 seconds a constant speed. Bring the vehicle to a complete stop. After 5 seconds, have the vehicle return to original speed for 3 seconds. <u>Once vehicle has originally stopped, start recording on stopwatch (in seconds) record how long the vehicle is at a complete stop before beginning to move once again</u>.
Energy Efficiency	2	Run the vehicle the length of the track 5 times and <u>measure voltage left in the battery after each run (in volts)</u>.
Vehicle Width	1	<u>Use a ruler to measure the width of the vehicle in inches</u> (Vehicle front face). Measure from the furthest leftward point to the furthest rightward point.
Number of Seats	1	Screw in 90 degree angles brackets (represents seats) that came in the AEV box to the main board and <u>count how many screws fit</u>.
Stability (left/right)	3	Hang the vehicle from two spring scales with one on the left and one on the right and <u>measure the difference between the scale readings.</u>

SCORE CARD

The vehicle design will be complete a success if it scores an 8 or above on five of the requirements, and the other three requirements score a 6 or above. This means the vehicle's total score should be no lower than a 58 out of 80 to be measured as successful.

Requirement	Vehicle Requirement	Score Rubric	Score
Mass	≤ 125 grams	-1 for each 5 grams over	**10**
Time to Dismantle	≤ 180 sec.	-1 for each 10 sec over	**10**
Stopping Precision	≤ 6 inches	-0.5 for every 1 in over	**10**
Pause for Gate	≤ 5 sec	-0.5 for every sec over	**10**
Battery Life (Energy Efficiency)	≥ 25 minutes	-1 for every 5 min under	**10**
Vehicle Width	6 inches	-1 for every inch over	**10**
Number of Seats	6 seats	-1 for each seat under	**10**
Stability (left/right)	45/55 to 55/45	-1 for each 2 deg.	**10**
		TOTAL SCORE	**80**

FINAL DESIGN

The final design of the vehicle is that it have mass less than 265 grams, energy efficient, total width of just 6 inches, can fit 6 seats and very stable. All of these characteristics that the company has for the prototype vehicle matched with the research findings. The company want vehicles that consume less energy, can fit more passengers, can travel through small streets around neighborhoods and really stable which will ensure the passengers' safety. One standard part used in the final design is the servo arm. This servo arm was extended and top with rubber to increase the frictional force between the top of the servo and the track. It functioned as the brake for the vehicle and this will increase the accuracy of the stopping precision.

TEST RESULT

The final score for the vehicle was a 77 out of 80 which is 96.25% as a total score. From these results, it can be concluded that the final vehicle tests were s a success. The main weakness of the scaled model vehicle centered around its energy efficiency which may have also been potentially the cause of an unreliable power source.

Requirement	Vehicle Requirement	Score Rubric	Possible Score	Data Verified		Score
Mass	≤ 265 grams	-1 for each 5 grams over	**10**	**10**		**10**
Time to Dismantle	≤ 180 sec.	-1 for each 10 sec over	**10**	**10**		**10**
Stopping Precision	≤ 6 inches	-0.5 for every 1 inch over	**10**	**10**		**10**
Pause for Gate	≤ 7.5 sec.	-0.5 for every 1 sec over	**10**	**10**		**10**
Energy Efficiency (Total Joules)	≥ 130 Joules (incline) ≥ 195 Joules (flat)	-1 for every 15 joules difference	**10**	**4**	**3**	**7**
Vehicle Width	6 inches	-1 for every inch over	**10**	**10**		**10**
Number of Seats	6 seats	-1 for each seat under	**10**	**10**		**10**
Stability (front/back)	50/50	-1 for each 2 deg.	**10**	**10**		**10**
				TOTAL SCORE	**77**	**80**

VALIDATION PLAN

TOP THREE USER NEEDS

1. **Student Safety:** This is the most important user need, as students want to have an ease of mind while using this service.
2. **Always Available:** Students want to be able to use this service when they are running late to classes during the day and when they are traveling at night so it is necessary that the service is provided at all hours of the day.
3. **Inexpensive:** Students generally do not have a large disposable income, so making this system inexpensive will encourage students to make smart choices without breaking the bank.

VALIDATION METHOD

To test that user needs are being met, potential users will be asked questions about the project's focus areas regarding whether they are relevant and whether the current plans would be attractive to users. An interviewing process will be used on people that live primarily off campus and East of High Street, and their answers will help guide in determining if the system is valid in its current state. Once the interviews are complete, the results will be collected and summarized to evaluate the validity of the system and to highlight the necessary problem areas. This will aid in identifying necessary adaptations to improve the system.

Interview Questions:

1. Would you use a ride requesting service that was strictly for OSU students?
2. Do you or anyone you know living on/around campus rely heavily on walking or buses for transportation?
    - If you had the opportunity to instead use this proposed system would you?
    - How often?
    - Do you think a car is the most efficient way of traveling around off campus?
3. How many people do you generally travel with?
4. Would you prefer that the vehicles were marked with OSU branding?
5. Would you feel more confident using the service if the driver was older or if they were
6. closer to common college age?
7. Are you concerned that the system does not focus on being environmentally friendly?
8. Would you be comfortable using this sort of system? Why or why not?

VALIDATION RESULTS

After meeting with 3-4 potential end users and interviewing each of them with the questions outlined in the validation method, it was evident that student safety was less of a focus than student convenience. This result was unexpected but did not disagree with the overall system design. While the system is intended to keep students safe, it is also formatted for student transportation convenience which seemed to be a more essential user need. While this was an unexpected result, it does not seem that there needs to be a change to the system design in regards to student safety this aspect.

Other than this, the results were rather positive. The users agreed that the system would be beneficial and that it met the defined needs adequately. For safety, the users appreciated that the system had specific routes during prime times to decrease wait time. It was also recommended that the OSU branding should be placed prominently on the vehicle because it would make it more difficult for the driver to leave campus grounds unwarranted. For reliability, the interview results suggested that users value a reliable system for scheduling a ride over a strong focus on the reliability of the vehicle itself. This is in line with the goals of the overall project. In regards to expenses, the users entirely agreed that a main focus of the project should be keeping costs low. While students may be interested in using a system such as the one presented, it will not be nearly as successful if it is not rather inexpensive to cater to student budgets.

The user interviews made it clear that the system would be most beneficial for upperclassmen students living off campus who are constantly traveling to and from classes or other campus buildings. The system is highly targeted towards this group and is not formatted for those living on campus or looking to travel long distances which may be a negative aspect of the system.

SOCIAL + ECONOMIC IMPACT

SOCIAL BENEFITS

The presented system will allow people to travel through and around campus in a more efficient way than taking the bus. The system will also reach a diverse population of the student body because it is open to anyone who is paying tuition at OSU. During the day, people that live far from campus and need to get to classes can use the system if there are no buses nearby or they are running late and need a more direct route to their academic hall. Some people that live far from campus or nearby events may feel unsafe walking back home, in this situation, requesting a vehicle would allow them and their friends to reach their destination, free of instant charge.

For a diverse set of users such as including professors, technicians, and general workers, this system also will be beneficial for them to travel around the campus in short of time. Thus, in general this will increase the efficiency of the works in OSU. Other than that, this system can help to ensure the safety of staff who want to return home late at night when bus is hard to get.

ECONOMIC ASPECTS

Cost & Revenue Analysis Table

Costs	Costs	Values
Research & Development	**$$**	
Design Research	$	
Prototype Modeling	$$	
Start-up, Operational and On-Going	**$$$**	
Cars	$$$	
Location (garage)	$$$	
Electricity	$	
Vehicle Maintenances	$$	
Drivers	$	
Quality Assurance	**$$**	
Model Upgrades	$$	
Values	**Costs**	**Values**
Income		**$$**
Users		$
Advertising		$$
Social Value		✓✓
Saved Time (increased efficiency)		✓✓
More Students in Class		✓
General/Student Safety		✓✓
Improved Mental Health		✓✓✓

Start-up, Operational and On-Going Costs

To begin the project, it is necessary to purchase several vehicles in order to operate at a sufficient level. A main location such as a garage is needed to store the cars to help keep them in good condition and cut down on required maintenance work. Maintenance costs of the vehicles could entail regular oil changes and part changes when needed. Because the cars are using electricity instead of fuel, the company would need to pay for electricity every month. The operating costs consist mainly of paying the driver their hourly wage, considering that they are the front runners of the system.

Sustainability

In terms of revenue, the general consensus is that this system could not be self sustaining, mainly because it is designed to give students peace of mind while traveling throughout campus at low cost to themselves. By making the system a small portion of tuition OSU students are required to pay (similar to the COTA fee included in student tuition), students will not need to directly pay their driver when they call for the service. This is intended to encourage people to use the system, especially when they feel unsafe. Students will have the option to tip their driver though as a way of helping subsidize the overall operations of the system. It is also possible for the university to find some of the project as it will benefit its population.

Possible Expansions

While the current system is only intended for use by OSU students, if the project were to be successful it could very easily be applied on other college campuses across Ohio and even potentially across the Midwest. This system could (ideally) improve student safety for other campuses if implemented. There would only need to be rerouting for different areas. It might also be beneficial to consider which vehicles are better for which campus types (rural, city, etc).

CONCLUSION

The current safe transportation systems provided for OSU students are limited to certain hours only and the waiting time for the buses is too long. The bus stops are also not safe waiting environments which can lead to potentially dangerous situations. The company designed a system that will always provide a direct route between places with shorter waiting times, this is done to ensure students' safety. This system is similar to Uber and Lyft but it is for students only. A specific boundary for the system has been identified which is the outermost northern and southern of the campus. However, this system will be more focused on the neighborhoods east of High Street up to Summit St. After development of a scale model, the final prototype vehicle was tested and compared against developed vehicle requirements. These tests proved the prototype was a complete success by company standards.

RECOMMENDATION FOR FUTURE DESIGN

VEHICLE DESIGN IMPROVEMENTS

In order to make the vehicle meet all of the requirements, the company should focus on being more accurate towards the amount of energy that the prototype vehicle outputted, as that was the only requirement not hit completely. To fix this problem, the company could have set the motor speed at a lower percent so that it would not use more energy than necessary. During some of incline runs, the vehicle would go up the incline fine, but once it hit the flat part of the track, it was traveling at a unnecessary fast speed. If the code was changed so that the propellers would spin at a slower percent once the track was flat, then the total energy output would be less than original, and potentially allow the vehicle to output an appropriate amount of energy.

CONCEPT SYSTEM DESIGN IMPROVEMENTS

In the future, the company would recommend to add more vehicles in the transportation system so that this system can help to carry more students to their destination. Other than that, by having more vehicles, the company can increase the number of advertisement put to the vehicle. Next, the company would increase the coverage area of the system so that students can reach further places than what provided by current system.

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[1] College Factual. (2018, September 27). “Ohio State University - Main Campus Crime”. Retrieved October 1, 2018. [Online]. Available: https://www.collegefactual.com/colleges/ohio-state-university-main-campus/student-life/crime/.

[2] Levinson, S. (2018, June 20). “College Campuses Have Become The Most Dangerous Places In America”. Retrieved October 1, 2018. [Online]. Available: https://www.elitedaily.com/news/world/college-campuses-dangerous-places-america.

[3] Samsel, H. (2017, August 10). “Report: Where students feel most — and least — safe on campus”. Retrieved October 1, 2018. [Online]. Available: https://www.usatoday.com/story/college/2017/08/10/report-where-students-feel-most-and-least-safe-on-campus/37434691/

[4] The Ohio State University. (2017, September 28). “The Ohio State University publishes annual crime report”. Retrieved October 1, 2018. [Online]. Available: https://news.osu.edu/the-ohio-state-university-publishes-annual-crime-report/

Appendix

TEAM WORKING AGREEMENT

1. **Group Information**

Lab Section #- 26221
Table Letter- M
Company- P & C Scott Worldwide
Instructor- Dr. Patrick Herak (herak.1@osu.edu)
GTA- Miranda McGrothers (mcgrothers.3@osu.edu)

2. **Contact Information**

Preferred Method(s) of Contact

- Group Me
- email

Expected Response time(s)

- Team members will respond to Group Me as soon as possible
- Team members will respond to Emails within 48 hours

Names	Email	Phone #
Amanda Becker	becker.623@osu.edu	419-989-9302
Zoë Karabinus	karabinus.4@osu.edu	216-904-3706
Logan Wiest	wiest.24@osu.edu	614-359-0735
Muhammad Aidil Bin Zolkable	zolkable.1@osu.edu	614-313-3631

3. **Team Goal**

This team expects high quality final projects with assignments getting composite scores of greater than or equal to 90%. Projects must be turned in on time, complete and neat. The minimum acceptable goals are 85%.

4. **Meetings**

- This team will meet once a week unless more meetings are decided on to complete a project.
- Primary Meeting Day/Time/Location the primary meeting day will be Thursdays at 5:15 pm primarily in Nosker lobby and secondarily in the 18th Avenue Library.

- Our secondary meeting day is Sundays afternoons.
- Zoë is in charge of agendas and reminders.
- Amanda, Logan, and Aidil in charge of minutes, in an alternating pattern.

5. General Team Member expectations

- Team members are expected to attend all lectures/labs and if unable to attend they are to get their project contributions to a team member as soon as possible.
- Members of Team M are expected to pay attention and stay on task in lab/class.
- During team meetings members will stay on task and complete scheduled tasks during meeting and socialize once meeting is over.
- Interactions between teammates will be respectful if not friendly. Members will not take outside frustration out on team members. If a reminder is necessary, it will be polite.
- Between classes, members of Team M will complete their assigned tasks, getting help if necessary, and come to lab/class with pre-class work completed and prepared for the class.
- To ensure the team stays on track, members will remind each other when they are getting off track and will attempt to concentrate on the assigned task.
- Documents will be shared over email.
- Team members will have their portions of the assignments completed at least two days before the assignment is due so that they can all be reviewed, and adjustments made if necessary.
- If a team member finds themselves struggling they will notify the group as soon as possible in order to get help from a teammate or referred elsewhere.

6. Individual Team Member Responsibilities/Deadlines?

- Roles and tasks will rotate each project.

7. Conflict Resolution

- Once the team goals, general member expectations, and individual team member responsibilities have been established, candid, non-threatening discussion must be held when the group or individuals are not meeting the agreed upon terms.
- Team members will be held accountable for their quality of work by both themselves and their teammates. If a team member is not meeting expectations, not contributing to the team effectively, the team will take time during a meeting to talk to them and attempt to solve whatever problem is occurring.
- Those team members interacting inappropriately with their teammates will initially be reprimanded during a team meeting once problem is reported. If repeated (whether or not

with the same team mate) the matter will be brought up before the UTA, GTAs or instructor as needed.
- Goals, expectations, and responsibilities can be redefined when deemed necessary by the team, while insuring that the workload is still as equivalent between team members as possible.
- The UTAs, GTAs, or the instructor will become involved in inner-team disputes if internal attempts at correction fail.

8. Expectations of Faculty and GTAs

- Suggested Statement: If the team notices that a team member is failing to live up to this agreement, the situation will be reported to the staff, but the team will still submit a completed assignment. Staff members will make time to meet with the individual alone and the entire team to resolve issues.

9. Team Signatures

Amanda Becker

Zoe Karabinus

Logan Wiest

Muhammad Aidil Bin Zolkable

INTERVIEW QUESTIONS & GUIDE

Introduction to the task

1. Do you live on or off campus?

2. Do you use public transportation?

Current experience performing the proposed task

1. What transportation methods do you currently use to travel on and around campus?

   a) What about these methods do you like?
   b) Why do you use these specific transportation options?

2. What about other modes of transportation do you dislike? Why do you not use other modes of transportation?

   a) What about these specific types of transportation is frustrating/not user friendly?

3. If you did not have access to a car on campus and you lived off campus in the surrounding neighborhoods what modes of transportation would you mainly use? Why?

4. Do you spend any time off campus in the surrounding neighborhoods or shopping areas?

   a) Do you generally feel safe when traveling through these areas? Why or why not?
   b) What time of day/week do you generally travel through these areas?
   c) Would you utilize a safer student-specific transportation system provided by the university? Why or why not?
   d) How do you determine whether transportation is safe or not? Or whether you need specific transportation to feel safe?

New ideas to discuss with users

1. Do you think this sort of solution (Uber like system) is practical? Do you think it is something you would utilize? Why or why not?

   a) Would a membership payment plan be preferable? How would you prefer to pay?
   b) Should the cost be included in fees for when paying tuition, should it be optional?

2. As a current user of transportation methods accessible on and around campus currently, do you have any ideas on how to improve these systems?

3. Do you have any suggestions for a new system?

a) What about this new system makes it preferable for students in similar situations such as yourself?

Closing, and future connections

1. Do you have any feedback about how the interview was conducted?

2. Can I have your email for any follow-up questions?

PRIMARY RESEARCH - DETAILED INTERVIEW RESULTS

Jesse - Senior

Jesse is a Senior at OSU, and last year he started a service called “U Cruz” that focused on transporting students to their dorms / houses late at night, or getting students to class on the other side of campus.

Jesse started a service last year where people were transported by an employee riding a bike and a few people would sit in a carriage in the back. He only operated during weekends late at night and mornings when early classes were in session. He thinks that if he lived off campus East of High Street, then he would expand his business to where a lot of the fraternities are located since there is a large crowd of people there late at night.

Emily - Sophomore

Emily is a Sophomore at OSU, she currently lives off campus in her sorority house. She is often traveling through the neighborhoods that the project is focusing on.

Emily would benefit from having a second type of transportation available to only students off campus in the suggested neighborhood. This opportunity would make her commute time to campus shorter each day and she would feel better about traveling at night if this sort of system were to be available.

Jack - Sophomore

Jack is a Sophomore at OSU, he currently lives on campus in the dorms but visits his friends who live off campus frequently. Many of his friends live in this neighborhood and he has become very familiar with it over the course of his second year at Ohio State.

Jack generally uses his bike when traveling off campus if it is not an area which he can take a COTA or campus bus. He expressed interest in the idea we suggested, and mentioned that the neighborhoods we are targeting do not have enough street room for a bus route because the streets are so narrow.

Natalie - Junior

Natalie is a Junior who currently lives and works on campus in one of the dorms as an RA. She enjoys eating off campus and exploring small shops in the nearby Columbus neighborhoods.

Since she lives on campus for her employment she enjoys eating out at different restaurants when she can and exploring the wider area around campus during the weekends. She is very cautious when traveling in the nearby areas alone which can sometimes ruin the experience because she is always making sure that someone knows where she is and that she isn't out too late. She likes the idea of a student-only orderable transportation system so she knows that she has a safe way to get home from any of the nearby neighborhoods. She also likes the flexibility of the suggested routes because this allows her to avoid waiting at bus stops alone where she often feels uncomfortable and unsafe.

Zach - Sophomore

Zach is a Sophomore at OSU, and currently lives in a South campus dorm. He uses the bus almost daily to get from his dorm to Fisher School of Business, and enjoys the convenience of knowing the location of OSU buses and how long he will have to wait at a stop until the next bus arrives at his stop.

Zach mentioned that it may be beneficial to use the bus past school limits to see different parts of downtown Columbus, but since he does not have a lot of freetime, he cannot just go and explore the city. He recently leased a house on 13th and would like a quicker way to get to campus, but thinks a bussing system would take too long and be inconvenient unless a stop is right next to his house.

Sabian - Freshman

Sabian is a Freshman at OSU who lives on North campus and enjoys traveling throughout Columbus and the nearby areas whenever he gets a chance.

Sabian gets to class almost everyday skateboarding and likes to ride the scooter to further parts of campus or to areas past North campus. He has never used the bussing system here at OSU, but plans on using it once it gets cold so he doesn't risk an injury on his skateboard once it gets icy out.

Luqman - Freshman

Luqman is a Freshman international student currently enrolled at OSU. He lives off campus further east than Summit St. He frequently uses the buses to get to campus and travel around Columbus.

He loves to use the COTA bus system to get to campus and he also uses it to to travel around Columbus. Sometimes he thinks that the buses can be uncomfortable when they become overcrowded with people, it is sometimes hard to find a seat and this is not ideal for long trips. He suggested that there should be more buses traveling along their routes to avoid this overcrowding and also suggested that there should be more space provided on each bus.

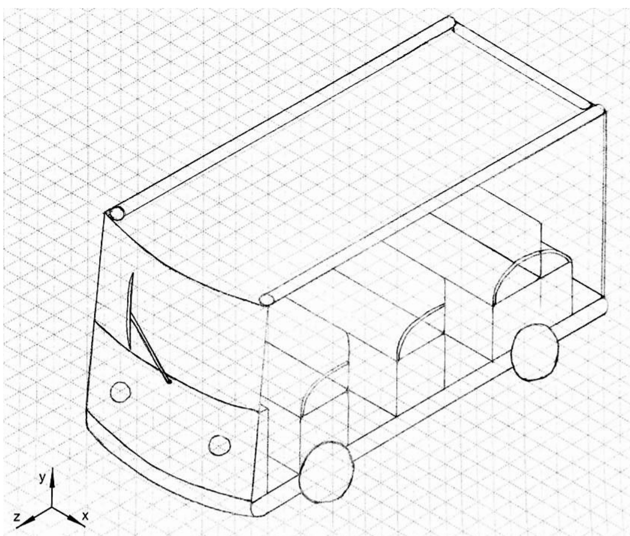
Bao - Freshman

Bao is a Freshman international student who lives on campus and loves traveling around Columbus to familiarize himself with the city and all its opportunities.

He uses the COTA buses frequently to aid in exploring off campus, however, he doesn't travel around the project's target neighborhoods very often. He mentioned how improving the already existing COTA buses may be a more likely solution to the problems being addressed.

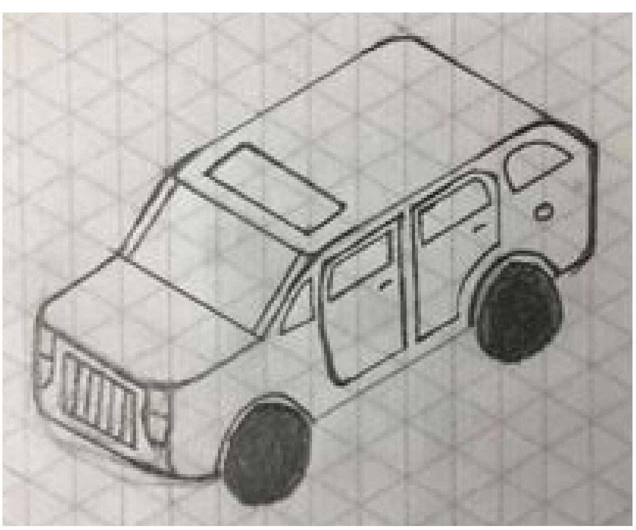
DETAILED BRAINSTORMING RESULTS

Solution #1



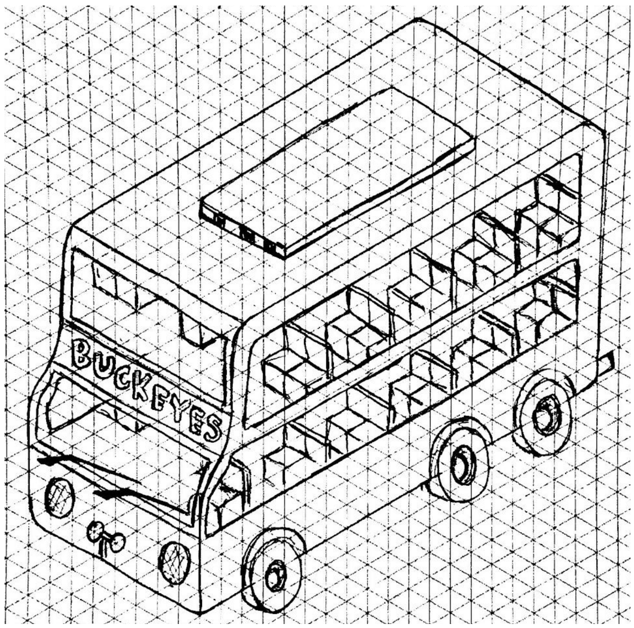
The solution is a large, modified golf cart which can hold up to 8 people comfortably including the driver. There is one extra seat in the back which is wheelchair accessible (this seat faces out the back of the vehicle). The vehicle has three rolls of thick, waterproof plastic that act as makeshift doors (with clear sections near the top which can act as windows). These rolls can be unrolled to protect passengers from any nonoptimal weather, they can also strap onto the support poles in the rear corners of the vehicle to minimize the wind's effect on their motion.

Solution #2



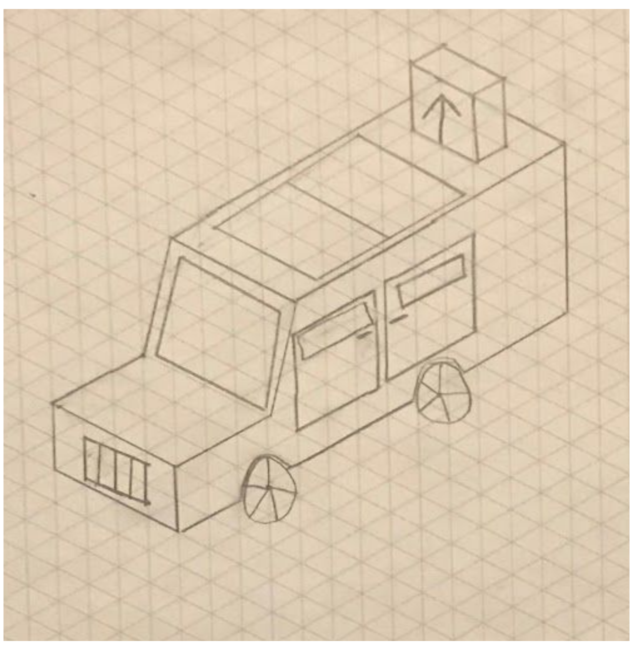
The solution suggested is to provide a student-run service similar to Uber exclusively for students. Drivers will be required to provide their own car that has at least 4 seats besides the driver. Cars will be kept clean and clear so that any large items (bags, wheelchairs, etc.) can be stored in trunk for trip. Cars and drivers will also have to pass a maneuverability test to ensure safety and ability to traverse the streets.

Solution #3



The idea for the concept sketch is to replace the current buses with a double-decker bus. This bus can load more passenger per route so this will reduce the number of passenger who need to stand while waiting especially during peak hours. This idea can help a large group of people ride together. Similar to a normal bus, it will also provide spaces for people in wheelchairs. Lastly, this bus can also be eco-friendly if is run on electric power.

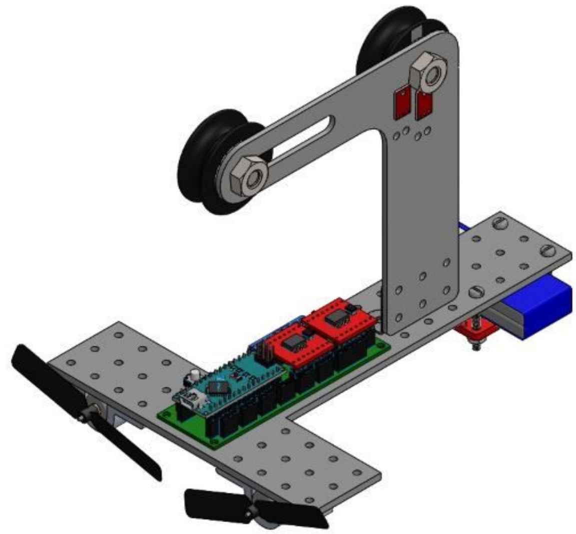
Solution #4



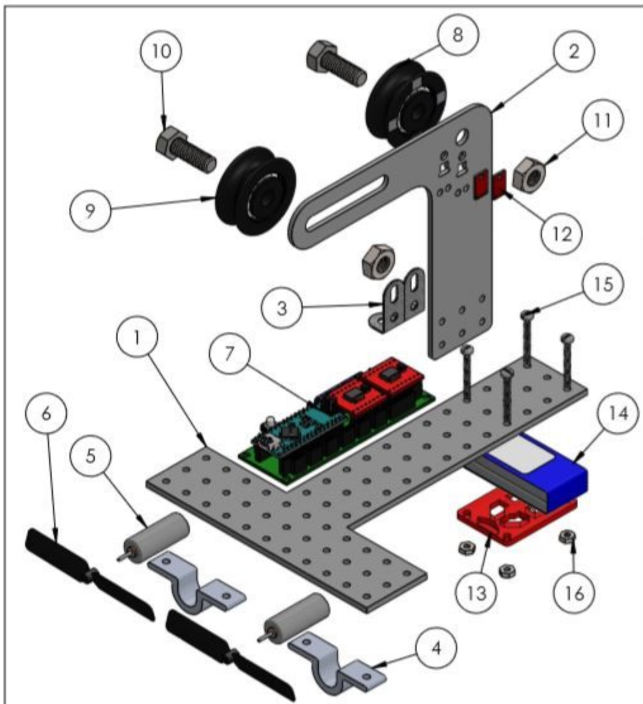
This solution is a compact car that travels through the streets east of High Street. It doesn't carry more than 4 people, but it is environmentally efficient. This car has enough trunk space so it can carry luggage or large items if required. There is also a sign on the car that illuminates at night so people know that it is a vehicle under the company business. The up arrow symbolizes that the car is vacant and can be used, and a down arrow symbolizes that the car is in use. There are also lots of windows to ensure the passengers feel safe.

DETAILED DESIGN DRAWINGS

Assembly Drawing



Exploded Assembly Drawing + Bill of Materials

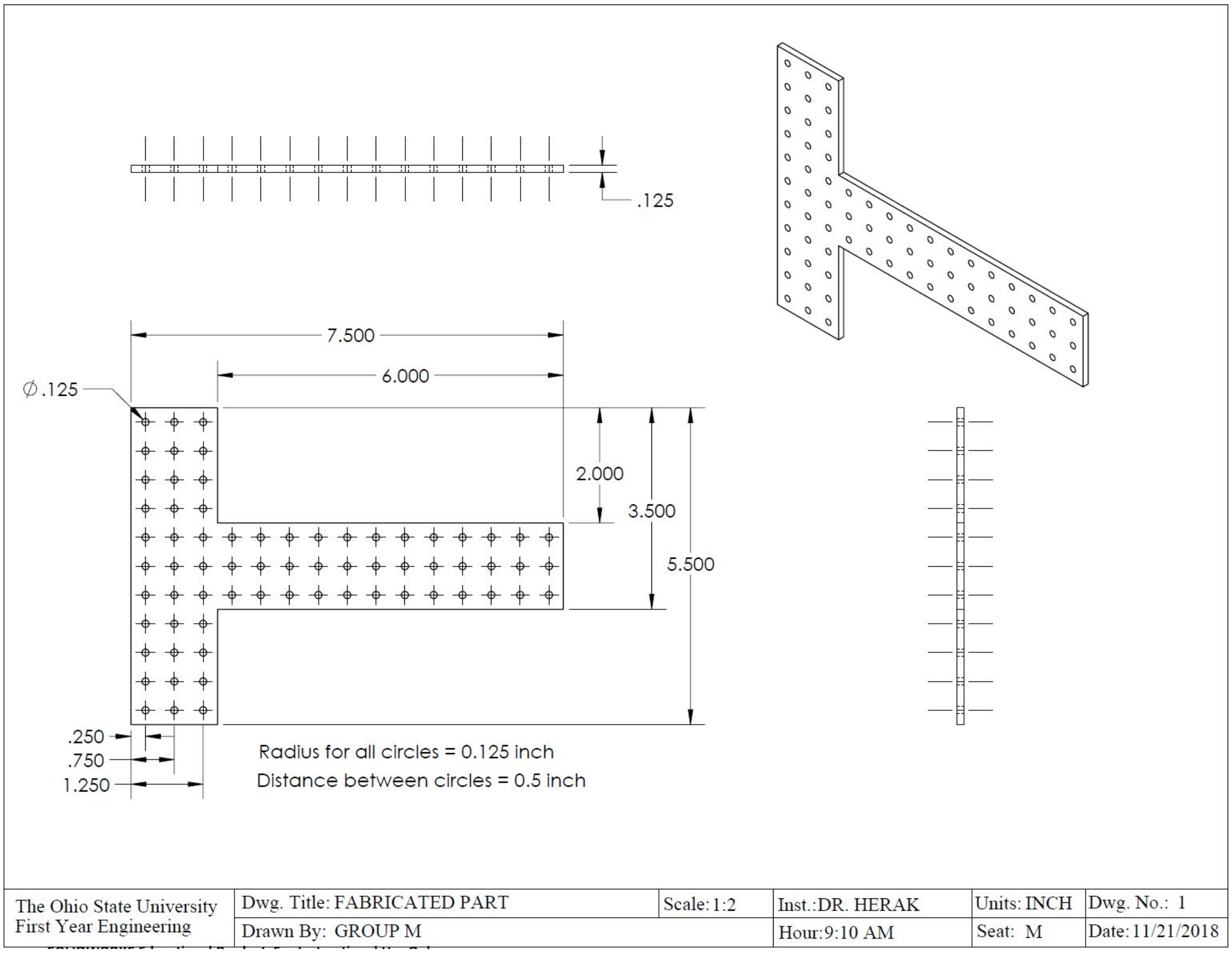


ITEM NO.	PART	MATERIAL	QTY.
1	T-Shape Base	Plastic	1
2	Support Arm	Plastic	1
3	90-deg Bracket	Metal	2
4	Motor Mount Clip	Plastic	2
5	Motor	Metal	2
6	3 inch Propellor	Plastic	2
7	Arduino	Mixed	1
8	Wheel w/ reflective tape	Plastic	1
9	Wheel	Plastic	1
10	Wheel Bolt	Plastic	2
11	Wheel Nut	Plastic	2
12	Rotation Sensor	Mixed	2
13	Battery Clamp Plate	Plastic	1
14	Battery	Mixed	1
15	Screw	Plastic	4
16	Nut	Plastic	4

The Ohio State University First Year Engineering	Dwg. Title: VEHICLE EXPLODED ASSEMBLY	Scale: 1:2	Inst.:DR. HERAK	Units: INCH	Dwg. No.: 1
	Drawn By: GROUP M		Hour:9:10	Seat: M	Date: 11/21/18

SOLIDWORKS Educational Product. For Instructional Use Only.

Detail Drawing for T-Shaped Base



SOFTWARE CODES

<u>STOPPING PRECISION ACCURACY</u>

Used for final code testing, this determines if the vehicle stops within 6 inches of the target distance of 8 feet.

```
motorSpeed(4,35);
goToRelativePosition(196);
brake(4);
rotateServo(170);
gorFor(2);
rotateServo(0);
```

PAUSE FOR GATE

Used for final code testing, this will make the vehicle stop and wait for the stop sign for at least 8 seconds, then proceed forward once the stop sign is no longer blocking the track.

```
motorSpeed(4,35);
goToRelativePosition(98);
brake(4);
rotateServo(170);
goFor(3);
rotateServo(0);
goFor(6);
motorSpeed(4,35);
goToRelativePosition(98);
brake(4);
rotateServo(170);
goFor(2);
rotateServo(0);
```

FINAL CODE

The final code for the flat track. The vehicle runs for 8 feet, pauses for 5 seconds, runs for 4 feet, pauses for 5 seconds. This is repeated once more for a total distance of 24 feet.

```
//travel 8 feet and pause for 5 seconds
motorSpeed(4,35);
goToRelativePosition(190);
brake(4);
rotateServo(170);
goFor(2);
rotateServo(0);
goFor(5);
//travel 4 feet and pause for 5 seconds
motorSpeed(4,35);
goToRelativePosition(92);
brake(4);
rotateServo(170);
goFor(2);
rotateServo(0);
goFor(5);
//repeat process to complete travel distance of 24 feet
```

```
//travel 8 feet and pause for 5 seconds
motorSpeed(4,35);
goToRelativePosition(190);
brake(4);
rotateServo(170);
goFor(2);
rotateServo(0);
goFor(5);
//travel 4 feet and stop
motorSpeed(4,35);
goToRelativePosition(92);
brake(4);
rotateServo(170);
goFor(2);
rotateServo(0);
```