DESIGN PROJECT REPORT

ENGR 131- Transforming Ideas to Innovation I

Section 211

Improving Campus Safety in the Purdue Bike Lanes

Team 19

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I. EXECUTIVE SUMMARY

The main goal of this project is to design and create a solution that effectively improves transportation safety across our client, Purdue University's campus. To attain this goal, we identified our users and their needs through the following design requirements: effective at improving safety, inexpensive, Purdue supported, microcontroller functionality, and longevity. Among the three solutions we considered (Pedestrian Alert System, Wearable Alert System, and Veo Sensor), we selected the Pedestrian Alert System as it was the solution that best fit our consumer's needs and our criteria and constraints. The Pedestrian Alert system costs approximately $363, and it will be implemented next to the bike lanes as a way to alert pedestrians when a biker is passing. With built-in ultrasonic sensors on either side of the sign, the system will detect when a biker is nearing. When the biker is within a certain distance, the buzzer also in the sign will beep and the red LED will light up to alert pedestrians to not cross the bike lane. When there is no bike, the green LED will be activated, and the beeping will stop. Our testing and experimentation showed that our Pedestrian Alert System would be widely approved by users and proficient on the college campus as there is currently no safety system in place for the bike lanes to prevent any sort of collisions. Some limitations of our solution include that the system might be difficult to implement in multiple locations on a campus with high pedestrian and bicyclist volumes throughout the day and that this design only addresses collisions within the bike lanes.

CONTENTS

II. TEAM MEMBER ROLES

Our project team included 4 members (See Figure 1). We allocated roles and responsibilities to each team member based on an estimation of how long each task would take. This was to ensure a relatively balanced contribution from every member. Certain tasks were assigned to members with prior experience in that relevant field.

Table 1. Team roles

Project milestones	Name	Specific responsibilities related to each milestone
Problem scoping	Ashton Merriam Nathan Laury Remley Hooker Avery Capps	▪ Problem Statement & Criteria/Constraints ▪ Section III C and D. ▪ Section III E ▪ Trade-off considerations & Assumptions about the Problem .
Idea generation	Remley Hooker Avery Capps Ashton Merriam Nathan Laury	▪ Section IV part E ▪ Exploring Prior Art ▪ Low Fidelity Prototyping/AI ▪ III part A
Prototyping	Remley Hooker Avery Capps Nathan Laury	▪ Veo Sensor w/ TI Kit Prototype ▪ Pedestrian Alert System Sketch ▪ Wearable Alert System Sketch
Testing	Remley Hooker	▪ Survey Creation
WDM	Ashton Merriam	▪ Prepare WDM for group analysis
Preliminary presentation	Avery Capps Ashton Merriam Nathan Laury Remley Hooker	▪ Criteria & Constraints, Limitations ▪ Team Intro, Problem Statement, Solutions Considered ▪ Design Overview, How it Helps ▪ How it Works, How prototypes were tested
Iteration	Avery Capps	▪ Iteration #2
Final report	Ashton Merriam Remley Hooker Nathan Laury Avery Capps	▪ CAD Prototype ▪ Physical Prototype ▪ Pseudocode and Data on Final Solution ▪ Design Optimization
Final presentation	Ashton Merriam Remley Hooker Avery Capps Natan Laury	▪ Intro and Problem Statement ▪ Cost and Design Lifecycle ▪ Criteria/Constraints and Limitations ▪ Data and Trade-Offs

Figure 1. Project team

III. PROBLEM SCOPING

a. Problem Statement

Purdue University is a large public school located in West Lafayette, Indiana that has roughly Fifty-thousand enrolled students that must traverse across campus daily. Purdue has contracted us to provide innovations that could improve transportation safety across campus. The school has not given us much direction on what specifically to improve on, so we aim to help as many people as possible as efficiently as possible.

As mentioned, our client is Purdue University, however, many other people have some kind of stake in transportation safety in West Lafayette. These would include any taxpayers (as Purdue is a public university), the government of Lafayette, the school itself, students at Purdue, residents of West Lafayette, and the families of anybody who works/ studies at Purdue.

The main problem stems from the diversity in transportation methods present at Purdue. Most commonly this includes bikes, cars, buses, skateboards/longboards, and electric scooters. Given that nearly 70% of people in the survey we conducted have witnessed some form of bike/pedestrian accident it becomes clear that this needs to be addressed to reduce that number to zero. Students need to be focused on their classes, not their ability to walk from one side of campus to the other without getting hit by a bike. That is where we come into play...

We seek to mitigate this problem by creating something that can improve safety to the greatest degree possible. While given a great deal of creative freedom to determine what this solution is, ultimately our solution needs to affect a great deal of people while also being cheap enough and practical enough for the university to implement.

b. Design Criteria and Constraints

Table 2. Design requirements

Criteria and Constraints	Metrics (ways to quantify and measure the performance of your solutions and measure success)	Metric units
The design must be relatively inexpensive.	Take a ratio of cost/estimate of number people affected.	Dollars/Person
It must be effective at improving transportation.	Take a survey of the number of people that find the solution helpful.	Percent

It should be environmentally friendly.	Keep the electricity consumption as low as possible.	kWh
Needs to match the “feel” of Purdue.	Take a survey of people to see if it “fits” with the aesthetic of Purdue	Percent
Needs to incorporate the TI kit in some part of the process.	Yes or no question on whether some functionality of the TI Kit lines up with the solution?	NA
Simplicity	Is the project simple enough that we could actually complete the project in the required time?	NA
Durability	Will the innovation be able to withstand the climate of Indiana?	NA
Longevity	Is the innovation able to scale with the growing population of Purdue, or will it temporarily fix an issue that will need to be re addressed in a few years?	Years
User-friendliness	Will the innovation be usable by Purdue students regardless of circumstances? This can be collected by a survey, or watching people interact with a prototype.	Percent
Compliance	Will the innovation be legal with both the government and okay with the school?	NA
Scalability	Could we use the innovation throughout campus, and will it be practical to do so?	NA

Trade-off Considerations

There are several important trade-offs to consider throughout our design process, which include the following. If we assess our problem quickly with more time efficiency, it may lead to a greater number of mistakes in our solution. If our solution is of higher quality, that may lead to an increase in cost. Making our solution with multiple functions can help solve a greater variety of problems, but it may lead to confusion with the users. Also, implementing any new solution to increase transportation safety may in time be effective, but it could cause confusion or opposition among traffic as users adapt to a new system that they have not seen before. In addition, making the new system safe could lead to more delays in traffic. Lastly, a new system could be extremely effective, but the more it is used and seen the less aesthetically pleasing for Purdue’s campus it may become.

c. **Direct Users and Stakeholders**

Since our problem revolves around campus transportation for students, the primary users would be students. Specifically, we want to focus on the issue of near misses and collisions between students using bikes and pedestrians. Our solutions would benefit riders as well as all students walking across the State Street and Grant Street intersection. It would also benefit the public walking around campus, as we are a publicly funded institution that needs to be safe for the public. This would also indirectly benefit families of students, who have a stake in their children’s safety and ability to make it to class.

Table 3. Empathizing with users

User segment (include an image and a label)	Methods used to empathize with the user (interview user, survey user, observe user, read about user, simulate user behavior, put yourself in his/her shoes)	Lessons learned from this interaction
Students  https://www.jconline.com/story/news/2020/05/20/coronavirus-indiana-second-student-sues-purdue-says-remote-classes-getting-booted-campus-wasnt-worth/5233879002/	To empathize with the user and gain a better understanding of the problem, we plan on surveying students walking through the intersection.	This interaction will allow us to get a temperature check of the problem as these students likely cross the intersection many times a week to get to class.
Non-student pedestrians  https://www.purdueexponent.org/campus/city-to-consider-naming-state-street-after-mitch-daniels/article_4cfa8d5a-71b6-11ed-8f3a-eba9aa079c90.html	To learn more about the general public opinion of the intersection, we can also conduct an on-the-spot survey of non-students walking through the intersection.	This interaction will allow us to know how the problem affects the general public.
Families  https://raisingchildren.net.au/grown-ups/family-diversity/blended-families-stepfamilies/blended-families	We can empathize with student families by putting ourselves in their shoes and analyzing the repercussions of student injuries at this intersection.	This interaction will give us more insight on the importance of the problem and how it indirectly affects families.

d. Problem Finding

In order to properly assess our problem, we will have to conduct on-site research to get a better understanding of the conditions in the State and Grant intersection. We will begin by observing the problem site for a set amount of time to determine how prevalent bike-pedestrian collisions are. We will also survey bikers and pedestrians in the area to see if this is a problem that needs to be addressed. Using the data we collect, we will be able to find the specific circumstances in which the problem occurs and then use that information to develop an effective solution.

e. Background Information

On college campuses across the United States, alternative modes of transportation such as bicycles, skateboards, and electric scooters have gained popularity due to their affordability, convenience, and eco-friendly nature. However, as the use of these modes of transport has increased, so have concerns about safety, particularly when it comes to interactions between non-motorized and motorized traffic.

A study by Loukaitou-Sideris et al. (2014) analyzed pedestrian and bicyclist safety on and near three U.S. campuses, revealing several critical insights into the causes and locations of accidents. The study identified three main types of crash-prone areas or "danger zones": campus activity hubs, campus access hubs, and through traffic hubs. Activity hubs are typically areas within the campus that experience high pedestrian and bicycle traffic, such as near dining facilities, libraries, and residence halls. Access hubs, which are often located at campus entry points, see a mix of vehicular, pedestrian, and bike traffic, increasing the risk of collisions. Though traffic hubs, such as main roads passing through or adjacent to campus, pose additional risks as they mix high-speed vehicle traffic with bicycles and pedestrians (Loukaitou-Sideris et al., 2014). The research also highlighted the issue of underreporting, suggesting that actual incident rates could be higher than available data indicates. Many minor accidents go unreported, which can lead to an underestimation of the risks present on college campuses. Addressing these safety concerns requires an integrated approach, including better infrastructure design (e.g., dedicated bike lanes, improved crosswalks), more comprehensive safety audits, and the promotion of safety awareness campaigns. Planners and campus authorities are encouraged to implement specific design improvements to address each type of danger zone, ultimately aiming to reduce modal conflicts between pedestrians, cyclists, and vehicles (Loukaitou-Sideris et al., 2014).

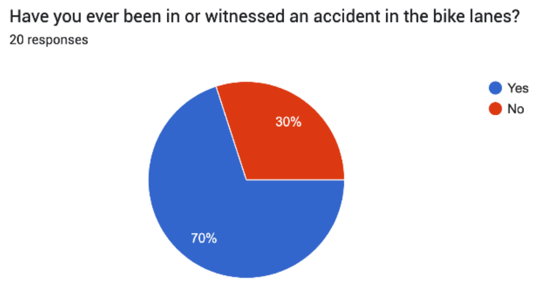
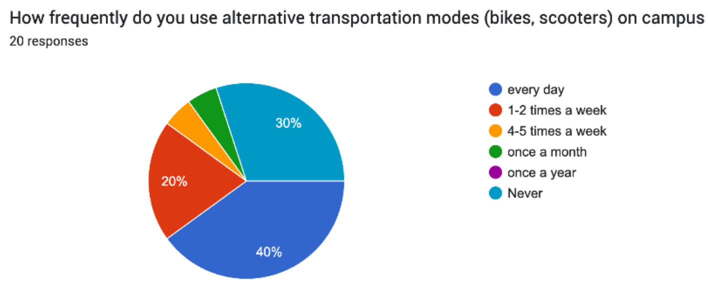
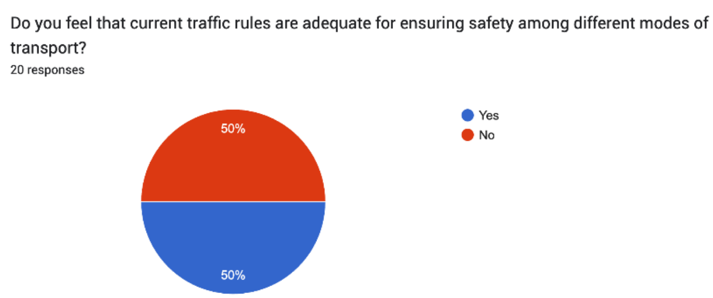
However, even with Purdue’s bike lanes, pedestrians, cars, and cyclists continue to face safety challenges. Issues arise from a combination of poor infrastructure design and inconsistent adherence to traffic rules. Cyclists report frequent incidents where stoplights, lane markings, and other signals are ignored, leading to unpredictable interactions among road users. Additionally, infrastructure flaws, such as narrow or shared paths that force two-way traffic into single lanes, increase the risk of collisions.

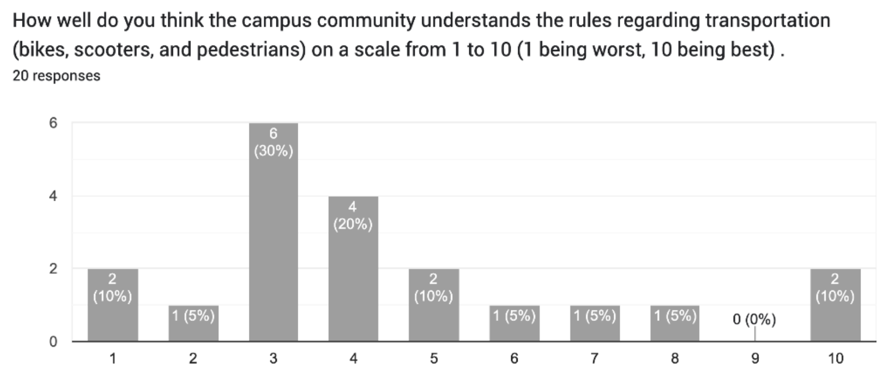
Beyond infrastructure, the growing use of electric scooters, like Veo, has introduced new challenges. For instance, one cyclist described being hit by a Veo scooter, resulting in a bent bike wheel and no way to follow up due to the lack of contact information. This incident underscores the potential for accidents involving electric scooters and highlights the need for clearer guidelines and enforcement to ensure all road users can navigate safely.
Addressing these safety concerns requires a multifaceted approach, including improved infrastructure design, stricter adherence to traffic rules, and better education and awareness to promote safe behavior among cyclists, scooter users, and pedestrians.

Improving the safety of alternative transport modes at Purdue could prevent injuries and promote healthier and more sustainable transportation options for students. Providing a solution to this problem is an integral step in upholding Purdue’s commitment to the planet and to its students.

Table 4. Information gathering for problem scoping

Questions asked	**Answers to questions (from Purdue's Transportation Problems (Responses).xlsx)**
• Have you ever been in or witnessed an accident in the bike lanes?	Answers from Purdue Students: - People often walk through the bike lanes not paying attention and it can cause collisions. - A skateboarder was coming off the sidewalk and into the bike lane. I was already in the bike lane rounding the corner. The skateboarder must not have seen me coming and bailed on his board causing it to go under my wheel and me falling off. Big sad. - I have seen many near collisions between bikes/scooters as they pass through pedestrian filled areas on/near the bike lane, I'd attribute this to a lack of predictability when moving around crowds. - Someone walked into the area between the bike lanes close to the underpass between brown and wetherill and someone on their bike ran into them

	- Student walking looking down at their phone did not look up before crossing the bike lane. I was watching this but could not stop completely before hitting them. - Motorized bike struck pedestrian. 
• How frequently do you use alternative transportation modes (bikes, scooters) on campus, and what factors influence your choice of transportation?	
• Do you feel that current traffic rules are adequate for ensuring safety among different modes of transport?	Answers from Purdue Students: - I ride in bike lanes, out of bikes lanes, roads, sidewalks, etc. I just ride carefully and cautiously. The issues lie with the fools riding at top speeds everywhere. Personally I think the Veos are the major issue. They need speed gated to 5 or 6 mph. - The problem stems from people not paying attention, not from any rule or regulation made by the school. - People using motorized vehicles do not follow rules. 

• How well do you think the campus community understands the rules regarding shared transportation (bikes, scooters, and pedestrians)?	Average Rating : 4.45 

f. Assumptions about the Problem

- Users, including students, faculty members, families, etc., will want to utilize and accept a new system.
- The solution adheres to legal requirements.
- There actually is a need for a new traffic safety system because of increased accidents and distractions and users believe that as well.
- Current safety systems are not sufficient.
- Our solution will fit well into the current infrastructure of roads, vehicles, and other modes of transportation.
- The current volumes of traffic and the amounts of people who walk or use bikes, scooters, or cars will remain constant as time goes on.

IV. IDEA GENERATION

a. Functional Decomposition

Main function	*Sub-functions*	*Design ideas that meet this function*

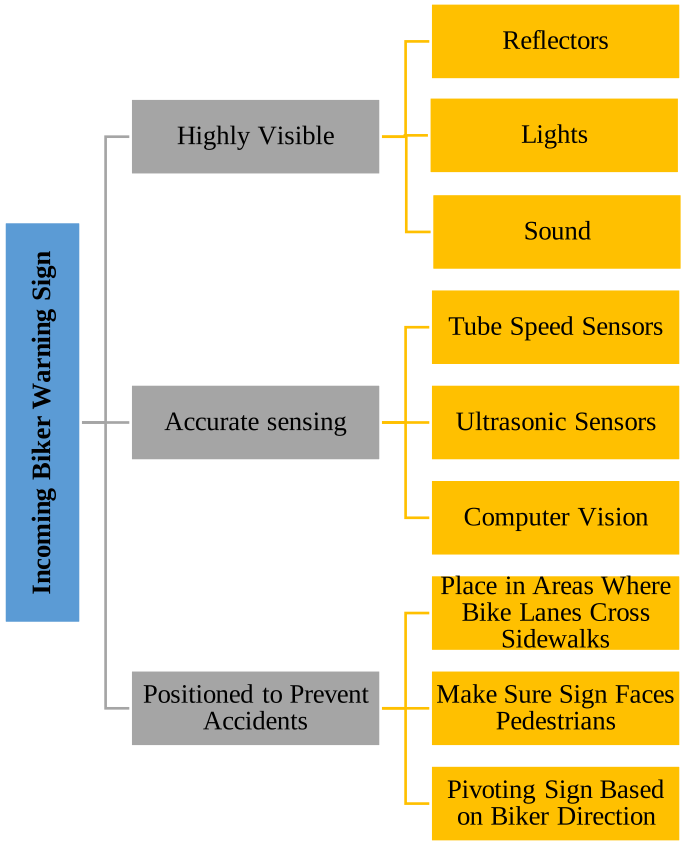


Figure 2. Functional Decomposition for Bike Warning Sign

b. Exploring Prior Art

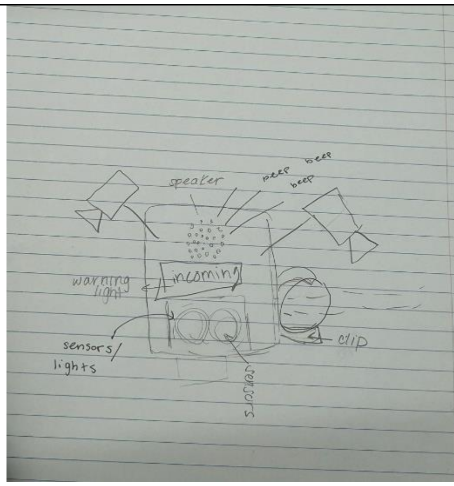
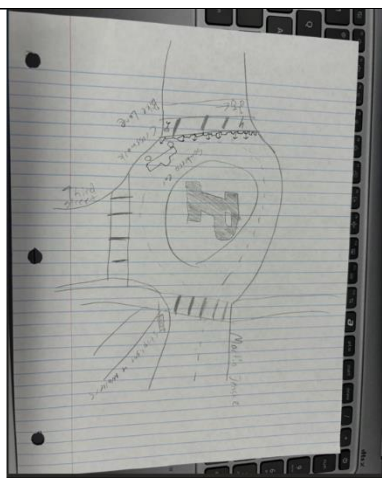
Table 5. Generating ideas by exploring prior art

#	**Image/Picture & Name of Prior Art**	**Strengths**	**Weaknesses**	**Improved alternative**
1	 (North Central Texas Council of Governments, 2017) Educational billboards on the sides of buses	• Easily seen by people getting on the bus • Simple to make and implement	• Difficult to read when the bus is in motion • Not going to be seen/read by every person	Place the signs in stationary places outside of buildings and along the sidewalks/roads along with the ones on buses.

2	 (Pedestrian and Bicycle Information Center, n.d.) Raised bike line separated from sidewalk by planted trees	• Bikers cannot easily go over on sidewalk with pedestrians because of the trees • Bikers are also protected by the parked cars • Environmentally friendly	• Does not prevent bicyclists from using the sidewalk • Pedestrians on the sidewalk might have to cross the active bike lane to get to their car/cross the road	Add signs/a crosswalk that shows where pedestrians can cross and where bikes must stop/slow down for pedestrians. Add sensors so that pedestrians know when bicyclists are coming and vice versa.
3	 (Flickr-Oregon DOT, n.d.) Bicycle specified signal	• Easily seen by everyone • Easy to understand	• Harder to implement a new stop light • Doesn't keep bicyclists from ignoring the signal	Add a sound system so that it is more alerting and causes people to pay attention.
4	 (Traffic Safety Warehouse, n.d.) Speed bump	• Cannot be avoided • Effectively slows the moving vehicle • Protects pedestrians and bikers	• Can be harmful for driver if gone over too quickly • Does not completely slow the vehicle if pedestrian is in the way • Only used for cars	Implement smaller speed bumps for bikers so that they are slowed down for pedestrians. Add warning signs when there is a speed bump coming up. Add a system that can detect how fast a vehicle or bike is moving and alerts when they are moving too quickly.

c. Sketching

Table 6. Generating ideas with sketching

#	Sketch	Solution name	Unique aspects, brief description
1		Veo/bike sensor	Has a clip that easily attaches to a bike/Veo. Senses when a person or object is in front of the bike/Veo. When the bike/Veo is a certain distance away from the person/object, it alerts the biker and any nearby pedestrians by making a loud beep. Also has a warning light/screen is illuminated when the biker gets too close to something.
2		Roundabout	The concept is to improve traffic at the intersection of Martin Jischke and Third Street by creating a roundabout. This could potentially incorporate a stoplight system to allow pedestrians to cross then let cars cross. The main goal would be to slow cars and people down to help everyone cross more effectively.

d. Low Fidelity Prototyping

Table 7. Generating ideas with low fidelity prototyping

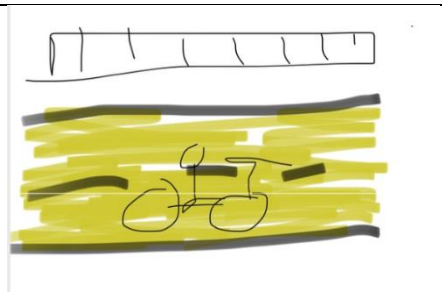
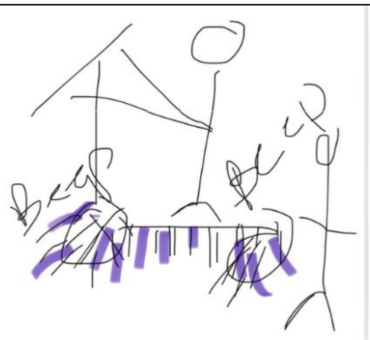
#	Prototype picture	Solution name	Unique aspects, brief description

1	 8inX4inX2in	Veo/bike sensor	A sensor part to go on front of bike that can alert pedestrians that the bike is coming.
2		Pedestrian Alert System	Sign strategically placed at busy intersections that senses bikers and warns pedestrians using lights.

e. Biomimicry

Table 8. Generating ideas with biomimicry

#	Sketch/picture/image	Solution name	Unique aspects, brief description
1		Bioluminescent inspired lights	Create bike lane markings using paint that glows at night, absorbing sunlight during the day. This would make bike lanes more visible without relying solely on streetlights.

2		Bioinspired reflective surfaces	Design bike lane dividers or lane markings that use reflective materials inspired by insect exoskeletons, improving visibility in low-light conditions.
3		Whisker-like sensors for collision avoidance	Like how cat whiskers work, install small, flexible sensors on bike lanes or bike handlebars that detect nearby objects, such as cars or pedestrians, and provide real-time alerts to cyclists if someone gets too close.

f. Artificial Intelligence

Table 9. Generating ideas with artificial intelligence using Microsoft Copilot (Copilot, 2024)

#	Ai Prompt Used	Brief description of the design idea. Include the unique aspects of the design idea.	Brief description of the plan to examine the correctness of the design ideas provided.
1	"Assume that you are an expert civil engineer improving walkways and roads in urban environments. A client wants to improve pedestrian safety at a university. The criteria for the project is that it must be reasonably inexpensive, match the feel of the university, and needs to incorporate a microcontroller in the process. Generate a list of 10 ideas on how transportation safety could be improved while also considering the constraints."	A smart crosswalk that uses the microcontroller motion sensor to automatically update the crosswalk when enough pedestrians are present.	This is a simple enough idea therefore it could work in practice if the microcontroller could handle the function of directing the traffic light. The test would be if we could write code that would allow it to perform this function.
2	"Assume that you are an expert mechanical engineer improving walkways and roads in urban environments. A client wants to improve pedestrian safety at a university where people frequently run into bikes and skateboarders.	An audible alert system that would use audio and visual alerts when a motion sensor detects a high-	The design is once again very straightforward so the only challenge would be to make sure that the visual and audible triggers created by the microcontroller are strong enough to alert

	The criteria for the project is that it must be reasonably inexpensive, match the feel of the university, and needs to incorporate a microcontroller in the process. Generate a list of 10 ideas on how transportation safety could be improved while also considering the constraints.”	speed biker or skateboarder.	distracted pedestrians to them. This could be done through a rapid-prototype test.
3	“Assume that you are an expert civil engineer improving walkways and roads in urban environments. A client wants to improve pedestrian safety at a university where people frequently run into bikes and skateboarders. The criteria for the project is that it must be absolutely effective, regardless of cost, match the feel of the university, and needs to incorporate a microcontroller in the process. Generate a list of 10 ideas on how transportation safety could be improved while also considering the constraints.”	This idea would be a smart pathway system that automatically separates bikers and pedestrians using barriers controlled by the microcontroller.	This design might be more trouble than it’s worth as the microcontroller could potentially remove a lane that someone is in which could cause issues. To test this, we could create a small 50ft walkway with the technology to test its effectiveness.

V. THOUGHT EXPERIMENTS

a. Thought Experiments with Pros and Cons Evaluation

Table 9. Thought experiments with pros and cons evaluation

#	Design Alternative (include a name and an image)	Pros (advantages)	Cons (disadvantages)
1	Smart Crosswalk	• Effective in improving transportation • Incorporates TI Kit • Durable • Scalable • User friendly • Compliance	• Expensive • Not Environmentally friendly • Not aesthetic • Not simple • Lifecycle (would have to be demolished and moved to a landfill
2	Pedestrian Alert System	• Effective in improving transportation • Incorporates TI Kit • Durable • Scalable • User friendly • Simple • Inexpensive	• Compliance • Not aesthetic • Not environmentally friendly

		• Lifecycle: steel from sign can be reused	
3	Roundabout	• Effective in improving transportation • Durable • Scalable • User friendly • Aesthetic • Compliance • Lifecycle: Permanent until torn down	• Doesn’t incorporate TI kit • Not simple • Expensive
4	Bio-inspired reflective surfaces	• Effective in improving transportation • Durable • Scalable • User friendly • Compliance • inexpensive	• Not Aesthetic • Doesn’t incorporate TI kit • Not simple • Environmental hazard • Lifecycle: can’t be reused
5	Veo/Bike Sensor	• Effective in improving transportation • Durable • Scalable compliance • Inexpensive • Incorporates TI kit • Aesthetic • simple	• Environmentally questionable • User friendliness questionable • Lifecycle: can’t be reused
6	Whisker-like sensors for collision avoidance	• Effective in improving transportation • Durable • compliance • Inexpensive • Incorporates TI kit • simple	• Not aesthetic • Not scalable • Not user friendly in terms of attaching whisker like things to bike • Lifecycle: can’t be reused

VI. ITERATION #1

Table 10. Responding to feedback

#	**Based on feedback/data from … about …..**	**We made changes in…by…**
1	Based on feedback given to us from the prototypes we created in class, we realized our VEO bike sensor was going to take a lot more	Therefore, we made changes by changing the idea in our heads to go from a solid ringlike structure to hang from under the

	development than we initially thought and that our current fastening system wasn't going to fly.	bike into a newer design that would use Velcro to fasten the contraption to the bike for better and more efficient use.
2	Our pedestrian alert system seemed to work on paper, but feedback given to us from team 20 pointed out that some folks are not going to pay attention to a device that alerts them, as distraction is already the primary problem as to why people are getting into pedestrian accidents at Purdue.	We altered this system to not only use lights but also audible cues to alert people to the incoming traffic like the current "wait" instructions at crosswalks. While it's very possible people will continue to ignore this as well, it would be rather difficult to create any other form of innovation to grab the attention of somebody when both visible and audible cues are in play.

VII. PROTOTYPING, TESTING AND WDM

a. Prototype Testing Protocol

Table 11. Design Testing Protocol

Criteria	Metric	Plan to collect evidence
Must not raise the cost of tuition.	Keep the cost under $10 per person	Get a rough estimate of cost of construction/implementation by researching relevant parts/materials.
Must be effective at improving safety.	Achieve the most support from stakeholders.	Take a survey of Purdue students, faculty, and others of whether they find the prototype helpful.
Needs to incorporate the TI kit.	Does it use the TI kit?	Create some pseudocode for each design and rate how difficult each will be.
Must fit the "feel" of Purdue	Achieve the most support from stakeholders.	On the same survey mentioned earlier, ask people which design fits Purdue the best.
Should be environmentally friendly	Use less energy than a standard stoplight bulb. Which is roughly 2.4 kWh per day.	Predict energy consumption of critical components and estimate power draw.
The product should be user friendly	Do most people understand how it functions intuitively?	Create a prototype and have stakeholders attempt to use it.
The product should be durable	Can the design withstand the conditions of Indiana.	Analyze materials, or similar devices and see how well they can work in Indiana's climate.
The product should be scalable.	Does the innovation have the capacity to be expanded?	Create a prototype and see how difficult it would be to create it in scale.

b. Prototypes

Figures 3 – 8 depict the testable prototypes for the Veo Sensor, Pedestrian Alert System, and Veo Wristband. The Veo Sensor attaches to a Veo and detects if there is a pedestrian near the Veo, to set off a buzzer. The Pedestrian Alert System tells users when they can cross or stop at the crosswalk. The wearable Veo Wristband alerts a pedestrian when a Veo is in the vicinity via GPS signals from the Veo.

Figure 3. Prototype Veo Sensor

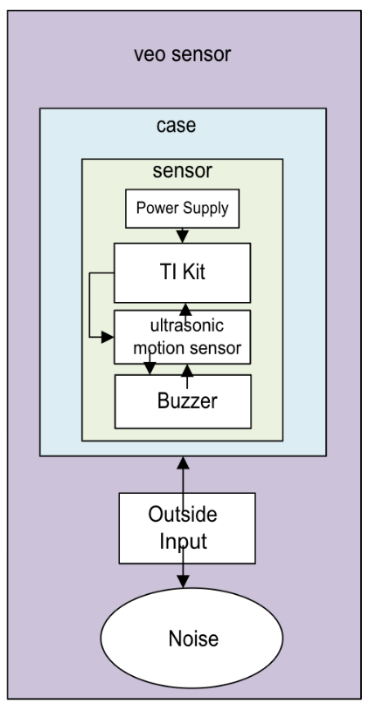


Figure 3. Prototype Veo Sensor Block Diagram

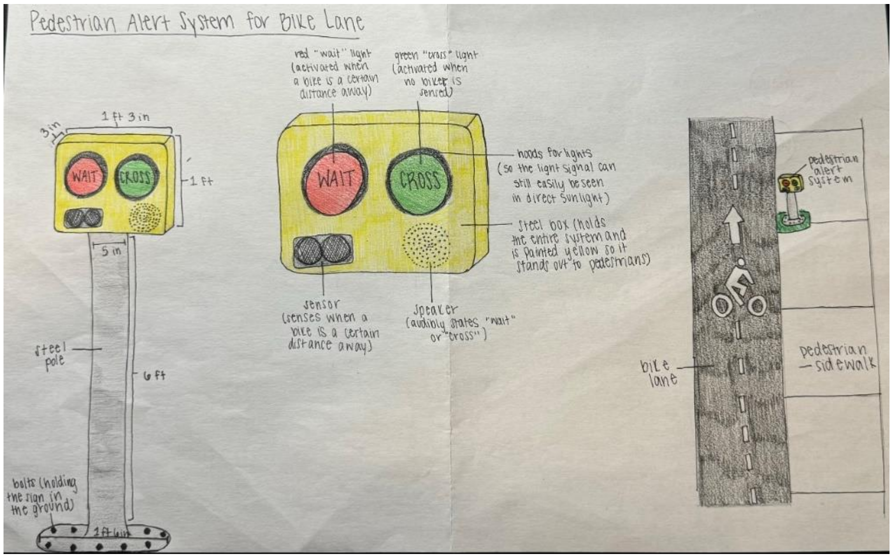


Figure 4. Prototype Pedestrian Alert System

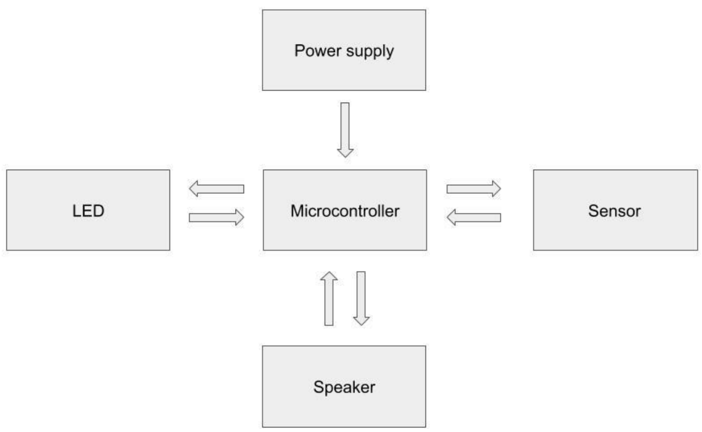


Figure 6. Prototype Pedestrian Alert System Block Diagram

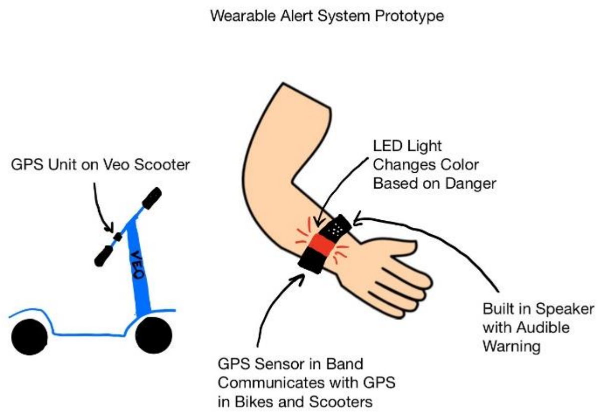


Figure 7. Wearable Alert System Prototype

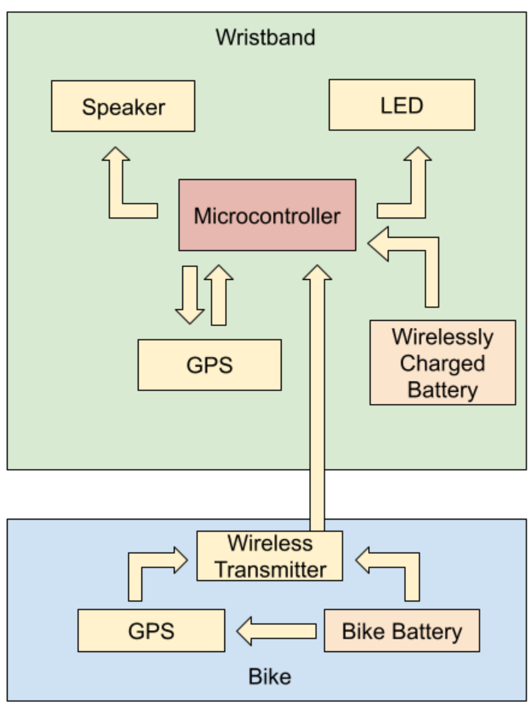


Figure 8. Wearable Alert System Block Diagram

c. Test Results for Top 3 Alternatives

Figures 9, 10, 11, and 12 show that the stakeholders would prefer the Pedestrian Alert System, rather than the Veo sensor or Veo wristband. The feedback that we received is that prototype 3, the pedestrian alert system, solves the problem cheaply and efficiently. It is also not hard to enforce like the Veo sensor or Veo Wristband.

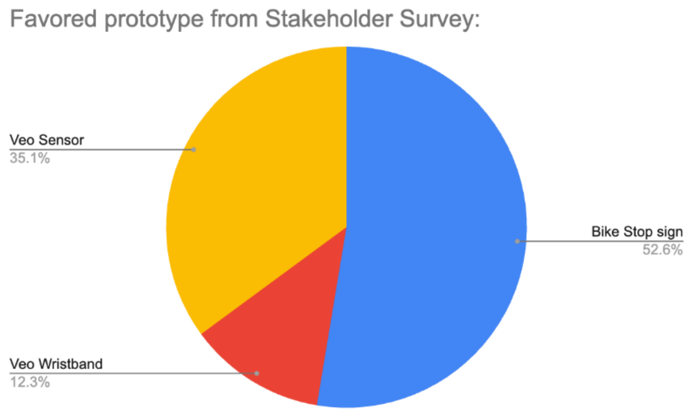


Figure 9. Survey results from stakeholders (Stakeholder Prototype Responses)

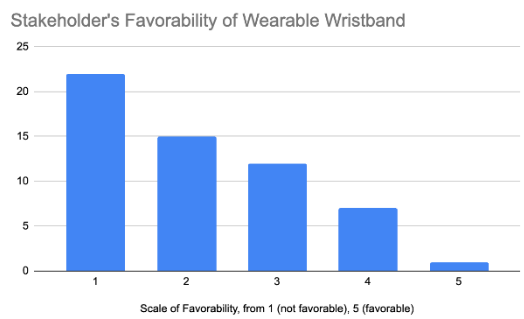


Figure 10. On a scale of 1-5 Stakeholders Rate the Favorability of the Wearable Wristband (Stakeholder Prototype Responses)

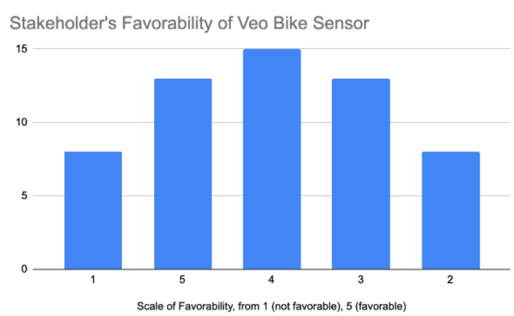


Figure 11. On a scale of 1-5 Stakeholders Rate Favorability of the Veo Bike Sensor (Stakeholder Prototype Responses)

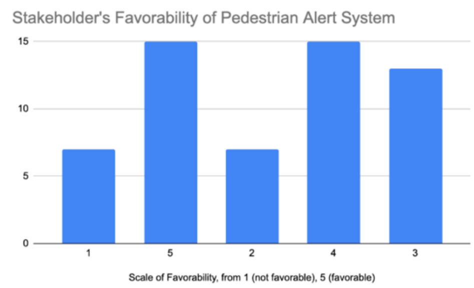


Figure 12. On a scale of 1-5 Stakeholders Rate Favorability of the Pedestrian Alert System (Stakeholder Prototype Responses)

d. Weighted Decision Matrix (WDM)

Weighting

Our weighted decision matrix tested the three prototypes found above on the following criteria.

- Effective at improving safety
- Inexpensive
- Purdue Supported
- Microcontroller functionality
- Longevity

Each of these criteria was given a weight from 5 to 15 depending on it's relevancy to the project. Microcontroller functionality was given a weight of 15, as it was specifically given to us that we needed to use the microcontroller in our final solution. Therefore, a design that could not effectively implement the microcontroller needed to be struck down in the decision matrix. Effective at improving safety, inexpensive, and Purdue supported were all given an equal weight of 10. All of these were given as constraints for the project therefore they needed to be seriously considered when making our final decision. However, to allow for flexibility in our solutions we decided to consider these all equal so that any idea could be considered even if it didn't fit one constraint so long as it met other constraints effectively. Finally, longevity was the final thing we considered, while not a criterion by the client, we reasoned that if a solution lasted a long time, and could be used throughout campus, it would be more effective than a solution that could not. Therefore, each criterion was weighted to allow for all each solution to be effectively weighted against each other in a numeric fashion.

Results

Our decision matrix pointed to the Pedestrian Alert System being the best design with a score of 212.5, followed by the Veo sensor with 188, and the Wearable alert system with 125. The Pedestrian Alert system yielded the highest stakeholder support for the effectiveness of the design with the most 4 and 5 votes out of the survey. Additionally, with microcontroller functionality, a long lifespan, effectiveness throughout campus, and inexpensive estimate of building materials this solution stood above the rest as the clear choice moving forward.

Refer to ENGR 131_A16_DesignProject_WDM_19.xlsx for additional information regarding the Weighted Decision Matrix

VIII. ITERATION #2

Table 12. Responding to feedback

#	**Based on feedback/data from … about …**	**We made changes in…**
1	Based on feedback from Team 10 about the design of the Pedestrian Alert System…	We made changes in our design to make it double-sided, so that it can detect bikes coming from either way of the bike lane.
2	Based on feedback from Team 10 about our presentation and the clarity of our solution…	We made changes to the presentation so that it includes a specific location in which this system will be implemented on Purdue's campus.

IX. OVERVIEW OF FINAL DESIGN

a. Detailed Design

Figure 12. Physical prototype of Pedestrian Alert System

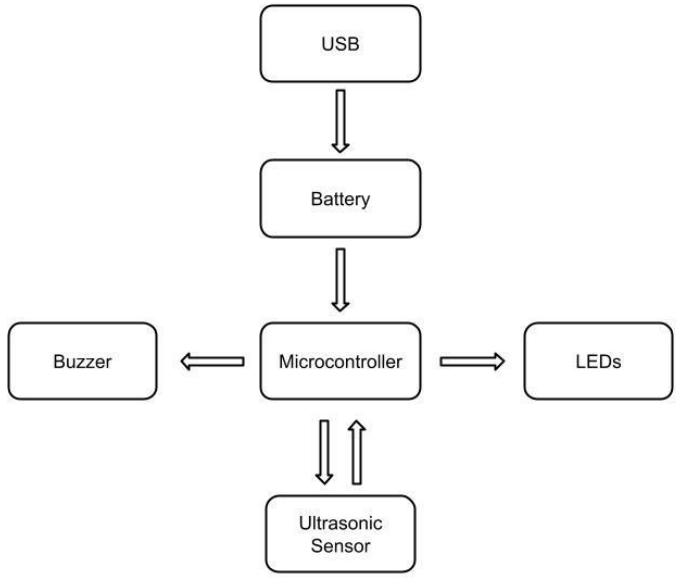


Figure 13. Block Diagram Prototype of Pedestrian Alert System

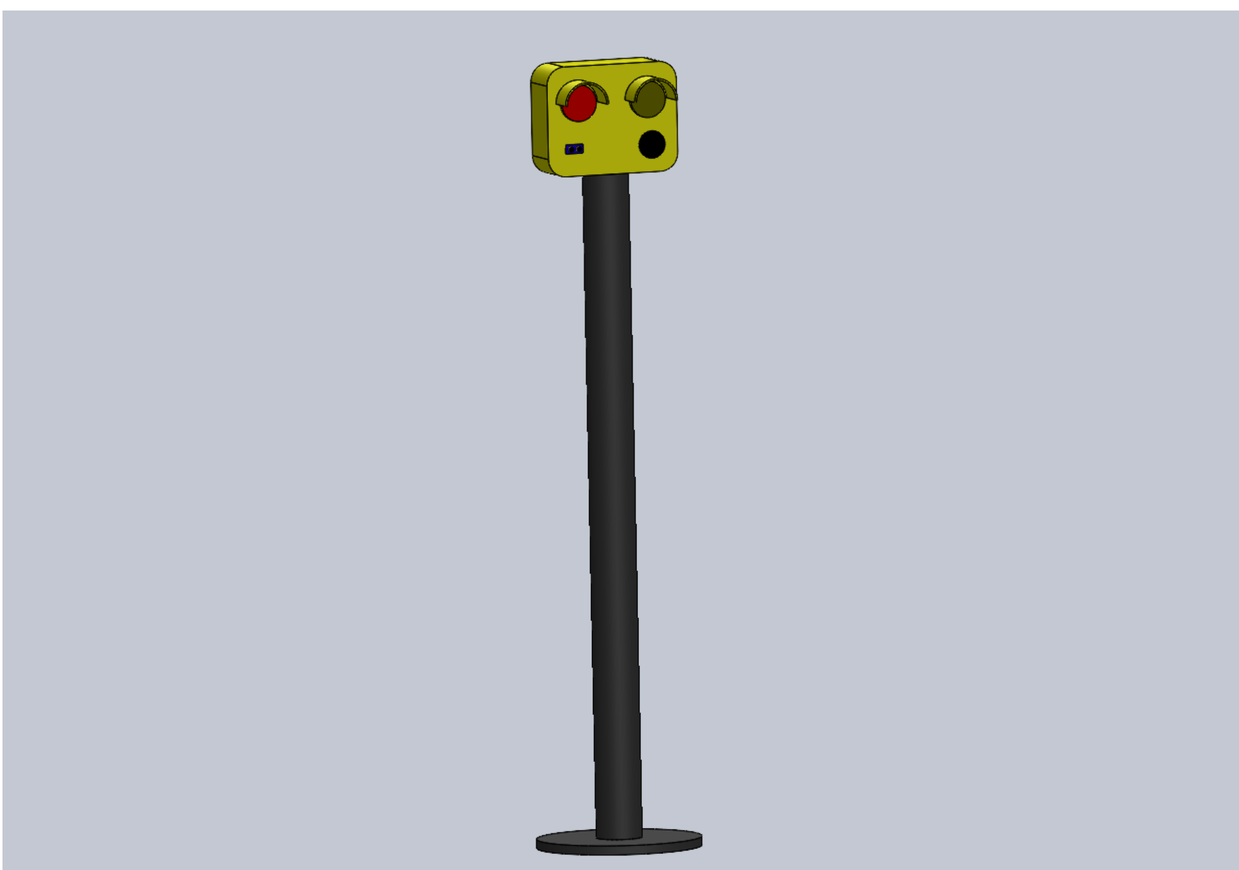


Figure 14. CAD Prototype

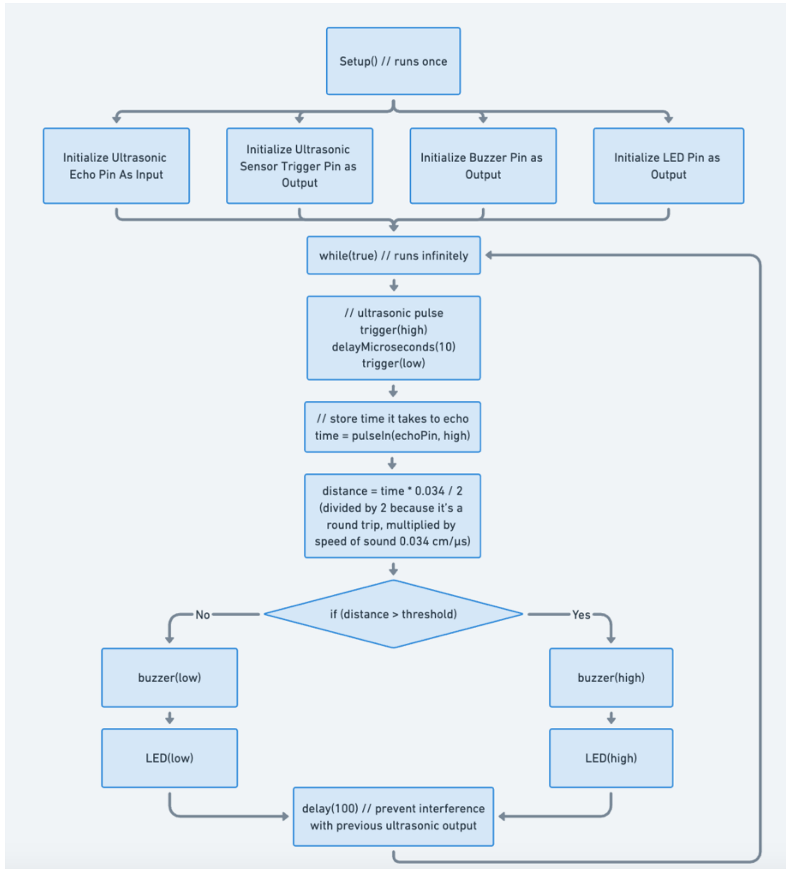


Figure 15. Pseudocode Flowchart for Pedestrian Alert System

b. Data on Final Solution

After testing our final prototype, we found that our solution meets all the design requirements we set. The first and easiest criteria we tested was incorporating a TI kit. Our solution uses a TI to detect traffic, display a message, and play a warning sound.

Another criteria we took into consideration was the cost of implementation. To test this metric, we made a comprehensive estimate of the costs associated with our solution. According to table 13, we can source the parts for each sign for $363.29 and install the solution for $1000, making the total for one sign $1363.29. This affordable price makes our design scalable and allows us to increase safety throughout campus without increasing tuition costs.

We also tested our prototype's functionality by measuring the distance at which the sensor activates. If we want to implement our solution as an effective safety feature, we have to make sure that it works accurately every time. To test the accuracy of the activation distance of the sensor, we used an object that we moved closer and closer to our prototype until the buzzer turned on. Using a ruler, we could measure the activation distance of each trial and record our results in Figure 16. Our results show that the average activation distance was 32.42cm and our expected distance was 33cm. The data indicates that our actual design had an error of 1.75%

compared to our theoretical value, which shows that the real-world implementation of our solution would be effective.

Trial #	Distance	Units
1	32.4	cm
2	32.2	cm
3	32.6	cm
4	32.4	cm
5	32.5	cm
Average:	32.42	cm

Figure 16. Functionality Testing

Lastly, we made sure that all of our metric ratings in our original weighted decision matrix still applied to our final prototype. After re-grading our solution, we found that the final prototype got the scores in Figure 17 against our criteria. Some of the main points are that the solution excels in terms of cost and durability, both crucial for real-world applications. One area that it could improve on is the environmentally friendly category where it only scores a 3, meaning it consumes between 3 and 5 kWh per year. In future generations, we could add a solar panel to improve this score. Overall, our design effectively meets all of our criteria making it a great solution to mitigate campus pedestrian collisions.

	Stakeholder Support	Construction Cost	TI Kit Usage	Matches Purdue "Feel"	Environmentally Friendly	Durability	Scalability
Pedestrian Alert System	3	5	5	4	3	5	3

Figure 57. Weighted Decision Matrix Data

Table 13. Cost Estimate for Producing the Final Prototype

Item	Source Item is Purchased From	Cost
TI Board	Texas Instruments	$30.00

Red LED light	Adafruit	$0.75
Green LED light	Adafruit	$0.75
Ultrasonic Sensor	Amazon	$1.29
Eco Friendly PLA filament	Amazon	$25.00
Buzzer	Amazon	$1.25
USB Cord	Amazon	$5.00
Carbon Steel	AG Metal Miner	$176.75
Polycarbonate	Plastic Business	$122.5
Installation Cost	Eco-Smart	$1000
	Total Cost:	$1363.29

c. Design Optimization

We made several choices that allowed our final design solution to be the most optimal. First, we placed the red light and the green light next to each other inside of stacked on top of each other, which uses less excess material that is unnecessary. We also changed the original design to make the system double-sided. This is more effective because it will be able to detect bikes coming from either way of the bike line, but it is also more optimal because we would no longer have to place more than one in the same location and use more materials. Lastly, all of the edges of the sign and the pole are rounded instead of perfect corners, which also takes less material.

d. Novel Aspects of the Solution

Our solution is both novel and innovative, as it uniquely addresses transportation needs within bike lanes directly from the bike lanes themselves. Unlike traditional systems, which primarily focus on car lanes, Purdue University has never implemented an alert system specifically designed for bike lanes. Most traffic signals are tailored to vehicles, often lacking sensors or solutions to accommodate pedestrians who wish to cross bike paths. What sets our solution apart is the integration of an ultrasonic sensor and a TI board for the electronics, along with a design that incorporates 3D printed exterior and supporting components.

e. Trade-off Decisions and Limitations of the Solution

Some potential limitations of our pedestrian alert system that we were unable to fully address include noise pollution and environmental impact. Noise pollution refers to unwanted sounds that negatively affect people, animals, or the environment. In our system, the buzzer could contribute to noise pollution when bicycles pass by. The environmental impact is another concern, while the PLA filament in our design is eco-friendly, the electronic components such as LEDs, wires, and power sources are not easily recyclable and could contribute to environmental harm if not properly disposed of, contributing to the climate crisis. In the future, integrating a renewable energy source and using more recycled materials would be a good way to combat this issue.

In terms of tradeoffs, to increase functionality we had to make the design double sided. This, however, would require additional money to produce and would possibly require an upgrade to the TI Kit system to handle the amount of traffic coming in both directions. This would likely be the greatest potential problem with our system. If two people are coming down the bike lane the system could pick up the slower one and not the faster one which could lead to issues. Our system was designed to be durable, but any particularly rough weather could also damage the system, creating a unforeseen problem. Another tradeoff is that of weight. Our system is extremely heavy according to CAD estimates and this is due to materials selected for cost and durability. We could potentially reduce the weight through better materials; however, we found cost to be more important than weight.

f. Lessons Learned

Our team learned quite a bit throughout our time on the project. We were strongest in idea generation and prototyping. Specifically, we were able to create many ideas in a very short time using the methods given to us in class. Then with these ideas, we quickly made many different forms of prototypes whether they be CAD, drawings, or simple physical prototypes. In terms of ways we could improve, we could do more research to validate our ideas instead of solely relying on data we personally collected. Strategies that worked for us were delegating relevant tasks to different members of the project, then meeting up to evaluate the work completed. Additionally, each person in the group had their own role that really helped to keep us on track and ensure that work was always completed on time. Over time, we developed better communication skills and teamwork which allowed us to more effectively work together to create better work, faster. I think our process at the start was workable, but over time we have refined our coordination to create an effective team structure that could work on more classes to come.

X. REFERENCES

City of Yakima. (n.d.). LED traffic signals. Retrieved October 24, 2024, from https://www.yakimawa.gov/services/streets/led-traffic-signals/

Copilot. (2023). Urban transportation safety enhancement strategies. [APA Response Example]. Microsoft Corporation.

Eco-$mart, Inc. (n.d.). *How much does a street light cost?* Retrieved December 2, 2024, from https://www.ecosmartinc.com/how-much-does-a-street-light-cost/

Flickr-Oregon DOT (n.d.). *Bicycle signal indication with bicycle stenciled lenses.* [jpg]. Retrieved from http://www.pedbikesafe.org/BIKESAFE/countermeasures_detail.cfm?CM_NUM=55

Lukaitou-Sideris, A., Medury, A., Fink, C., Grembek, O., Shafizadeh, K., Wong, N., & Orrick, P. (2014). Crashes on and near college campuses: A comparative analysis of pedestrian and bicyclist safety. *Journal of the American Planning Association, 80*(3), 198-217. https://doi.org/10.1080/01944363.2014.978354

MetalMiner. (2024). *Carbon steel*. MetalMiner. https://agmetalminer.com/metal-prices/carbon-steel/

North Central Texas Council of Governments (2017). *Billboards on the sides of buses with educational tips for motorists, bicyclists, and pedestrians.* [jpg]. Retrieved from https://highways.dot.gov/public-roads/julyaugust-2017/focused-approach-pedestrian-and-bicycle-safety

Pedestrian and Bicycle Information Center (n.d.). *People walk on a sidewalk next to a raised bike lane protected by parked cars and tree plantings.* [jpeg]. Retrieved from https://www.transportation.gov/pedestrian-bicycle-safety\

Plastics Business. (2011). *Polycarbonate and ABS engineering resins markets see global tightening*. Plastics Business. https://plasticsbusinessmag.com/articles/2011/polycarbonate-and-abs-engineering-resins-markets-see-global-tightening/#:~:text=The%20wide%20price%20range%20represents,%242.50%20%E2%80%93%20%243.50%20per%20pound%20range.

"Student Enrollment, Fall 2023." *Student Enrollment - Undergraduate Admissions - Purdue University,* www.admissions.purdue.edu/academics/enrollment.php. Accessed 21 Oct. 2024

Traffic Safety Warehouse (n.d.). *Speed bump.* [jpg]. Retrieved from https://www.trafficsafetywarehouse.com/Resources/speed-bumps-how-effective-are-they.asp

XI. APPENDICES

Purdue's Transportation Problems (Responses).xlsx
Stakeholder Prototype Responses.xlsx
ENGR 131_A16_DesignProject_WDM_19.xlsx