# Milestone 2

## Self-Driving Infrastructure

*Engineer 2PX3 – Integrated Engineering Design*

**Team 17**

**T06**

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## Executive Summary

With the rise in advanced technology, the future of self-driving vehicles is nearby. Society, as well as engineers of several specializations are presented with the opportunity to redesign infrastructure that is custom-built for the use of self-driving technology.

When pursuing design options, many stakeholders and their concerns must be considered. Along with drivers, pedestrians, as well as cyclists are significant stakeholders that share roads and intersections with the rest of society. Each stakeholder expresses concerns regarding different PERSEID layers including performance, environmental, regulatory, and socio-economic. When it comes to redesigning infrastructure, a series of designs are considered, with each including improvements from the last. As some PERSEID layers will be compromised in order to prioritize others, one constant factor remains; that is safety. Along with satisfying stakeholders involved, the consideration of unintended implications on the environment and liability in different scenarios are also crucial in ensuring an efficient design. The focus of this project was decided to be the redesigning of an intersection as it contains more relatable and complex aspects that will provide a challenging experience for the team.

## Introduction

With the advent of self-driving car technology, transportation by road gained the potential for many things that were not previously possible. It became possible to imagine significantly more efficient roads with computers at the wheel; however, before this could ever become a reality, there must be a period where roads are used by both self-driven and human-driven vehicles. With that in mind, our goal is to design an intersection for the future where both human-driven and self-driven vehicles are first-class users of the roads. The human time and lives saved by potentially more efficient and safe intersections made possible with self-driving vehicle technology is enough motivation to consider solutions to this problem. In our previous report, we considered the impact of intersection design on its main stakeholders and concretely defined how we would model and measure the performance of our design. In the following weeks, we created, and evaluated many intersection designs. We first evaluated our designs on their technical performance, modifying them and choosing the best performing designs to move forward with. We repeated this process, evaluating designs on from socio-cultural, regulatory, and environmental lenses. By this process, we created highly feasible designs with their impacts, benefits, and losses carefully considered. In this report, we will outline the strengths and weaknesses of several candidate intersection designs, as well as the results of evaluating designs through the various lenses of the PERSEID method of design.

## Overview of Design Constraints

| Design | Constraints | |
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| A | Technical | - Pedestrians travel one way only<br>- All traffic comes from the left (including pedestrians) |
| | Socio-Cultural | - Emergency vehicles and larger vehicles can go around traffic with ease<br>- Pedestrians travel one way only |
| | Regulatory | - All traffic comes from the left |
| | Environmental | - Reduce idle time |
| C | Technical | - Virtually no wait for low traffic |
| | Socio-Cultural | - All vehicles are treated equitably<br>- Pedestrians are seen as an after-thought<br>- Emergency vehicles do not get prioritized |

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| | Regulatory | - Safety depends on driver predictability/competence |
| | Environmental | - Virtually no idle time for low traffic |
| **E** | Technical | - No speed-limit for self-driving vehicles<br>- Self-driving vehicles have a harder time turning right |
| | Socio-Cultural | - Self-driving vehicles are rewarded<br>- No benefits for emergency response vehicles and pedestrians |
| | Regulatory | - Double left turn lanes may be dangerous |
| | Environmental | - Higher idle time |

Design A (Figure 1) had some strengths and weaknesses with respect to the funnel considerations and parameters. From a technical and regulatory perspective, having all its traffic coming from the left is a strength as all its users would only need to check its left side. From a socio-cultural perspective, emergency vehicles and larger vehicles like trucks can go around with ease. Roundabouts also reduce idle time which is a strength using the environmental lens. The only weakness is that pedestrians can only travel one way (socio-cultural and technical constraint).

From a technical and regulatory perspective, Design C (Figure 2) uses special traffic lights which has virtually no idle time for low traffic.  From a socio-cultural perspective, all vehicles are treated equitably which leads to one of its weaknesses; emergency vehicles and pedestrians are not prioritized. Another weakness is seen from the regulatory lens, where road safety heavily depends on the how predictably the drivers are as these sensors need to be able to predict when the vehicle crosses the intersection.

Unlike the previous two designs, Design E (Figure 3) has a higher idle time and from an environmental lens, this can contribute to higher carbon emissions. Another weakness can be found through the socio-cultural and technical lens where self-driving vehicles are rewarded with the lack of speed limit, but they have a difficulty turning right. Adding on, from a regulatory perspective, the double left turns may be dangerous or confusing to navigate.

## Details Assessment of Design Options

Design A (as seen in Figure 1) was the group's top design. This design is an add-on to the classic roundabout, which are becoming more common on newly built roads. This design contains a single lane for vehicles, in which the traffic flows in a counter-clockwise motion, but it also has a cyclist lane (located in between the roads and the pedestrians) and only allows pedestrians and cyclists to move in a counter-clockwise motion as well. By doing so, human-driven vehicle drivers only must worry about the oncoming traffic from the left, and in a self-driven vehicle, sensors will only need to be placed on the left side. In addition to this, the roundabout also has an emergency lane located between the single lane for vehicles and the cyclists. This emergency lane has many uses, but its main purpose is to allow emergency vehicles to pass through traffic so that no other vehicles have to change lanes to allow the emergency vehicle to pass through. The emergency lane can also be used as an emergency stop lane by other vehicle drivers, so that they can pull over for any reason and keep the roads safe and the added distance between vehicles and cyclists/pedestrians helps keep them safe as well. This lane can also be helpful for larger vehicles, such as trucks and buses, as they always need some extra space while making turns. This design has many strengths, such as short wait times for all vehicles and easily seeing oncoming traffic, and it is beneficial for almost all the stakeholders involved and does not discriminate between self-driving vehicle owners and regular vehicle owner. The only stakeholder who may be negatively impacted may be the pedestrians, who now have to walk all the way around the roundabout (in a worst-case scenario) instead of being able to cross the road as they were able to do in our regular traffic intersections.

Design C (as seen in Figure 2) was the design that is most similar to a regular traffic intersection, which are seen at almost every intersection. This design requires sensors to be placed 50 meters down each road which will affect the functions of the preinstalled traffic lights. The sensors that are used in this design are able to sense the cars and calculate their respective speeds. From there, it then calculates if the vehicle travelling has any chances of colliding with another vehicle travelling perpendicular to it. Based on variables such as speed and distance from intersection, the intersection lights will turn green for the vehicle that will approach the intersection first, and as soon as they are able to pass through, the lights will turn green for the second vehicle approaching the intersection (assuming there is another vehicle coming). In situations where the sensors pick up that there is a lot of traffic coming from all four directions, the traffic lights will default to a timed traffic system, where the lights will stay green for about 45 to 60 seconds for each side. This design also has lane dividers to separate incoming and outgoing traffic, which is also large enough to act as a platform for pedestrians to gather on. It allows pedestrians to cross the road half at a time, which can sometimes allow pedestrians to cross the road faster and not hold up traffic on the road altogether just to let them pass. This intersection lights are always red by default and will turn green later and not vice-versa to add more safety at the intersection in the case where the lights no longer work or if any issues with the sensors arise. A big strength of this design is that as a concept, it has virtually no wait time, or even as a worst-case scenario, only a few seconds of wait time, similar to that of a regular traffic intersection and it does not discriminate between self-driving vehicle owners and regular vehicles. Unfortunately, the safety of every stakeholder involved relies heavily on the competence and predictability of the human driver (in a human driven vehicle) or the code (in a self-driving vehicle), which overall does not make this design very safe for many of the stakeholders involved.

Design E (as seen in Figure 3) is also very similar to a regular traffic intersection, as they look and operate the exact same way, except it has many more lanes, all having a different purpose. Like most traffic intersections, this design also has two lanes for outgoing traffic and two lanes for incoming traffic, but this design also has one extra lane on the very left of the two lanes exclusively for self-driving vehicles. The self-driving vehicles have a strong advantage in this design, as they do not have any speed limits imposed on them while they are in their own lane, except when they are close to a traffic intersection, as the safety of many stakeholders is now also involved. Since this traffic intersection operates like a regular one, when a human-driven vehicles approaches the intersection, a new left turn lane is creates in between the human-driven vehicle lane and the self-driving vehicle lane in which human-driven vehicles are only allowed to make a left turn, and the human-driven vehicle lane to the very right is then converted into a right turn lane. A very similar scenario exists for the self-driving vehicles as a new left turn lane is created to the left of the self-driving lane as one would approach the intersection, but if a self-driving vehicle were to make a right turn, they would have to leave their self-driving lane and join the human-driving right turn lane in order to make that right turn. While both of the left turn lanes do not exist past the intersection, the right turn lane on the human-driven vehicle side still exists past the intersection as it is used by other vehicles to make a right turn into it. The traffic lights in this design are slightly different to a regular traffic intersection, but they do exist in places where a business or building has an entrance/exit onto a busy road. These traffic lights first allow any vehicle (traveling in opposite directions) to make either a left turn or a right turn. Once that traffic has been cleared out, the vehicles travelling parallel to one another are then allowed to make travel across the intersection while pedestrians can also make their way across one side of the intersection. Lastly, the red light appears so that vehicles traveling in the perpendicular direction are able to go. This design presents many pros and cons for a few of the stakeholders, but for many, this new design would not alter their regular experience at a traffic intersection, although some stakeholders, such as regular vehicle owners may feel discriminated against due to the fact that there is no speed limit on self-driving vehicle lanes as well as self-driving vehicles have the privilege of getting their own lane and still being able to use the human-driven vehicle lanes.

## Conclusion

In conclusion, the redesigning of the infrastructure for a smart intersection will bring about many concerns from various stakeholders such as self-driving and traditional vehicle drivers, pedestrians, emergency vehicle drivers, and more. Given that, crucial decisions will be made as not all concerns will be accounted for since some take precedence over the other and hold a greater value. The defining problem and basis of this project is how the new design of the infrastructure will be accommodated to satisfy the important stakeholders, by ensuring it is structured to be efficient, safe, and advanced for all members sharing the road. In order to do this, many parameters are defined that act as a blueprint for all the designs that are considered, where metrics are put in to place to measure important factors that determine the overall success of the project objectives.

## References


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[3] C. of Toronto and T. Services, "Road Engineering Design Guidelines Version 2.0 2.0 Lane Widths Road Engineering Design Guidelines 2.0 LANE WIDTHS GUIDELINE City of Toronto, Transportation Services Road Engineering Design Guidelines Version 2.0 2.0 Lane Widths," 2017.

## Appendix

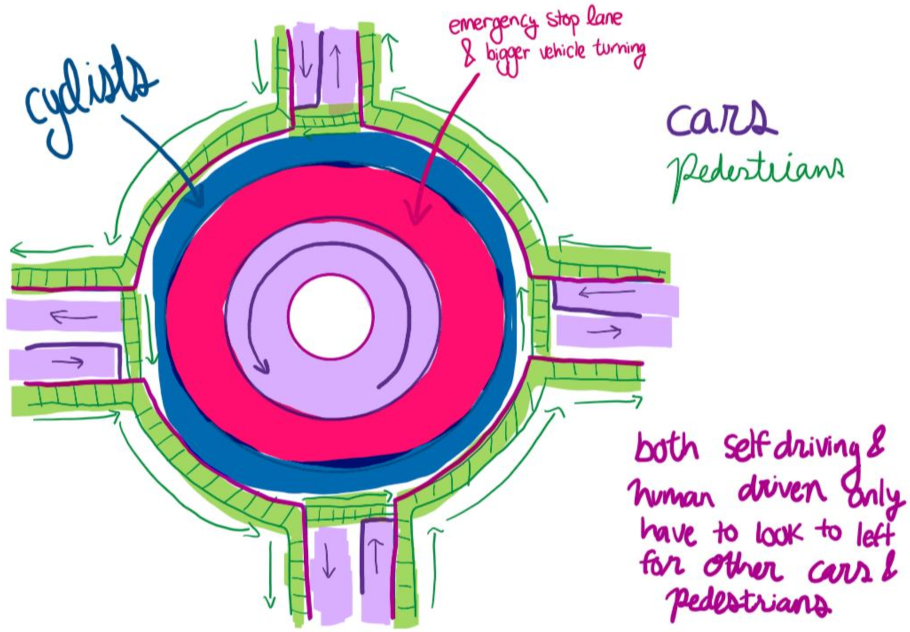


Figure 1: Design A

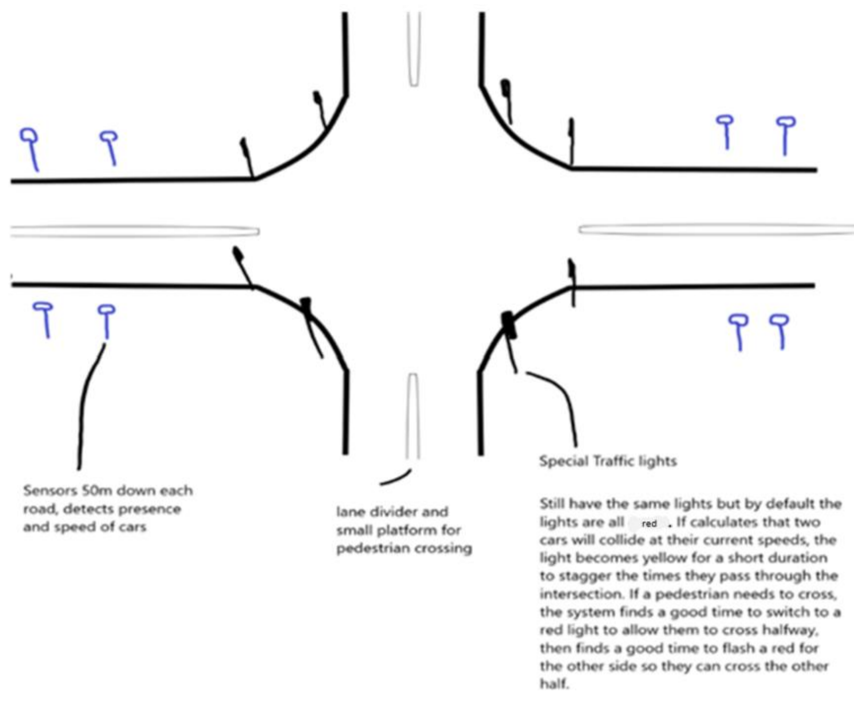


Figure 2: Design C

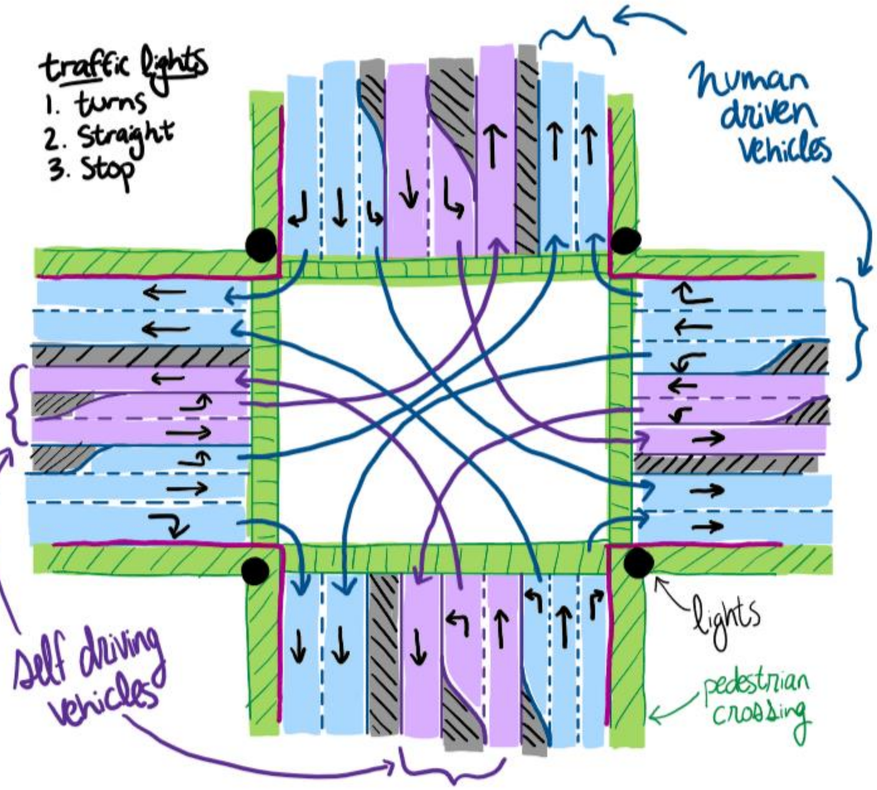


Figure 3: Design E