Final Report

Self-Driving Infrastructure

Engineer 2PX3 – Integrated Engineering Design

Team 17

T06

April 14, 2022

Eman **Ashraf**	400330524
Elliot **Chong**	400325433
Gurleen **Dhillon**	400301955
Abdul **Zulfiqar**	400315591

Academic Integrity Statement

As a future member of the engineering profession, the student is responsible for performing the required work in an honest manner, without plagiarism and cheating. Submitting this work with my name and student number is a statement and understanding that this work is our own and adheres to the Academic Integrity Policy of McMaster University and the Code of Conduct of the Professional Engineers of Ontario. [Gurleen Dhillon, 400301955]
As a future member of the engineering profession, the student is responsible for performing the required work in an honest manner, without plagiarism and cheating. Submitting this work with my name and student number is a statement and understanding that this work is our own and adheres to the Academic Integrity Policy of McMaster University and the Code of Conduct of the Professional Engineers of Ontario. [Eman Ashraf, 400330524]
As a future member of the engineering profession, the student is responsible for performing the required work in an honest manner, without plagiarism and cheating. Submitting this work with my name and student number is a statement and understanding that this work is our own and adheres to the Academic Integrity Policy of McMaster University and the Code of Conduct of the Professional Engineers of Ontario. [Elliot Chong, 400325433]
As a future member of the engineering profession, the student is responsible for performing the required work in an honest manner, without plagiarism and cheating. Submitting this work with my name and student number is a statement and understanding that this work is our own and adheres to the Academic Integrity Policy of McMaster University and the Code of Conduct of the Professional Engineers of Ontario. [Abdul Zulfiqar, 400315591]

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. In the coming together of our final design, many of these compromises and important decisions were made. The first major decision made was to center the focus of our design on redesigning an intersection. As individuals interact with intersections more frequently daily as opposed to a highway, the team decided it would be more relatable to input personal experiences. The final design consisted of a one-way round-about in which human-driven and self-driven vehicles share the road. This design poses an advantage over other design options that were considered as it allows increased performance and safety for all stakeholders involved. It was noted that other design options put one stakeholder at an advantage over others. Since our goal was to create a design that incorporates self-driving vehicles rather than prioritizing self-driving vehicles, the chosen design was the most efficient as it favored all stakeholders. 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. Given that, additional lanes and pedestrian walkways were put into place. In order to continue to make this design a success, some next steps for the team include incorporating sensors and signals to display signs of clear traffic, busy traffic, and pedestrian signals. Moreover, we aim to increase accessibility by incorporating audible cues and ramps on sidewalks. In order to ensure that emergency lanes are used solely for emergency vehicles and purposes, a meeting may need to take place to implement regulations preventing regular vehicles from interacting with them.

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, but we also aim for our design to have a low or non-existent negative impact towards other stakeholders as well. 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 reports, we evaluated our intersection design candidates and considered the impact of the intersection design on its main stakeholders and concretely defined how we would model and measure the performance of our design. In the following weeks, our team was tasked with finalizing a design and creating a simulation to test our design in action. Over the past few weeks, we have used the various lenses of the PERSEID method of design - such as socio-cultural and performance, which were of great importance to our team - to evaluate and improve our designs to reach where we are today. Using these lenses, we were able to successfully create and simulate our intersection design that we believe would be a benefit for all stakeholders involved, and would not prioritize self-driving vehicles, but include them into our progressing society. In this report, we will outline the strengths and weaknesses of several intersection designs alternatives and explain how our final intersection design came to be.

Conceptual Design

Our design process consisted of 6 main stages, the first of which was design space exploration. The process began with the creation of 6 designs which we would evaluate on various criteria throughout the remaining 5 stages. The next 4 stages, in order, involved evaluating our 6 designs on performance, socio-cultural factors, regulatory concerns, and environmental concerns. In the last stage, we took all factors into consideration to choose a final design among the candidates and refined the design with our insights from the design evaluations in previous stages.

When the original 6 designs were made in the first stage, we noticed some similarities between designs that would help us simplify our comparisons in the future. Our 6 designs were spread equally among 3 main types of intersections: roundabouts, regular traffic light intersections with special lanes, and regular lane intersections with special traffic lights. In future stages we decided to include a design from each section in our top 3 since the similarities between the designs would allow us to incorporate elements of designs of the same type if needed.

At the performance stage of design evaluation, the key consideration was how much time would pass on average in between a car arriving to and leaving from an intersection, this is a metric we refer to as average clear time. There were 3 designs that we determined would give us considerably low clear times, these were designs A (fig. 1), C (fig. 2), and E (fig.3). These 3 designs are each from one of the 3 types of intersections mentioned above and would be the prime candidates for the future. (All performance rankings can be seen in table 2.)

Design A is a roundabout design with extra features to accommodate for a larger subset of our stakeholders. It has emergency stop lanes that double as large vehicle turning lanes when needed, as well as bike lanes all around. It also initially restricted pedestrians to moving counter-clockwise similar to vehicles at the intersection in order to simplify the decision-making process for drivers; however, this idea was later scrapped.

Design C is a 4-way intersection with regular lanes and special traffic lights. The traffic lights in this intersection use many sensors reaching as far as 100 meters away from the intersection to detect the flow of traffic to optimize the lights to allow traffic through with the minimum slowdown necessary. For example, if two cars, one heading north and one heading east wanted to pass through the intersection 1 second apart, the lights would change to allow both through without unnecessary slowdowns

Design E is a 4-way intersection with special lanes and regular traffic lights. This design has special segregated lanes exclusively for self-driving vehicles in which they would have a higher speed limit enabled by the increased safety of self-driving vehicles. This simplicity allows the design to enjoy better performance along with most of the benefits of modern intersection.

With the 3 prime candidates for our design, the next stage was considering socio-cultural factors. The key considerations for this stage were how much of the stakeholder set the designs accommodate for, how equitable the design is for its stakeholders, and how the design would fit in society. Design E only has special accommodations for self-driving vehicles, leaving it with a low coverage of the stakeholder set. This design also has issues with equity and its fit in society, since it amounts to a fast pass for people who can afford to buy self-driving vehicles, which is an issue. Design C would accommodate for different vehicle types differently with its algorithm controlling traffic flow, giving it decent coverage of stakeholders and equitable depending on the algorithm; however, the design has very different, and more difficult to follow rules to existing intersections, making it a poorer fit in society. Design A was the best of the prime candidates in this category by far, with the widest coverage of the stakeholder set, and being an established intersection design, it would have no trouble fitting into society. The one issue was that pedestrians were being put at a major disadvantage (only being able to go counter-clockwise around the intersection), for the minor convenience of drivers; however, scrapping that aspect of the design solved that problem.

The next stage for consideration was the regulatory concerns. The key considerations for this stage were the safety of a design for all stakeholders, and clarity of liability. Design C largely fails in this area, as it can lead to fatally unsafe situations if the directives of the traffic lights aren’t closely followed. In addition to this, the use of a complicated algorithm for the traffic lights can complicate the issue of liability for road accidents, since it will add the possibility to argue that traffic lights are making incorrect decisions. Design E provides benefits to safety for self-driving vehicles since they have exclusive lanes and can communicate with each other. The separation of self-driving and human driven vehicles may also help with the clarity of liability. Design A, being a roundabout, is the safest of our designs with no left turns and relatively low speeds on the roundabout. Being an existing design also means there's a solid base of rules that can be used to determine liability, with new rules only needed to deal with self-driving cars rather than any complications caused by the intersection itself. (All regulatory rankings can be seen in table 3.)

The final stage of the PERSEID layers we considered was environmental concerns. The key consideration for this stage was wastage of energy (measured by deceleration/stopping required i.e., idle time). Design E inherits the issues with idle time from regular traffic light intersections in that there is a lot of time spent idle at red lights. Design C has the potential to remove idle time altogether for low traffic situations; however, as traffic increases it must make more cars slow/stop at the intersection to manage traffic. The power cost of the maintenance and operation of traffic lights was also a factor to consider. Design A, while requiring more slowing down on average than Design C, consistently mitigates stopping to a greater degree, making it unclear which of the two are optimal here. (All environmental rankings can be seen in table 4.)

The final stage of our design process took all the previous considerations into account using a decision matrix (Table 5) as well as other factors that do not fit with the key considerations of the PERSEID layers. From our discussions throughout, our priorities were with safety and performance, followed by sociocultural, then environmental concerns, and this was reflected in our decision matrix. Before deciding on a design, we discussed other factors that affected our designs. Design E has a flaw with its segregated lanes where it is only used to its full potential when about ⅓ to ½ of all vehicles on the road are self-driving. When this is not the case, there is wasted space in either self-driving or human driving lanes. Both Designs C and E are less resilient in the face of power outages and require more maintenance overall since they use traffic lights. In the end the final choice was Design A with its notable lack of deficits in any area, while having particularly superior performance and the best safety out of our designs.

Final Proposed Design

Our group's final design (fig. 1) is a roundabout containing a lane for self-driving and human-driven vehicles, a lane for cyclists, and a lane that is reserved for emergency vehicles and situations. This emergency lane set between the main lane and the cyclist lane serves as a way for emergency vehicles such as fire trucks and ambulances to reach their destination with greater ease and efficiency. Other purposes for this lane include providing extra space for larger vehicles such as transport trucks to enter and exit the intersection as well as allowing any on-road vehicles to pull over. This buffer can help reduce on-road traffic congestion and keep the roads safe as pedestrians and cyclists are further distanced from the main on-road traffic. All on-road traffic flows in a counterclockwise motion. There is a pedestrian walkway revolving around the intersection. Pedestrians can travel both clockwise and counterclockwise and can cross half the walkway at a time.

This design has several strengths and weaknesses but ultimately outshines its competitors as the other designs were lacking in more fields than our final design. One of its biggest strengths includes short wait times for all vehicles on the road. From a socio-cultural perspective, the short wait times in the roundabout do not discriminate between self-driving vehicles and human-driven vehicles. From an environmental perspective, the lower wait time would mean lower idle time, which reduces the amount of fuel wasted. This fuel reduction would also lead to the reduction of carbon emissions. The other strength is that all on-road vehicles can easily see oncoming traffic. By having all its traffic coming from the left, all its users would only need to check its left side. This is proven to be a strength from a performance and regulatory perspective. From a socio-cultural perspective, senior drivers, who tend to be over-involved in crashes occurring at intersections, tend to be more careful of roundabouts. With all traffic flowing in the same direction, our design creates a safer environment for all drivers, especially senior drivers, as all vehicles must yield for them when they turn into the roundabout [4]. In addition, several IIHS studies conclude that the public's opinion on roundabouts positively changed after the drivers become accustomed to them [4]. Another strength includes having an emergency vehicle lane. As mentioned earlier, it allows on-road vehicles to pull over safely and, emergency vehicles and larger vehicles like trucks can go around with greater ease. This emergency lane proves to be a strength in all aspects of the PERSEID layer.

However, this design has a few flaws. As mentioned earlier, all vehicles must yield for all vehicles entering the roundabout. This on paper may sound less efficient, but the flow of traffic is never impeded. Thus, the roundabout is an efficient way of lowering traffic jams and is best suited for roads where traffic is equally dispersed in all directions [4]. Another flaw that was improved upon included the directions of travel for pedestrians. Initially, we planned on having the pedestrians travel only in the counterclockwise direction, and instead of being able to cross half the walkway at a time, pedestrians had to commit to walking the entire length at once. After carefully reviewing, we decided to change our current design; pedestrians can travel both clockwise and counterclockwise and can cross half the walkway at a time. The change in design would aid pedestrians in reaching their destinations faster and allow those with mobility issues to cross with greater ease. From a socio-cultural and performance perspective, this change greatly improved from the previous iteration. Next, the emergency vehicle lane is not distinguishable enough from the main lane. Making the emergency vehicle lane would help prevent misuse of the lane. To make the lane more distinguishable, a solid line will be used instead of a dotted line. Road paint was considered but was soon discarded due to it not being as environmentally friendly.

Design verification was an important factor in evaluating our final design, and while using the established roundabout concept allowed us to gain insight into the real-world performance of the design through research, another important component of this was a simulation of our design. Our roundabout simulation (code shown in figure 6) was tested thoroughly to confirm the functionality of each method of the simulation class and compared directly to the given simple all-way stop simulation which was assumed to work correctly. The results of comparing the wait times of these two designs via simulation yielded the results shown in Table 1 (shown graphically in Figure 5). As can be seen, the all-way stop performs better for low traffic, but fails terribly when more than 1 vehicle shows up every 2 seconds. In contrast, the roundabout design can handle 4 times that traffic before failing. This result supports the utility of our design in medium traffic situations, where it can still handle traffic gracefully.

In the future, we plan on making our roundabout more accessible for pedestrians that are hard of hearing, experience mobility issues, and/or are visually impaired. Since there are no lights to indicate if pedestrians are crossing as the traffic timer would have to be generalized, so vehicles and cyclists would have to stop if they see a pedestrian crossing. However, with pedestrians with disabilities, this can be difficult to do so. To improve upon this system, our team would like to add specialized traffic lights that could help pedestrians navigate the roundabout to ensure their safety and wait times are the same as on-road vehicles. Specialized traffic lights could be initiated by the pedestrian by pressing a button, which would signal the on-road vehicles to stop. The pedestrian will cross to the halfway point and repeat the same process until they reach their destination. These specialized traffic lights will also have audible cues. We would also add tactile paving to assist pedestrians with visual impairment. The downsides to these additions would be their environmental impacts. The initial design's lack of traffic lights and signal detectors leads to fewer raw materials being sourced, thus lowering the carbon footprint of the intersection. With these new additions, the carbon footprint of the roundabout would be roughly the same as that of a regular traffic light intersection. Not to mention, the efficiency of road vehicles may decrease, which increases the idle time and thus its carbon footprint. From a socio-cultural perspective, however, all stakeholders equally benefit from this change as all stakeholders, on-road vehicles, and pedestrians will experience roughly the same wait times. Our team plans on reviewing more on this change to ensure before committing to it for our final design.

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. Metrics are put in to place to measure important factors that determine the overall success of the project objectives. Looking ahead, some next steps that would be taken would be to consider technical aspects such as sensors and communication between traffic signals and self-driven vehicles. Through this project, a new aspect of teamwork was learned as working with individuals of different specializations brought about new strategies and tactics to go about each milestone. Each team member was able to effectively communicate their share of opinion and discuss the contributions they can make to each task given their skillset and educational background. For future purposes, our team would aim to structure the design process by analyzing the final design based on our main objectives and goals in order to implement feedback and changes to adhere to those goals. For instance, one of our goals was to increase accessibility and evaluating the design based on our goals would allow us to implement features to reach this goal. In the future, our team would make efforts to learn and gain knowledge on the skills and areas of expertise of other members in order to further contribute to the completion of tasks and components of the design. This will help in receiving additional opinions and feedback in order to enhance the quality and function of each task or milestone.

References

[1] "Project Module - Infrastructure for Self-Driving Vehicles - ENGINEER 2PX3:Integrated Engineering Design Project 2." https://avenue.cllmcmaster.ca/d2l/le/content/430517/viewContent/3560654/View (accessed Feb. 05, 2022).

[2] Olivier Bellefleur and National Collaborating Centre for Healthy Public Policy, "Traffic Lane Width of 3.0 m in Urban Environments," 2014, Accessed: Feb. 05, 2022. [Online]. Available: www.ncchpp.ca

[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.

[4] Insurance Institute for Highway Safety, "Roundabouts," IIHS, Mar-2021. [Online]. Available: https://www.iihs.org/topics/roundabouts#roundabouts-defined. [Accessed: Mar-2022].

Appendix

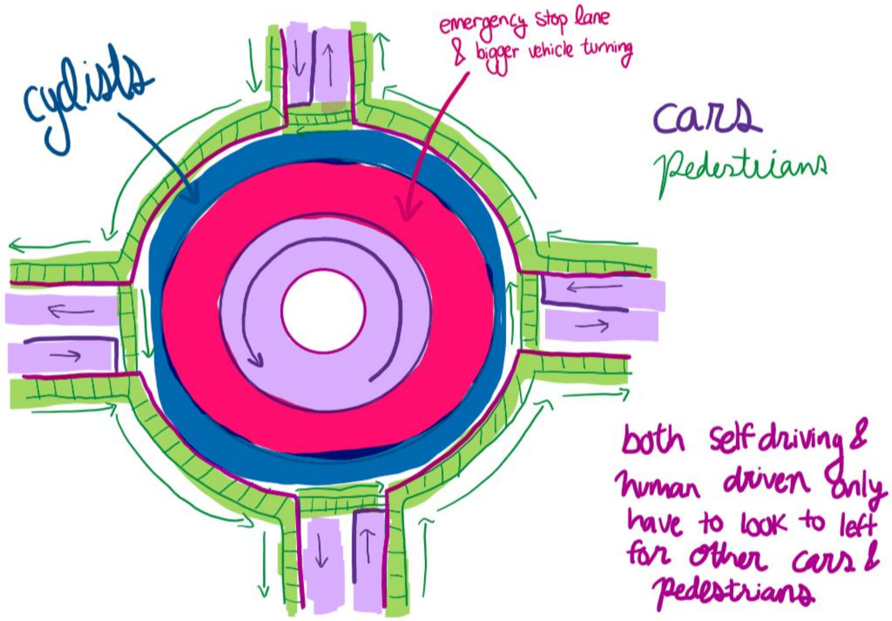


Figure 1: The preliminary version of the Final Design also known as Design A

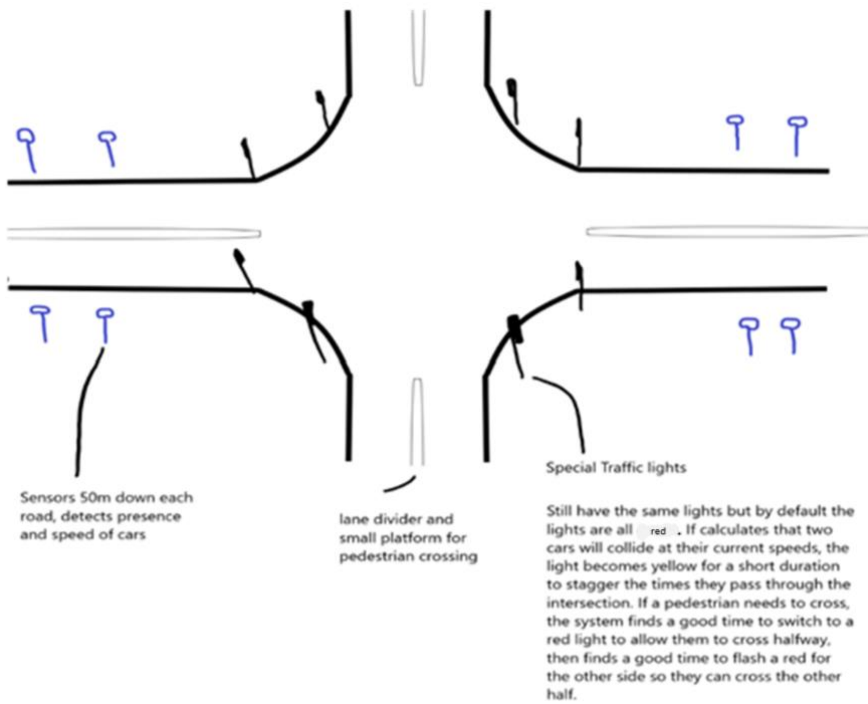


Figure 2: The 1st alternate design also known as Design C

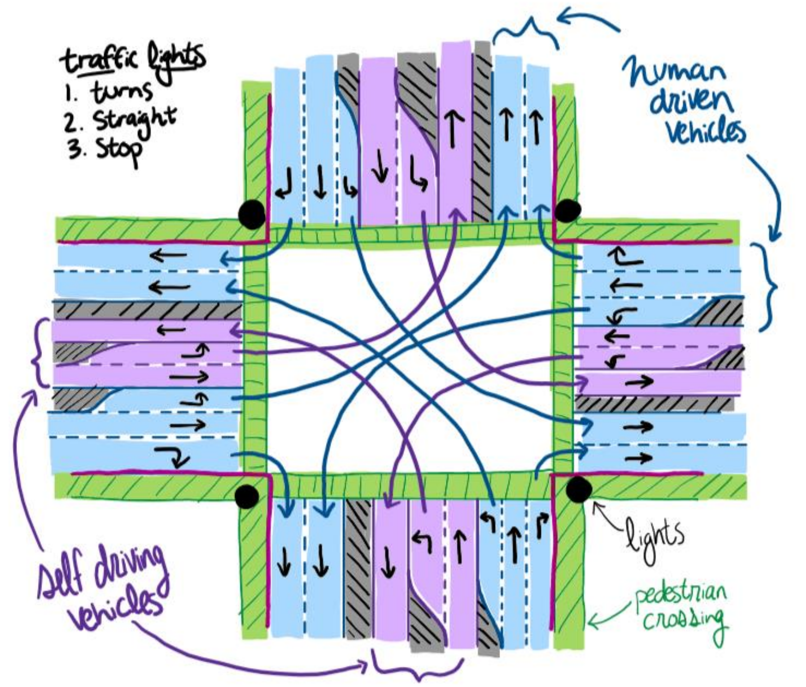


Figure 3: The 2nd alternate design also known as Design E

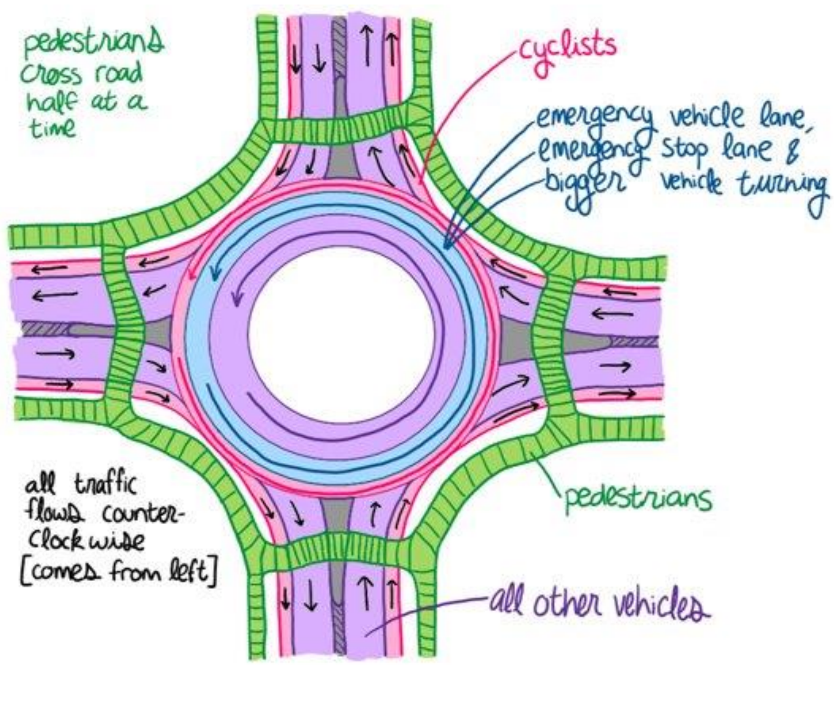


Figure 4: The Final Design for our intersection

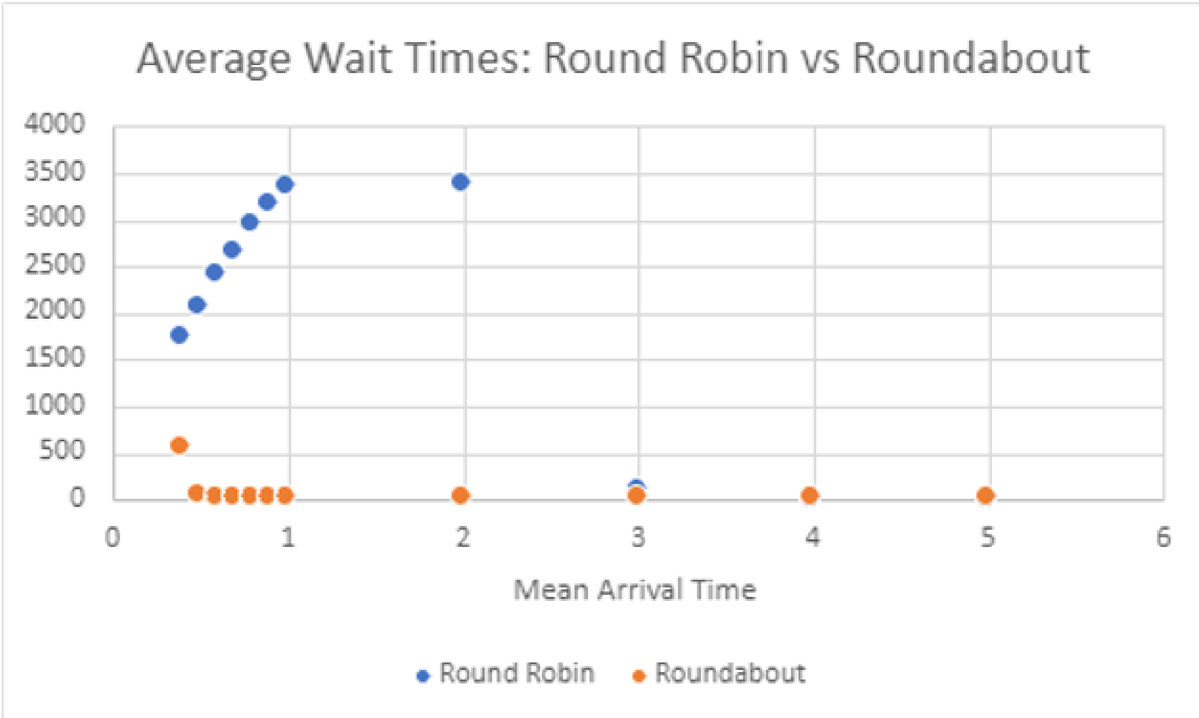


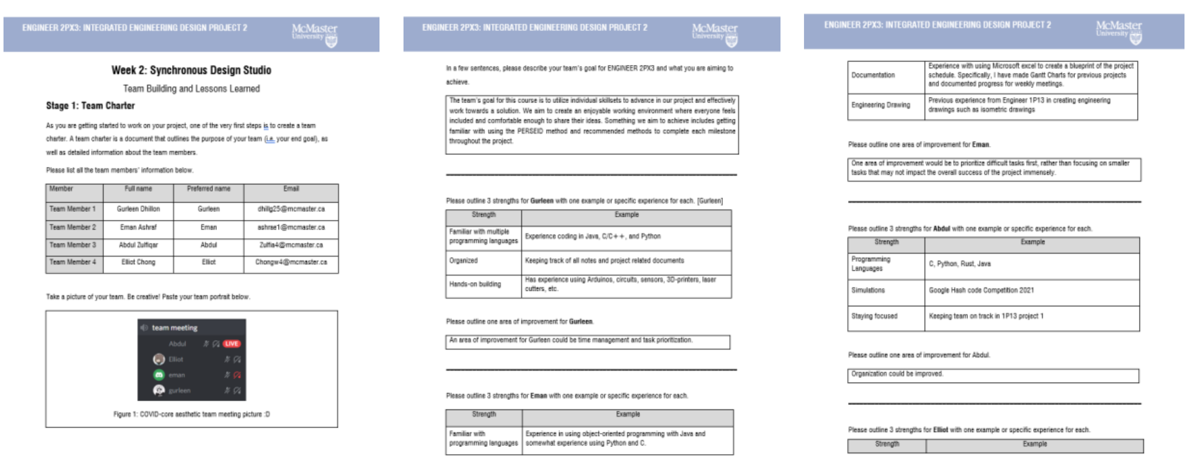
Figure 5: A graph of the average wait times of a round robin compared to a roundabout from the simulation results

```python
from ast import List
import random

"""
Roundabout Design Modelling choices:
1) Vehicles arrive from N E S W and enter the roundabout if there is atleast a two second window to turn right
2) Vehicles take the shortest path to the exit in the direction they want to go (this has no chance of requiring a stop)
3) Pedestrians arrive from N E S W and only cross counter clockwise (maybe not the best idea) in the direction they want to go
4) Pedestrians cross in two parts, each part requiring a two second window
5) Pedestrians are leave the roundabout when they no longer need to cross
"""

#Constants
ARRIVAL = "Arrival"
DEPARTURE = "Departure"
STOP = "Stop"

MEAN_ARRIVAL_TIME = 5
VEHICLE_SPEED = 1
ROUNDABOUT_SIZE = 5
N = ROUNDABOUT_SIZE*2
E = ROUNDABOUT_SIZE*1
S = ROUNDABOUT_SIZE*0
W = ROUNDABOUT_SIZE*3
CAPACITY = ROUNDABOUT_SIZE*4
PRINT_EVENTS = False

class Driver:
    def __init__(self, name, arrival_time, arrival_direction, departure_direction):
        self.name = name
        self.arrival_time = arrival_time
        self.departure_time = 0
        self.turn_signal = False
        self.position = arrival_direction # represents the position of the car in the roundabout, inital values can be 1,6,11,16
        self.departure_direction = departure_direction # represents the position at which the car will leave the roundabout, values can be 0,5,10,15
```

```python
class Simulation:

    upper_arrival_time = 2 * MEAN_ARRIVAL_TIME

    def __init__(self, total_departures):
        self.num_of_departures = 0
        self.total_departures = total_departures
        self.clock = 0
        self.north, self.east, self.south, self.west = [], [], [], []
        """
        lists of drivers from each direction
        """

        self.center = []
        """
        list of Drivers representing circular section of a roundabout, can contain 20 elems max
        Drivers can use this to check positions of other drivers and make decisions based on that
        """

        self.print_events = PRINT_EVENTS
        self.total_times = []
        self.load = []

    #Enable printing events as the simulation runs
    def enable_print_events(self):
        self.print_events = True

    #Method that runs the simulation
    def run(self):
        while self.num_of_departures <= self.total_departures:
            self.generate_arrival()
            self.operate_entrances()
            self.operate_roundabout()
            self.clock += 1
        print(average(self.total_times))

    def operate_roundabout(self):
        removal_indices = []

        for index in range(len(self.center)):
            if self.center[index].position == self.center[index].departure_direction:
                removal_indices.append(index)

            if self.center[index].position >= CAPACITY - VEHICLE_SPEED: # the highest "position" in the system loops back around to the lowest
                self.center[index].position += VEHICLE_SPEED - CAPACITY
            else:
                self.center[index].position += VEHICLE_SPEED

        removal_indices.reverse()
        for index in removal_indices:
            driver = self.center.pop(index)
            wait_time = self.clock - driver.arrival_time
            load = len(self.south) + len(self.east) + len(self.north) + len(self.west)
            if self.print_events:
                print("time:" + str(wait_time))
                print("load:" + str(load))
            self.load.append(load)
            self.total_times.append(wait_time) # total wait time
            self.num_of_departures += 1



    def operate_entrances(self):
        south_clear = True
        east_clear = True
        north_clear = True
        west_clear = True
        for driver in self.center:
            if driver.position >= CAPACITY - VEHICLE_SPEED:
                south_clear = False
            elif driver.position >= E - VEHICLE_SPEED and driver.position < E:
                east_clear = False
            elif driver.position >= N - VEHICLE_SPEED and driver.position < N:
                north_clear = False
            elif driver.position >= W - VEHICLE_SPEED and driver.position < W:
                west_clear = False
        if south_clear and len(self.south) > 0:
            self.center.append(self.south.pop(0))
        if east_clear and len(self.east) > 0:
            self.center.append(self.east.pop(0))
        if north_clear and len(self.north) > 0:
            self.center.append(self.north.pop(0))
        if west_clear and len(self.west) > 0:
            self.center.append(self.west.pop(0))
```

```python
    def generate_arrival(self):
        r = random.random()
        vehicles_per_sec = 1/MEAN_ARRIVAL_TIME
        if vehicles_per_sec <= 1 and r < vehicles_per_sec:
            self.generate_driver()
        elif vehicles_per_sec > 1:
            for _ in range(round(2*vehicles_per_sec*r)):
                self.generate_driver()

    #Generate a car arriving at the intersection
    def generate_driver(self):
        a = random.random()
        d = random.random()
        arrival_direction = -1
        departure_direction = -1

        if d < 0.25:
            departure_direction = S
        elif d < 0.5:
            departure_direction = E
        elif d < 0.75:
            departure_direction = N
        else:
            departure_direction = W

        if a < 0.25:
            arrival_direction = S+1
            self.south.append(Driver(self.clock,self.clock,arrival_direction, departure_direction))
        elif a < 0.5:
            arrival_direction = E+1
            self.east.append(Driver(self.clock,self.clock,arrival_direction, departure_direction))
        elif a < 0.75:
            arrival_direction = N+1
            self.north.append(Driver(self.clock,self.clock,arrival_direction, departure_direction))
        else:
            arrival_direction = W+1
            self.west.append(Driver(self.clock,self.clock,arrival_direction, departure_direction))


    def print_state(self):
        print("[N,E,S,W,C] = ["+ str(len(self.north)) +","+ str(len(self.east)) +","+ str(len(self.south)) +","+ str(len(self.west)) +","+ str(len(self.center)) +"]"

    def generate_report(self):
        #Define a method to generate statistical results based on the time values stored in self.data
        #These could included but are not limited to: mean, variance, quartiles, etc.
        print()


def average(L):
    return sum(L)/len(L)
```

Figure 6: The simulation code for the roundabout


ENGINEER 2PX3: INTEGRATED ENGINEERING DESIGN PROJECT 2 McMaster University

Week 2: Synchronous Design Studio

Team Building and Lessons Learned

Stage 1: Team Charter

As you are getting started to work on your project, one of the very first steps is to create a team charter. A team charter is a document that outlines the purpose of your team (i.e. your end goal), as well as detailed information about the team members.

Please list all the team members' information below.

Member	Full name	Preferred name	Email
Team Member 1	Gurleen Dhillon	Gurleen	dhillg25@mcmaster.ca
Team Member 2	Eman Ashraf	Eman	ashrae1@mcmaster.ca
Team Member 3	Abdul Zulfiqar	Abdul	Zulfia4@mcmaster.ca
Team Member 4	Elliot Chong	Elliot	Chongw4@mcmaster.ca

Take a picture of your team. Be creative! Paste your team portrait below.

Figure 1: COVID-core aesthetic team meeting picture :D

1

ENGINEER 2PX3: INTEGRATED ENGINEERING DESIGN PROJECT 2 McMaster University

In a few sentences, please describe your team's goal for ENGINEER 2PX3 and what you are aiming to achieve.

The team's goal for this course is to utilize individual skillsets to advance in our project and effectively work towards a solution. We aim to create an enjoyable working environment where everyone feels included and comfortable enough to share their ideas. Something we aim to achieve includes getting familiar with using the PERSEID method and recommended methods to complete each milestone throughout the project.

Please outline 3 strengths for **Gurleen** with one example or specific experience for each. [Gurleen]

Strength	Example
Familiar with multiple programming languages	Experience coding in Java, C/C++, and Python
Organized	Keeping track of all notes and project related documents
Hands-on building	Has experience using Arduinos, circuits, sensors, 3D-printers, laser cutters, etc.

Please outline one area of improvement for **Gurleen**.

An area of improvement for Gurleen could be time management and task prioritization.

Please outline 3 strengths for **Eman** with one example or specific experience for each.

Strength	Example
Familiar with programming languages	Experience in using object-oriented programming with Java and somewhat experience using Python and C.

2

ENGINEER 2PX3: INTEGRATED ENGINEERING DESIGN PROJECT 2 McMaster University

Documentation	Experience with using Microsoft excel to create a blueprint of the project schedule. Specifically, I have made Gantt Charts for previous projects and documented progress for weekly meetings.
Engineering Drawing	Previous experience from Engineer 1P13 in creating engineering drawings such as isometric drawings

Please outline one area of improvement for **Eman**.

One area of improvement would be to prioritize difficult tasks first, rather than focusing on smaller tasks that may not impact the overall success of the project immensely.

Please outline 3 strengths for **Abdul** with one example or specific experience for each.

Strength	Example
Programming Languages	C, Python, Rust, Java
Simulations	Google Hash code Competition 2021
Staying focused	Keeping team on track in 1P13 project 1

Please outline one area of improvement for Abdul.

Organization could be improved.

Please outline 3 strengths for **Elliot** with one example or specific experience for each.

Strength	Example

3

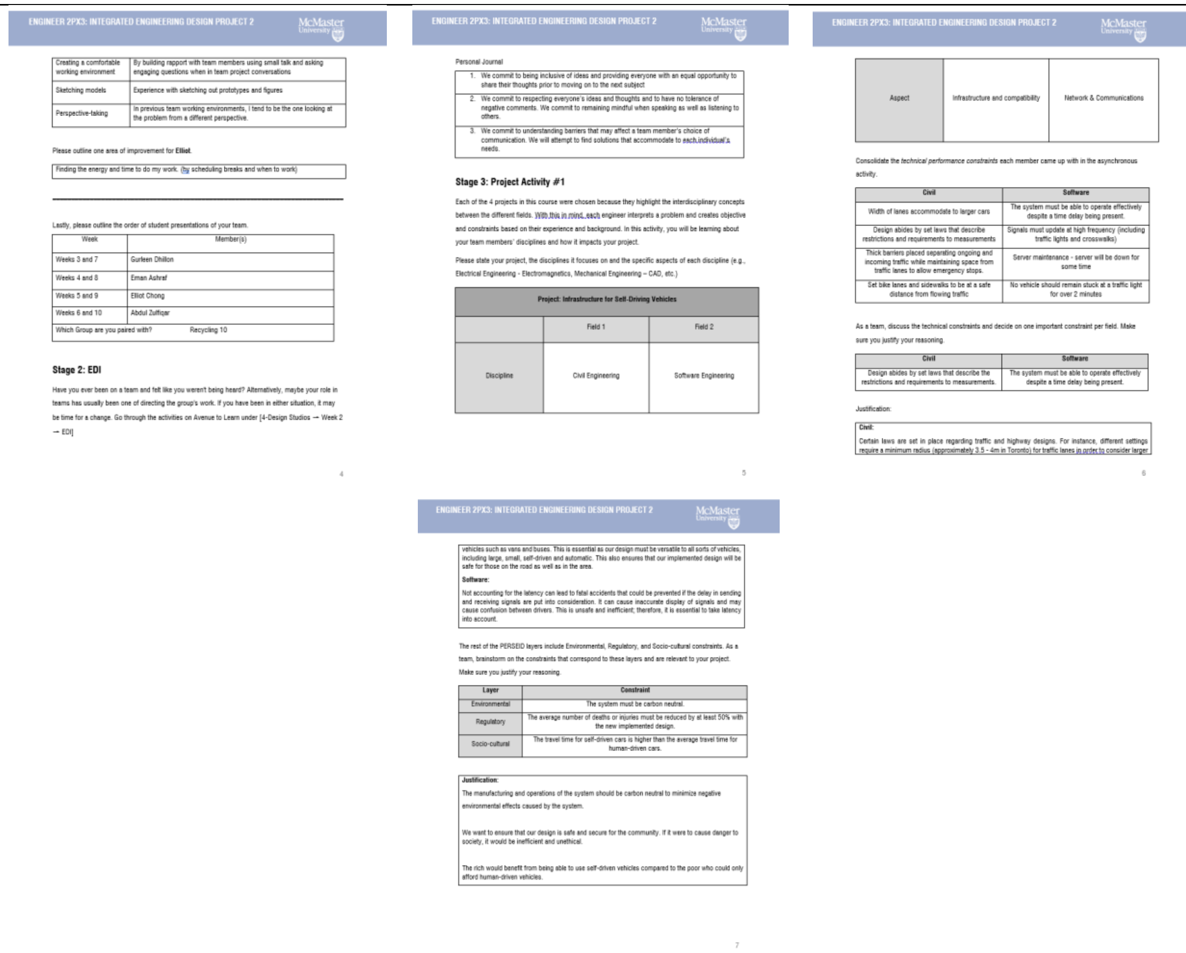
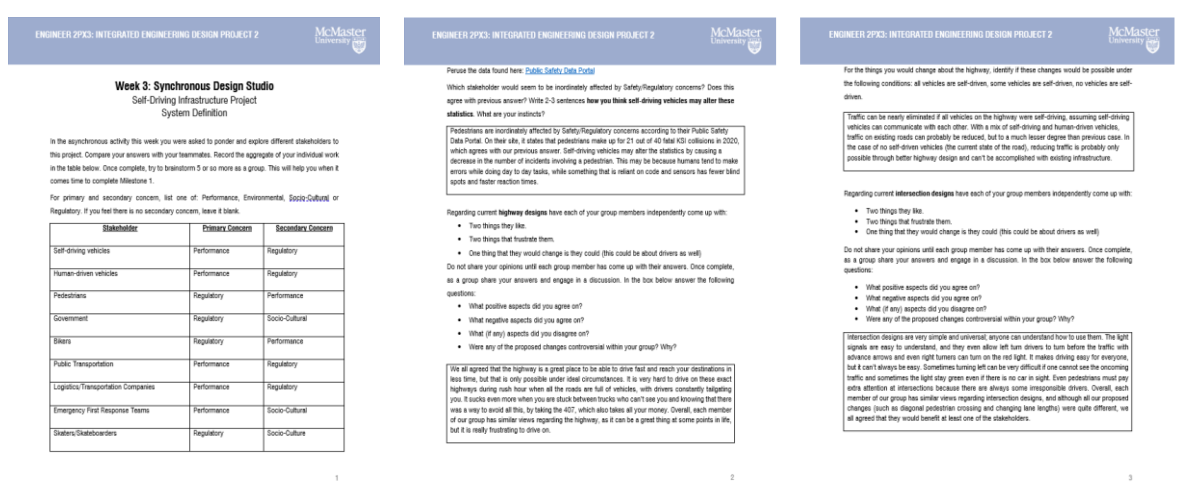


Figure 7-13: Synchronous Design Studio worksheets week 2



ENGINEER 2PX3: INTEGRATED ENGINEERING DESIGN PROJECT 2 — McMaster University

For the things you would change about the intersection, identify if these changes would be possible under the following conditions: all vehicles are self-driven, some vehicles are self-driven, no vehicles are self-driven.

> Extending turning lanes and allowing diagonal pedestrian crossings would be equally difficult to implement regardless of the presence of self-driven vehicles on the roads. If all vehicles on the roads were self-driven, it may be possible to get rid of traffic signals all together, creating roads without interruptions. In the cases of intermixed self-driven and human-driven vehicles, traffic signals could be made smarter, although, with safety in mind, the intermixed case doesn't give much more leeway for improvement over the case of only human-driven vehicles.

If you were driving a traditional vehicle on a road which was designed to also account for self-driving vehicles, how might you treat a self-driven vehicle differently? Would you? Consider the cases where you perfectly trust the self-driving technology, vs not trusting it at all. Put your group's answers in the box below. It's not required to answer the question, but you may be interested in reading this:
Human Drivers and Autonomous Cars Mix Like Oil And Water

> A self-driven vehicle would appear to be more advanced in comparison to a traditional vehicle as the road was designed to take its features and technology into account. A self-driven vehicle driver may benefit from this design more than a traditional vehicle driver as it may be able to receive traffic signals ahead of time and make calculated decisions accordingly, whereas a traditional driver would have to make those decisions themself. I would trust a self-driven vehicle in times where it is safe, such as straight or simple highways and roads. However, there is always doubt in fully trusting technology, and for instances where it is not entirely safe, such as driving by pedestrian crosswalks or traffic signals where other vehicles and persons are engaged and could potentially be harmed if there was any significant error or delay in the sensory equipment, the self-driving technology would not be trusted.

What would be true about a poorly designed intersection and/or stretch of highway. Or in other words, what would be true of a perfect highway/intersection? Could it be there are two distinct designs, but it cannot be said one is better than another? If so, what would have to be true in this scenario?

> The qualities of a poorly designed highway include: the fact that it is hard to change lanes and some lanes with a terrible merging system in mind. For example, a ramp speed may be too low and not enough of the lane is left to merge onto the highway or multiple lanes get merged into one. In an ideal highway, there would be carpool lanes to reduce the traffic in the main lanes, multiple lanes (if there is

4

ENGINEER 2PX3: INTEGRATED ENGINEERING DESIGN PROJECT 2 — McMaster University

> always traffic), as well as more space between the lanes and the barriers to create space for emergency stops (on both sides) as to not disrupt the traffic flow.
>
> In a poorly designed intersection, some features that make it very hard to drive on include uneven land (which creates many blind spots), lack of safety for pedestrians, and awful time distribution for the stakeholders. Our group's ideal intersection would accommodate pedestrians' and drivers' safety. For instance, for pedestrian safety, there would be audible cues of when pedestrians are able to cross, and the intersections are accessible to wheelchair users. The intersection would also have little to no blind spots so all users can see oncoming traffic for safety measures. Adding on to safety, the intersection would be simple and easy to follow for both self-driven and traditionally driven vehicles. Lastly, the wait times at the intersection would be greatly reduced for all its users.
>
> On an idea road, it would be best if all stakeholders could add in features that best suite their desires, but unfortunately that cannot be the case in most scenarios. Sometimes there are multiple designs that include different features, in which case the design that has the most effective and necessary components would be the better design.

Read the article found here: John and Main tops the list of Hamilton's most dangerous intersections for pedestrians

Does their definition of "worst" match up with yours? Is it possible to create an intersection with zero collisions? If so, what would it look like?

> The article measures the dangerousness of intersections by the number of collisions resulting in injuries and deaths occurring at the intersections. We believe his straightforward metric is a good representation of whether an intersection is "better" or "worse", especially from a safety perspective, although a full picture would include other metrics such as the average traffic and wait times at the intersection. Creating an intersection with no collisions is not a realistic goal, as not all human error can be accounted for; however, with fully self-driving vehicles, it would be much more realistic to get very close to zero collisions.

As a group, discuss which project option interests you more: the highway or the intersection. For the remainder of the course/project, you will focus on **only one of the two options**. In the box below declare which project option you wish to proceed with and give a justification as to why your group chose one over the other.

5

ENGINEER 2PX3: INTEGRATED ENGINEERING DESIGN PROJECT 2 — McMaster University

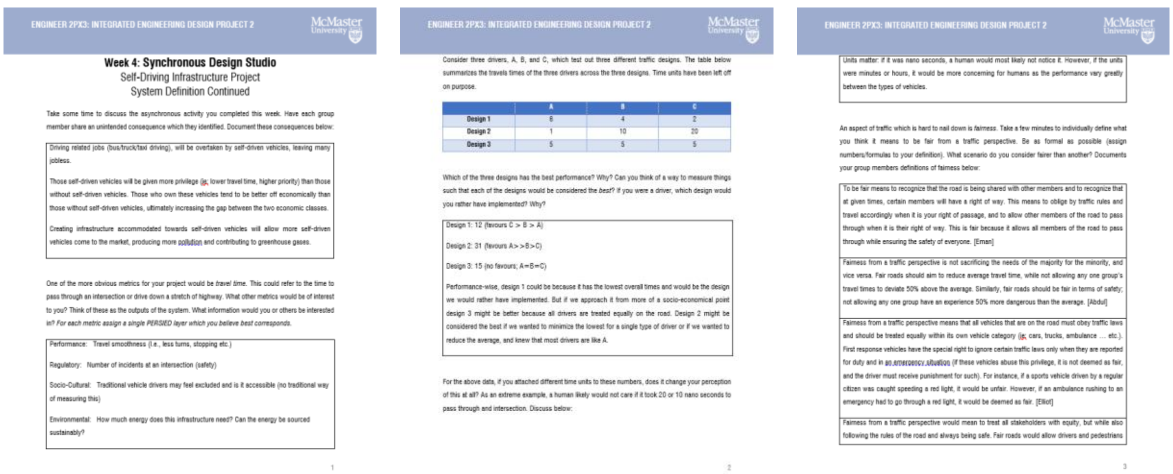
> As a group, we are more interested in exploring the **intersection**. Firstly, we use the intersection more frequently in our daily lives compared to the highway. This means that our personal understanding of the intersection is greater than our understanding of the highway, meaning that we would be able to draw from our experiences much better. Intersections also have more stakeholders involved and aspects that can be changed (e.g., stop signs, traffic lights, crosswalks, turning lanes etc.). This gives us more areas where we can potentially improve them. Another criterion that we can examine includes the many accidents that take place at intersections. Our group can focus on reducing these numbers and using the number of accidents that take place at the intersection as a merit.

Submission Instructions

1. Upload a ***.PDF** copy of the Wk-3 - Synchronous Design Studio 3 Worksheet to the Avenue Dropbox titled **Synchronous Design Studio Week 3** by Jan 30th
   - Use the following naming convention: **Tut06_Team17_SynchDS3.pdf**

6

Figure 14-19: Synchronous Design Studio worksheets week 3



ENGINEER 2PX3: INTEGRATED ENGINEERING DESIGN PROJECT 2 — McMaster University

Week 4: Synchronous Design Studio
Self-Driving Infrastructure Project
System Definition Continued

Take some time to discuss the asynchronous activity you completed this week. Have each group member share an unintended consequence which they identified. Document these consequences below:

> Driving related jobs (bus/truck/taxi driving), will be overtaken by self-driven vehicles, leaving many jobless.
>
> Those self-driven vehicles will be given more privilege (ie; lower travel time, higher priority) than those without self-driven vehicles. Those who own these vehicles tend to be better off economically than those without self-driven vehicles, ultimately increasing the gap between the two economic classes.
>
> Creating infrastructure accommodated towards self-driven vehicles will allow more self-driven vehicles come to the market, producing more pollution and contributing to greenhouse gases.

One of the more obvious metrics for your project would be *travel time*. This could refer to the time to pass through an intersection or drive down a stretch of highway. What other metrics would be of interest to you? Think of these as the outputs of the system. What information would you or others be interested in? *For each metric assign a single PERSIED layer which you believe best corresponds.*

> Performance: Travel smoothness (I.e., less turns, stopping etc.)
>
> Regulatory: Number of incidents at an intersection (safety)
>
> Socio-Cultural: Traditional vehicle drivers may feel excluded and is it accessible (no traditional way of measuring this)
>
> Environmental: How much energy does this infrastructure need? Can the energy be sourced sustainably?

1

ENGINEER 2PX3: INTEGRATED ENGINEERING DESIGN PROJECT 2 — McMaster University

Consider three drivers, A, B, and C, which test out three different traffic designs. The table below summarizes the travels times of the three drivers across the three designs. Time units have been left off on purpose.

	A	B	C
Design 1	6	4	2
Design 2	1	10	20
Design 3	5	5	5

Which of the three designs has the best performance? Why? Can you think of a way to measure things such that each of the designs would be considered the *best*? If you were a driver, which design would you rather have implemented? Why?

> Design 1: 12 (favours C > B > A)
>
> Design 2: 31 (favours A>>B>C)
>
> Design 3: 15 (no favours; A=B=C)
>
> Performance-wise, design 1 could be because it has the lowest overall times and would be the design we would rather have implemented. But if we approach it from more of a socio-economical point design 3 might be better because all drivers are treated equally on the road. Design 2 might be considered the best if we wanted to minimize the lowest for a single type of driver or if we wanted to reduce the average, and knew that most drivers are like A.

For the above data, if you attached different time units to these numbers, does it change your perception of this at all? As an extreme example, a human likely would not care if it took 20 or 10 nano seconds to pass through and intersection. Discuss below:

2

ENGINEER 2PX3: INTEGRATED ENGINEERING DESIGN PROJECT 2 — McMaster University

> Units matter: if it was nano seconds, a human would most likely not notice it. However, if the units were minutes or hours, it would be more concerning for humans as the performance vary greatly between the types of vehicles.

An aspect of traffic which is hard to nail down is *fairness*. Take a few minutes to individually define what you think it means to be fair from a traffic perspective. Be as formal as possible (assign numbers/formulas to your definition). What scenario do you consider fairer than another? Documents your group members definitions of fairness below:

> To be fair means to recognize that the road is being shared with other members and to recognize that at given times, certain members will have a right of way. This means to oblige by traffic rules and travel accordingly when it is your right of passage, and to allow other members of the road to pass through when it is their right of way. This is fair because it allows all members of the road to pass through while ensuring the safety of everyone. [Eman]
>
> Fairness from a traffic perspective is not sacrificing the needs of the majority for the minority, and vice versa. Fair roads should aim to reduce average travel time, while not allowing any one group's travel times to deviate 50% above the average. Similarly, fair roads should be fair in terms of safety; not allowing any one group have an experience 50% more dangerous than the average. [Abdul]
>
> Fairness from a traffic perspective means that all vehicles that are on the road must obey traffic laws and should be treated equally within its own vehicle category (ie; cars, trucks, ambulance .... etc.). First response vehicles have the special right to ignore certain traffic laws only when they are reported for duty and in an emergency situation (if these vehicles abuse this privilege, it is not deemed as fair, and the driver must receive punishment for such). For instance, if a sports vehicle driven by a regular citizen was caught speeding a red light, it would be unfair. However, if an ambulance rushing to an emergency had to go through a red light, it would be deemed as fair. [Elliot]
>
> Fairness from a traffic perspective would mean to treat all stakeholders with equity, but while also following the rules of the road and always being safe. Fair roads would allow drivers and pedestrians

3

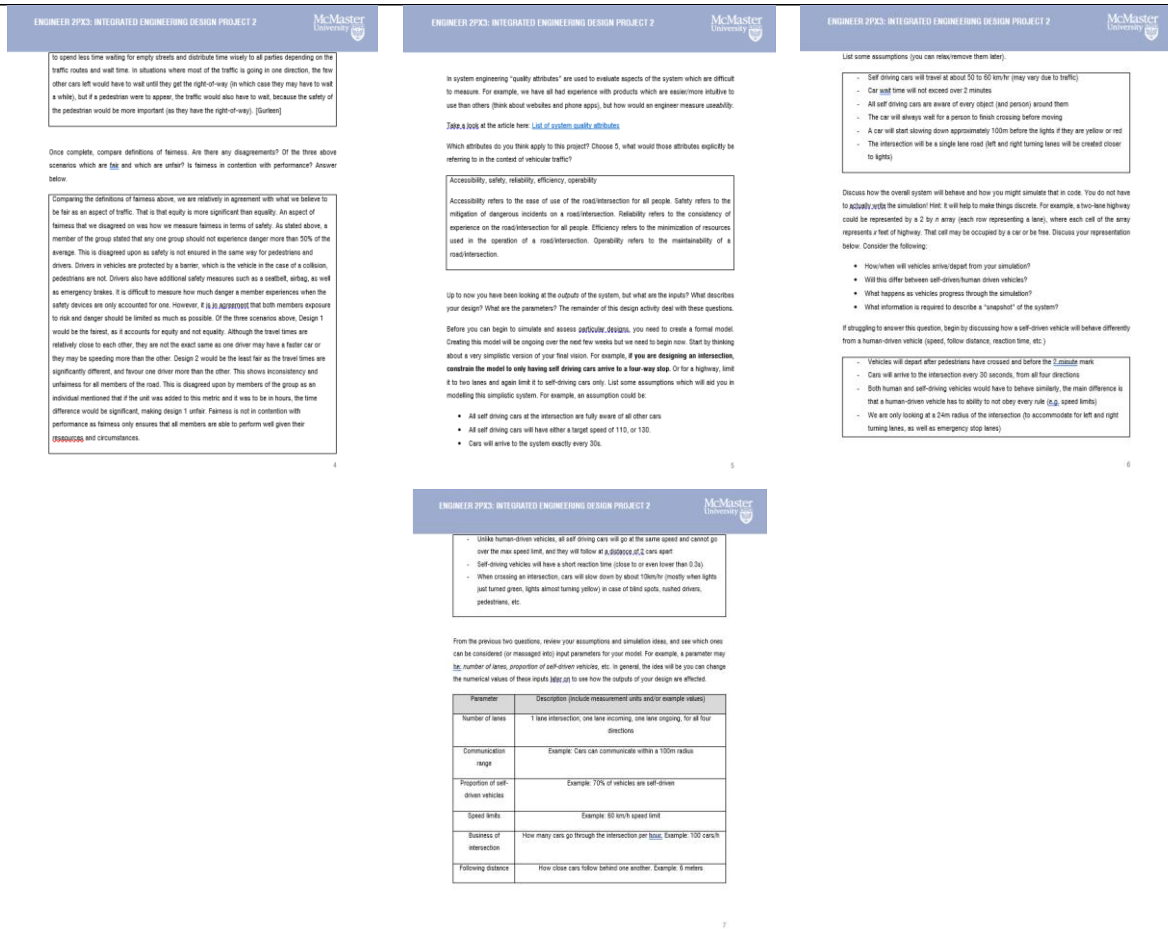
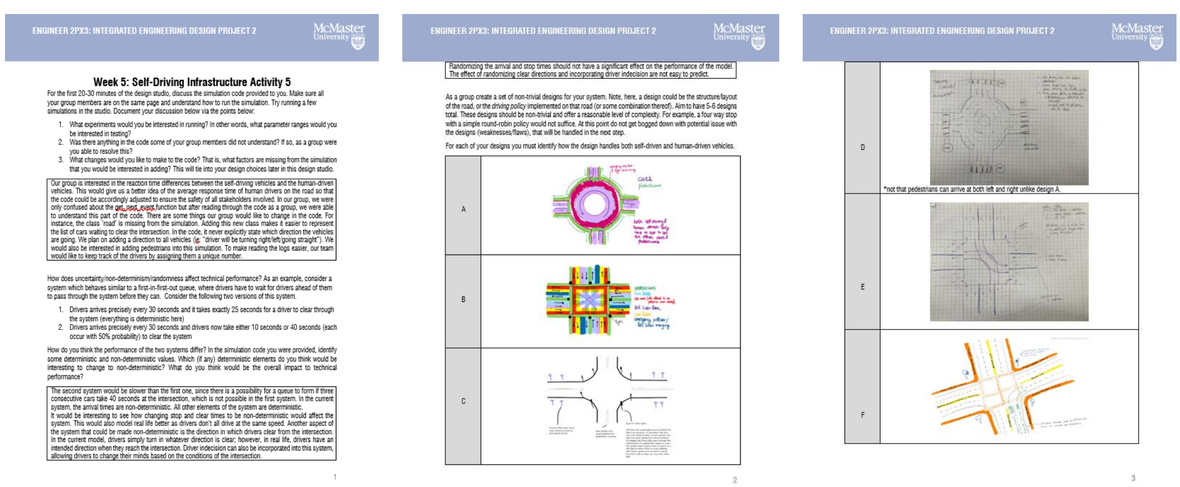


Figure 20-26: Synchronous Design Studio worksheets week 4



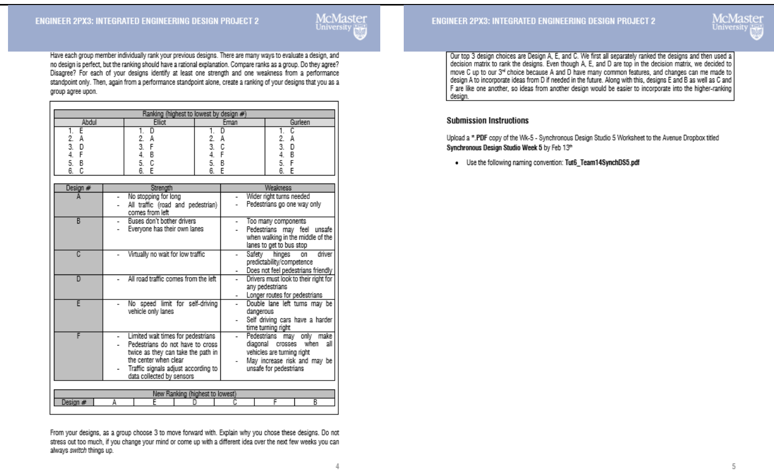


Figure 27-31: Synchronous Design Studio worksheets week 5

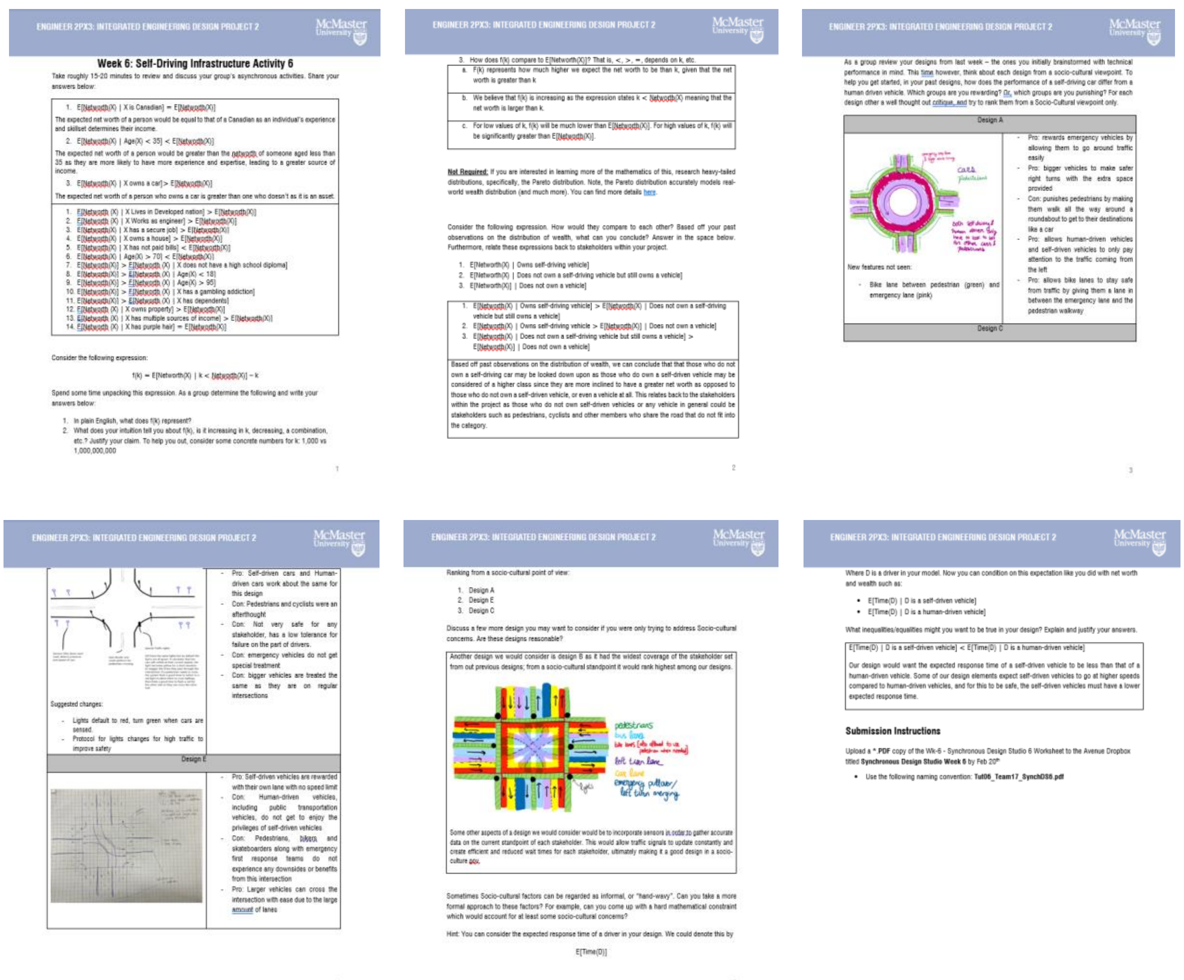


Figure 32-37: Synchronous Design Studio worksheets week 6

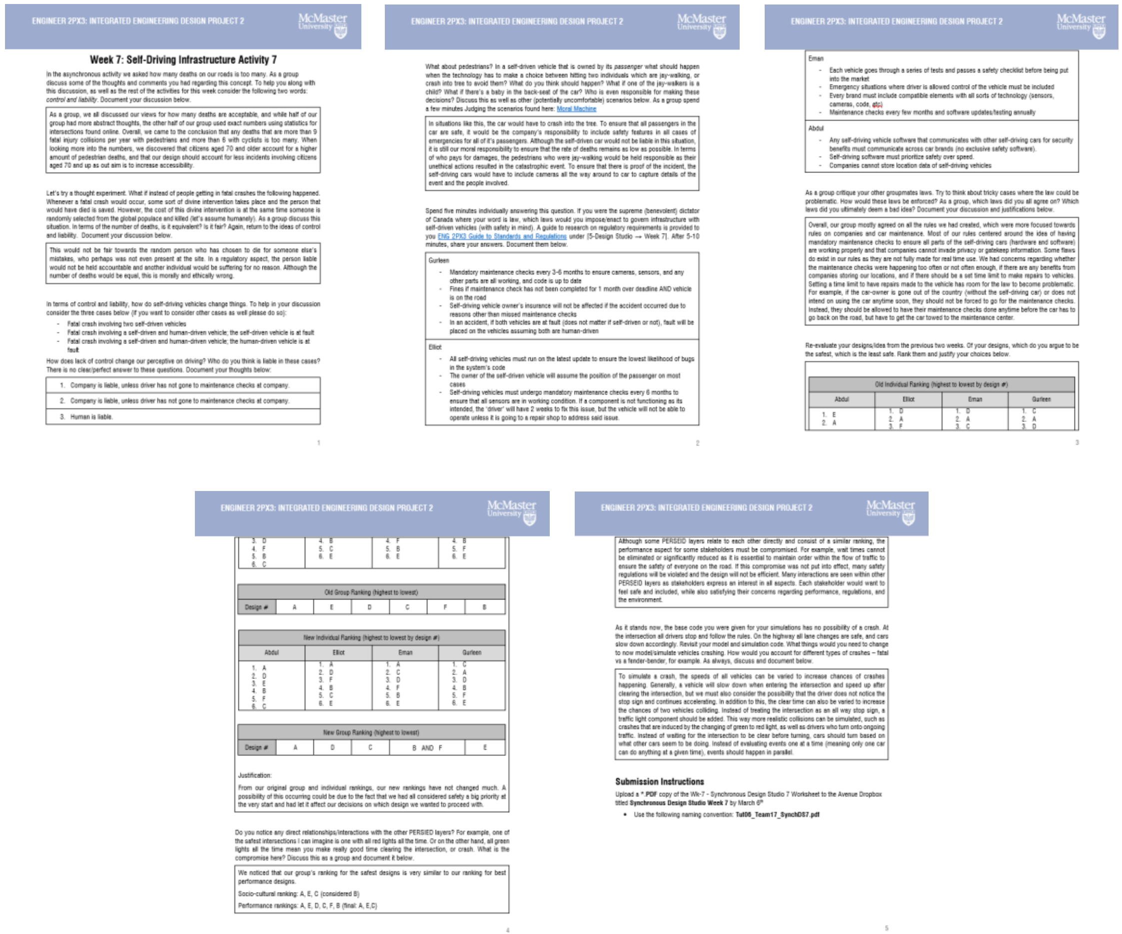
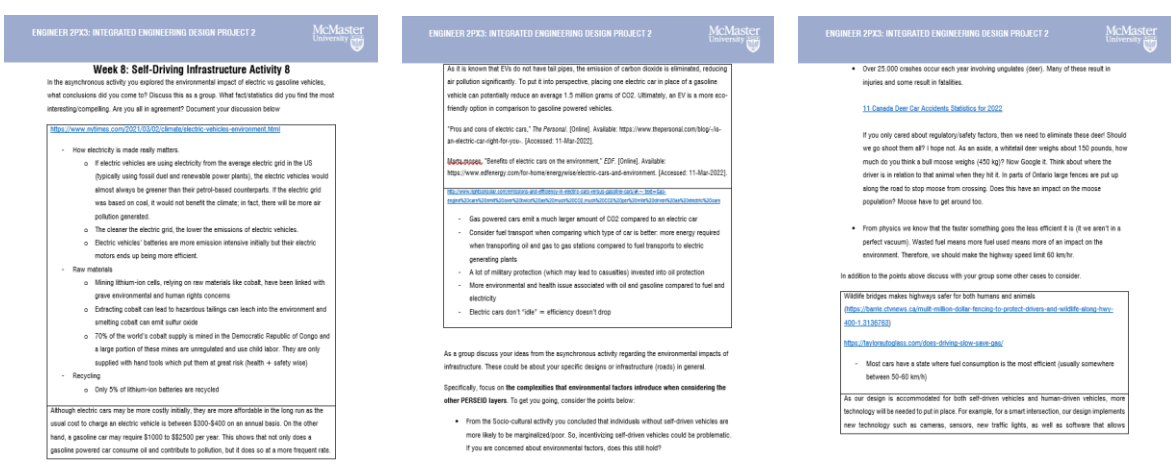


Figure 38-42: Synchronous Design Studio worksheets week 7



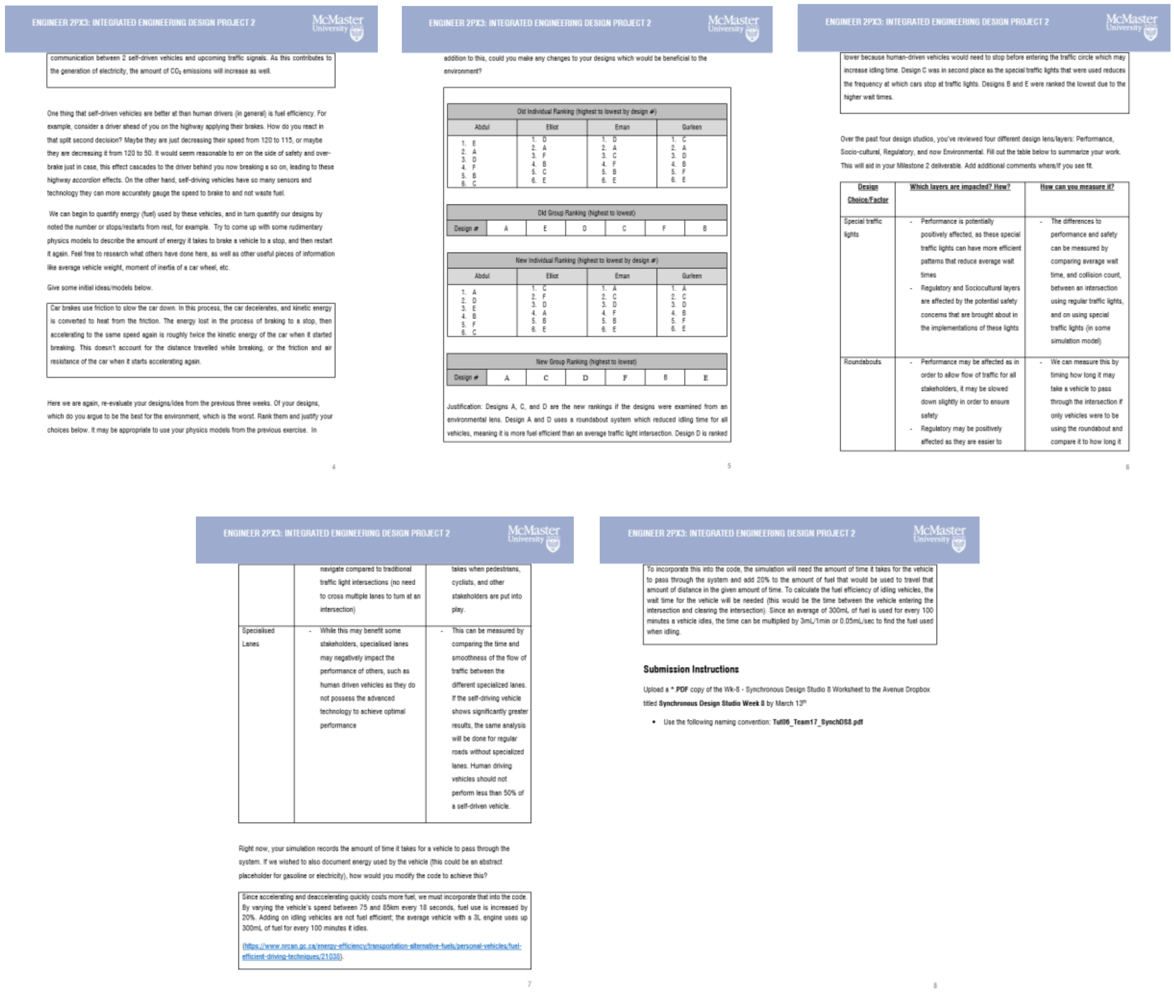
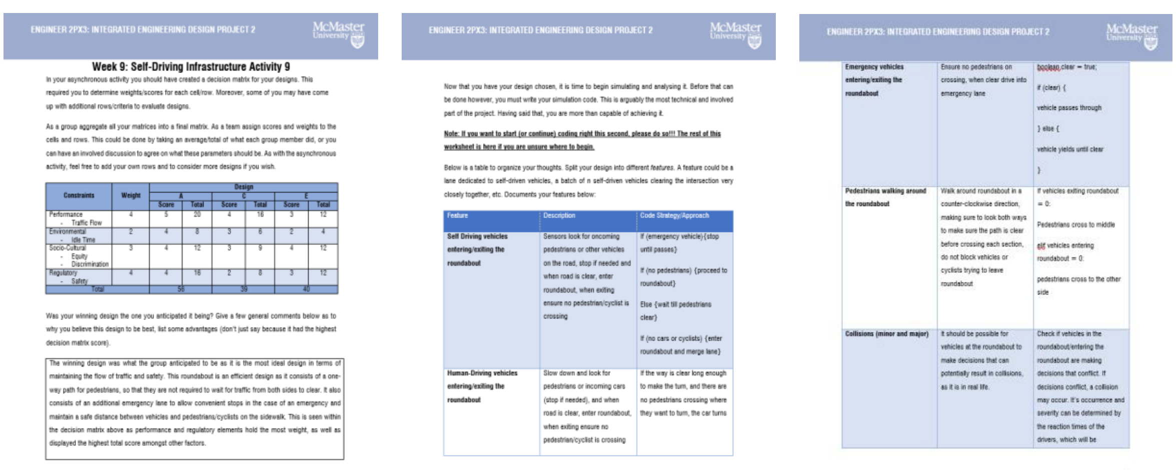


Figure 43-50: Synchronous Design Studio worksheets week 8



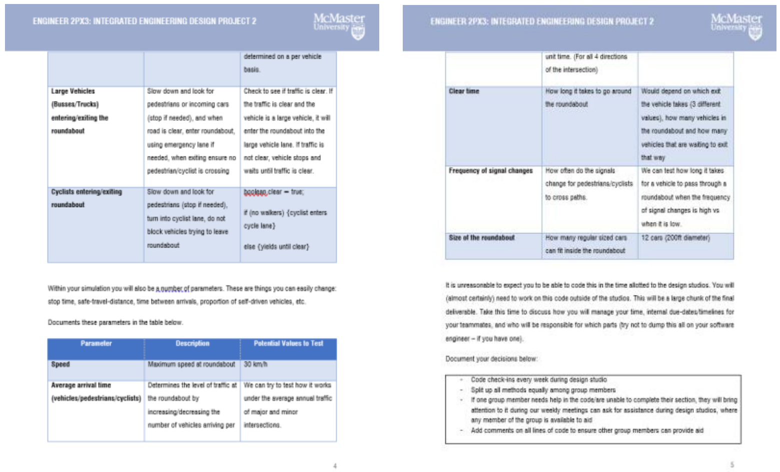


Figure 51-55: Synchronous Design Studio worksheets week 9

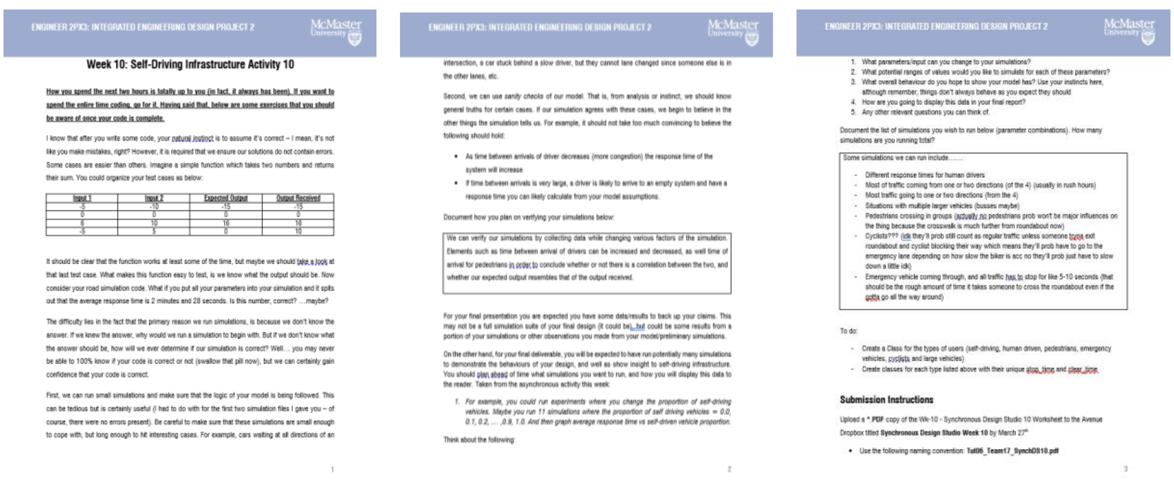


Figure 56-58: Synchronous Design Studio worksheets week 10

Table 1: The clear times for a roundabout versus a roundrobin provided by our simulation code

Mean Arrival Time (seconds)	Clear Time (seconds)	
	Roundabout	Roundrobin
0.4	1745.038334	561.236529
0.5	2071.8782	56.06049395
0.6	2415.088635	20.34113177
0.7	2666.793432	15.77062294
0.8	2959.009569	13.68406319
0.9	3160.798488	13.3159684
1	3349.399905	12.61923808
2	3388.294237	12.14748525

3	113.7515083	11.8370163
4	7.564806388	11.75122488
5	6.817137199	11.65096981

Table 2: The design matrix ranking for our 6 designs as seen through the performance layer

Team Members' Scores	Team Members Scores					
	A	**B**	**C**	**D**	**E**	**F**
Abdul	5	2	1	4	6	3
Elliot	5	3	2	6	1	4
Eman	5	2	4	6	1	3
Gurleen	5	3	6	4	1	2
Total	**20**	**10**	**13**	**20**	**9**	**12**

Table 3: The design matrix ranking for our 6 designs as seen through the regulatory layer

Team Members' Scores	Team Members Scores					
	A	**B**	**C**	**D**	**E**	**F**
Abdul	6	3	1	5	4	2
Elliot	6	3	2	5	1	4
Eman	6	2	5	4	1	3
Gurleen	5	3	6	4	1	2
Total	**23**	**11**	**14**	**18**	**7**	**11**

Table 4: The design matrix ranking for our 6 designs as seen through the environmental layer

Team Members' Scores	Team Members Scores					
	A	**B**	**C**	**D**	**E**	**F**
Abdul	6	3	1	5	4	2
Elliot	3	2	6	4	1	5
Eman	6	2	5	4	1	3
Gurleen	6	3	5	4	1	2
Total	**21**	**12**	**17**	**17**	**7**	**12**

Table 5: The final design matrix for our top 3 designs that considers all PERSIED layer constraints

Constraints	Weight	Design					
		A		**C**		**E**	
		Score	**Total**	**Score**	**Total**	**Score**	**Total**

Performance - Traffic Flow	4	5	20	4	3	3	12
Environmental - Idle Time	2	4	8	3	6	4	4
Socio-Cultural - Equity - Discrimination	3	4	12	3	9	4	12
Regulatory - Safety	4	4	16	2	8	3	12
Total		**56**		**39**		**40**	