BDA450 W23 Project

Due date: April 19th, 11:59pm

This is a GROUP assignment. Teams have been formed as discussed in class, and posted on the course page. Submit your code, and one PDF document for your report (i.e., only one person will submit for your team!) in Learn. The names and student ID numbers of all group members on the cover page.

All members of a group will receive the same grade. Only in extraordinary cases will exceptions be made—in particular, if you were assigned to a group and a group member did not communicate/participate at all. In these cases, a group member's mark may be lowered, but do not expect other members' marks to increase.

The work that you complete and submit must be that of your own group, not the work of others. It is permissible to discuss the assignment with members of other groups in general terms, discuss general approaches to problems, help someone to understand a concept or give them a bit of advice if they have a problem, etc. However, you are not permitted to 'work together' with other groups, nor to give/receive solutions (whether partial or complete) to/from other groups.

If you are unclear at all about what is permissible, please ask your professor.

Despite the fact that we will not be having in-person classes at this time, I am still available to you for assistance. If you need help, contact me. There are numerous ways that we can connect (ones that are more fully-featured than simple email/telephone).

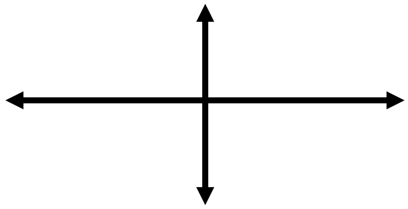
Late submissions will not be accepted.

Scenario

You are working in the traffic operations and planning department for a medium-sized city. As the population has grown, traffic has increased in the periphery of the city. With this increase, many of the existing roads and intersections do not have sufficient capacity.

As your department examines the best ways to increase capacity (within the constraints of your budget), you are using simulation to investigate efficiency. In particular, you are looking at intersections that had light traffic in the past, and to date have only had stop signs. You wish to explore which choice is more efficient: traffic lights or roundabouts.

In this simulation, you will consider one particular simple intersection where two roads cross. While the roads are currently single-lane in both directions, you plan to widen both roads to four lanes (two lanes in each direction), so your study should reflect this.



The speed limit in the area is 60 km/h, but of course, people may have to stop or slow down when making turns, waiting for traffic to clear, etc.

You have been provided with a data file showing traffic counts for a typical week-day. The file breaks down the traffic counts for each hour of the day. It also breaks down the data by the direction of travel[1] of cars entering the intersection, and by whether cars went straight through the intersection, turned left, or turned right. Most of the people driving through the area are commuters travelling to and from work, and you will notice these patterns reflected in the data.

There are no other intersections close enough to impact your analysis here. As such, you can model the intersection in isolation (using just the traffic flows in/out), without considering issues such as traffic jams exiting the area or the interaction between your choices and the timing of other intersections.

Task

You job is to build simulator(s) for traffic flow through the intersection, with two issues of concern:

- The amount of time taken for drivers to pass through the area, and in particular the amount of time spent by each driver waiting.
- The amount of CO_2 pollution generated by the cars, which is related to both the amount of waiting time, and stopping/accelerating.

You must simulate (separately) the intersection using a traffic light, and using a roundabout, so that the results can be compared.

Most people are well aware of the function of traffic lights. An excellent primer on the operation of roundabouts can be found at https://www.youtube.com/watch?v=46mOPz3rhHs.

Outputs from your simulation should include appropriate analysis/presentation of waiting times (e.g., average, standard deviation, percentiles, histogram, etc.) Pollution generated should be broken down by (at least) idling, acceleration, and 'normal' driving.

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[1] Not that the direction of travel indicates the direction the car is moving, *not* the direction from which the car entered the intersection. For example, a 'northbound' car is entering the intersection from the south.

Beyond simply building the simulation, you should also perform some investigation: how does the timing of the traffic light (how long it remains green in each direction) impact emissions and wait times (both average and extremes)? Based on your findings, can you recommend a particular set of timings?

For simplicity, you can assume that all vehicles are similar passenger cars, with reasonably similar drivers. The typical driver will accelerate at a rate of 6 km/h per second (meaning that it takes 10 second to accelerate from a stopped position to 60 km/h). Drivers will vary, however, in how quickly they accelerate; they will also vary in how quickly they begin to accelerate when the space/intersection in front of them is clear, how much space they will need in front of an oncoming car before pulling out in front of it, how late they will wait before braking (and thus, how quickly they will brake), etc.

You may assume that each car generates 1 g of CO_2 per second when idling, 2.5 g per second when travelling at constant speed, and 5 g per second when accelerating at the typical rate indicated above.[2] (This should probably be somewhat higher for a driver that accelerates quickly.) Very slow speed/distance movement (like moving the length of one car when the car ahead of you proceeds through a stop sign) can be treated as idle time.[3]

You will not have all of the information that you might like to have! In some cases, you will need to make reasonable assumptions or estimates (e.g., how long after a car goes through an intersection until another car can go through?) Some values of your model should be set as parameters, so you can experiment with them and/or calibrate your model.

One of your first, and most important, tasks will be to decide on the paradigm you will employ. This situation can successfully be implemented using discrete time or discrete event simulation, with or without agents. (Note that certain techniques, like agents, won't be introduced until after the break.) Think carefully about the possible approaches and how they might apply to this situation, including issue such as:

- Natural correspondence to the scenario
- Ability to model the simulation realistically, and capture important, accurate data
- Ease of building the simulation, and building it correctly
- Computability of the simulation (how long will it take to run?)

You will also need to make decisions such as what degree of detail to model. A situation such as this might be modelled down to the detail of pressing the gas pedal and the brake pedal (and all of the physics involved), or as simple queues of arriving objects. You should choose a level of

[2] Emissions rates are loosely based on information contained in Zhai, Zhiqiang, et al. "Capturing the Variability in Instantaneous Vehicle Emissions Based on Field Test Data." *Atmosphere* 11.7 (2020): 765.

[3] Initially, it may seem that you only need to consider the area of the intersection itself. However, please note that we are interested in emissions due to acceleration, and it may take some time after exiting the intersection before the car is back up to speed (and has finished accelerating). As such, it is suggested that you take into account some length of road beyond the intersection when building your simulation.

detail that allows you to capture realistic, accurate data that you need, without unnecessarily complicating the situation. Depending on your choices, you may or may not use all of the information or address all of the issues discussed here.

You will need to consider all major issues discussed this term: choices of distributions, verification/validation/calibration, etc. Some of required tasks have not yet been covered at the time this project is assigned. You will be able to apply the material as it is covered in the second half of the course.

A caution: based on past projects, it may be tempting to build a simulation that is, for example, very visually appealing, but which runs too slowly to study the full scenario. Please be sure that your work addresses the relevant questions!

Requirements

You must submit your code; you must also submit a report including key data generated by the simulation (appropriately presented/analyzed). Beyond this, your report should also (briefly) explain and justify each aspect of your work, including:

- Your choice of your simulation paradigm;
- The architecture and design of your simulation;
- Choices of input distributions;
- Verification/validation/calibration;
- Limitations of your simulation.