BDA450 Final Project

Dr. Reid Kerr

April 20, 2022

Efat Gorji: 160504197

Ali Satari: 134986207

Victoria Villani: 124307208

Michael Uzoma: 140382185

**Data Generated from Simulation**

To avoid issues of initial transient, a steady-state start interval was graphically detected by running the simulation several times to determine when the warm-up period ends, and thus where the steady-state period begins.

**Note: the system is simulated separately for rush hours (4-7 am, 13-21 pm) and regular hours (all other times during the day) to reflect real-world traffic flow.**

*Rush Hour Average Waiting Time and Average Passing Time, Respectively*

**Chart, scatter chart

Description automatically generatedChart, line chart

Description automatically generated**

*Normal Hours Average Waiting Time and Average Passing Time, Respectively*

**Chart, line chart

Description automatically generated Chart

Description automatically generated**

\*\* Note that x-axis represents the number of drivers, and the y-axis represents waiting/passing times \*\*

Based on the graphical output, it was concluded that the steady-state period began at 150 drivers for rush hour and 10 drivers for normal hours. Therefore, the statistics generated from this simulation will ignore the warm-up period and will reflect the steady-state simulation for rush hours and normal hours.

|  |  |  |
| --- | --- | --- |
| **Statistics** | **Rush Hour** | **Normal Hours** |
| Distance between cars | 4 m | 4 m |
| Area average waiting time | 37.66 sec | 18.74 sec |
| Waiting time standard deviation | 27.03 sec | 20.09 sec |
| Minimum waiting time | 0 sec | 0 sec |
| Maximum waiting time | 76.52 sec | 62.34 sec |
| Q1:  Q2:  Q3: | 0 sec  50.60 sec  59.04 sec | 0 sec  12.51 sec  35.01 sec |
| Passing time | 51.44 sec | 31.16 sec |
| Idle emissions | 11204.85g | 2897.53g |
| Acceleration emissions | 4863.85g | 2105.42g |
| Normal driving emissions | 7802.71g | 3623.44g |

*Table 1: Simulation Statistics*

*Rush Hour Histogram Average Passing Time and Waiting Time, Respectively*

Chart, histogram

Description automatically generated Chart, histogram

Description automatically generated

*Rush Hour Histogram Average Passing Time and Waiting Time, Respectively*

Chart, histogram

Description automatically generated Chart, histogram

Description automatically generated

Based on the statistics generated from the simulation, average waiting time in the intersection area was greater in rush hour (37.66 sec) than it was during normal hours (18.74 sec). This is also true for the amount of time taken for vehicles to pass through the intersection, where average passing time for rush hour was 51.44 sec compared to 31.16 sec in normal hours. This can be seen in the histograms, as waiting times and passing times for rush hour show greater frequencies for larger time values.

Additionally, average emissions generation was greater in vehicles driving during rush hour. Specifically, during idling rush hour emissions generated 11204.85g of CO2 compared to 2897.53g for vehicles driving during normal hours. This trend can also be observed in acceleration and normal driving emissions, where vehicles travelling in rush hour generated 4863.85g and 7802.71g of CO2 compared to 2105.42g and 3623.44g for vehicles travelling during normal hours, respectively.

**Simulation Paradigm**

Discrete event simulation was selected to appropriately simulate traffic flow and accurately collect and generate data, while maintaining a relative level of simplicity. While discrete time can be an appropriate paradigm to simulate traffic flow, to implement the conditions in which the cars must stop, it felt appropriate to create Simpy Resources for these conditions. It did not seem appropriate to gather data at every time step, but rather collecting data about a vehicle’s waiting time and emissions as they exist in the simulation. This also allowed for simplicity in design, as vehicles can be queued as arriving objects and request to pass through intersection A or B based on the Resource and its conditions.

**Simulation Architecture and Design**

The simulation has been divided into two classes, the first class is to track and determine the behaviour relevant to the driver. This includes randomly determining drivers speed and their reaction time, and variables to track key data (total CO2 emissions during idle, acceleration, and normal driving). The second class initiates variables relative to both intersections and the area between them (425m). Note that all areas outside of those mentioned were ignored. The area class includes resource handling, triggering events manually (i.e., when the lights at intersection A turn green), and collecting important data that occurs while a vehicle spends time in the area.

***Resources***

***Intersection A****:* requests made here for vehicles to pass through intersection A (North/South & East/West lights). Red and green light times have been assumed according to the real-world traffic lights. Note that at the beginning of the simulation, the state of the traffic light state is unknown, and thus is determined randomly.

***Intersection B****:* set as a priority resource to mimic the actions of stop signs. Requests made here for priority 2 north and southbound travelling cars to yield until priority 1 east and westbound cars have cleared the way.

***Eastbound Road****:* this is referring to the area between intersection A and B (425m). The capacity for this road has been calculated by determining how many vehicles can fit in the space. The average car size is 4.5m and the distance between cars has been set as an argument so that the capacity of the road would be 425m/(4.5+distance) which is equal to 50 when the distance is equal to 4. Therefore, the capacity will constantly change based on the distance available. This is useful to avoid traffic jams and vehicles wishing to travel in this area when it is full.

***Westbound Road****:* identical logic as above, but of opposite roadside.

The following functions aid in supporting the simulation structure and will be briefly described here.

**Driver\_arrive():** responsible for initiating the queue of vehicle arrivals. These arrival times were set by randomly generating values based on the appropriate distribution and calculating the average. Arrival times have been divided into ‘rush hour’ and ‘normal hours.’ In addition, this function is responsible for defining which intersection each vehicle will enter and the direction as well as the turn the vehicle will choose. The intersection, direction, and turn selections for drivers upon arrival is based on the probability distributions calculated in a separate python program (submitted along with the main program and this report) based on the given dataset.

**Driver\_in\_A():** responsible for all vehicles received at intersection A. Based on the drivers’ direction, it will send a request to the to the intersection A lights and either leave the area or continue towards intersection B entering the area. If a driver intends to move toward intersection B, a request will also be sent to the road. The amount of waiting time and the gas emitted to the area will be calculated based on the drivers’ status. Once the vehicle reaches intersection B, a request is sent to the intersection B resource. Based on priority queues, vehicles travelling East/Westbound will be released through this intersection first.

**Driver\_in\_B():** This function acts similarly to the function above but covers the drivers entering from intersection B.

**Distribution Selection**

To determine the distribution of drivers’ arrival, the data related to drivers that arrived from out of the area (drivers arriving from directions 0, 1, or 2 to intersection A, and drivers arriving from directions 3, 4, or 5 to intersection B) have been considered for distribution detection in both rush and regular hours. Thus, it was observed that the distribution of driver arrivals in rush hours is “foldcauchy” and the distribution of driver arrivals in regular hours is “johnsonsu” according to the given dataset. In addition, when observing the density plot of both distributions and finding their similarity with the “poisson” density plot and noting that inter arrival times typically follow exponential distribution, a similar approach was used in this scenario. Further, in selecting an intellectual average (lambda) for the exponential distribution, the averages of random values generated from both “foldcauchy” and “johnsonsu” distributions were calculated. Upon completion of the above steps, as well as attempting to reflect the real world, interarrival times were set to 5 and 2 for regular and rush hours, respectively.

**Verification/Validation/Calibration**

Distance between cars was set as a parameter in order to calibrate the program appropriately. Because this value can be easily adjusted in the real world to limit waiting time and pollution emissions, it felt suitable to set distance between cars as a parameter.

To calibrate this parameter, different values were selected to average waiting time, average passing time, pollution generated in the area during the simulation time. Thus, the range (3m, 6m) inclusive have been selected as calibration values for distance.

When observing the output during rush hour, when distance between cars is 3m, waiting time is low but pollution is high. Therefore, this is not an ideal situation.

After observing all the output information generated from the range (3m, 6m), 4m was selected as an ideal distance during rush hour, where 5m was selected as the most appropriate distance during regular hours. However, assigning different distancing rules for different hours of the day is not a realistic approach. Therefore, to generate an acceptable waiting time and pollution emissions, a distance of 4m was set for regular hours as well. In conclusion, 4m between vehicles in the area is an appropriate value for this simulation.

**Traffic Light Timing Investigation Recommendations ‎**

Through various trials for testing multiple values for greenlight time duration and redlight time ‎duration to determinate the lowest average waiting time and pollution emissions, the ‎following conclusions were made: ‎

The most efficient time for rush hours:‎

The values of green light time = 25sec and red light time = 55 sec, results in an average rush ‎hour wait time of 26.823 sec and an average pollution of 7367.5g

The most efficient times for regular hours:‎

The values of green light time = 30 sec and red light time = 40 sec, results in an average regular ‎hour wait time of 10.311 sec and an average pollution of 2057.10g

Because traffic lights are typically dependent on traffic, these times are appropriate to ‎implement into a simulation. ‎

**Simulation Limitations**

Despite many efforts to make this simulation closely reflect reality, there are some limitations about this program and improvements in these areas would result in a better simulation with more reliable results. The disadvantages points of this simulation include, but not limited to, ignoring weather conditions, U-turns, pedestrians, potential car crashes, the emergency vehicles that should be given priority to pass, breaking rates, traffic light changes dependent on traffic, and so on.