Traffic Model Simulation

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Abstract

This paper examines a traffic model created to simulate a red light intersection with three different traffic lanes. The model was run with various traffic patterns and red light configurations. The ultimate goal of the model is to determine various factors that impact the length of time it takes cars to get through the intersection. The main factor this model researched was how long a green light is open for a particular direction of traffic. This included both the duration, as well as the proportion of time a green light was open to a lane relative to the proportion of total traffic that lane saw. The conclusions of the model simulation runs show a consistent relationship between the duration of a green light and the average time it takes all cars to make it through the intersection. Across multiple traffic conditions, increasing the time a green light is open to a direction of traffic decreases the average wait time per car, therefore increasing the number of cars that can make it through an intersection in a given time period. The model simulation runs also show that traffic lights should give longer green light times to the lanes of traffic that have more traffic. This decreases the average wait time per car and increases the number of cars that make it through an intersection in a given time period. This paper will go into the motivation for the model, how it was created in the Julia programming language, and the results the model produced under various circumstances.

Introduction

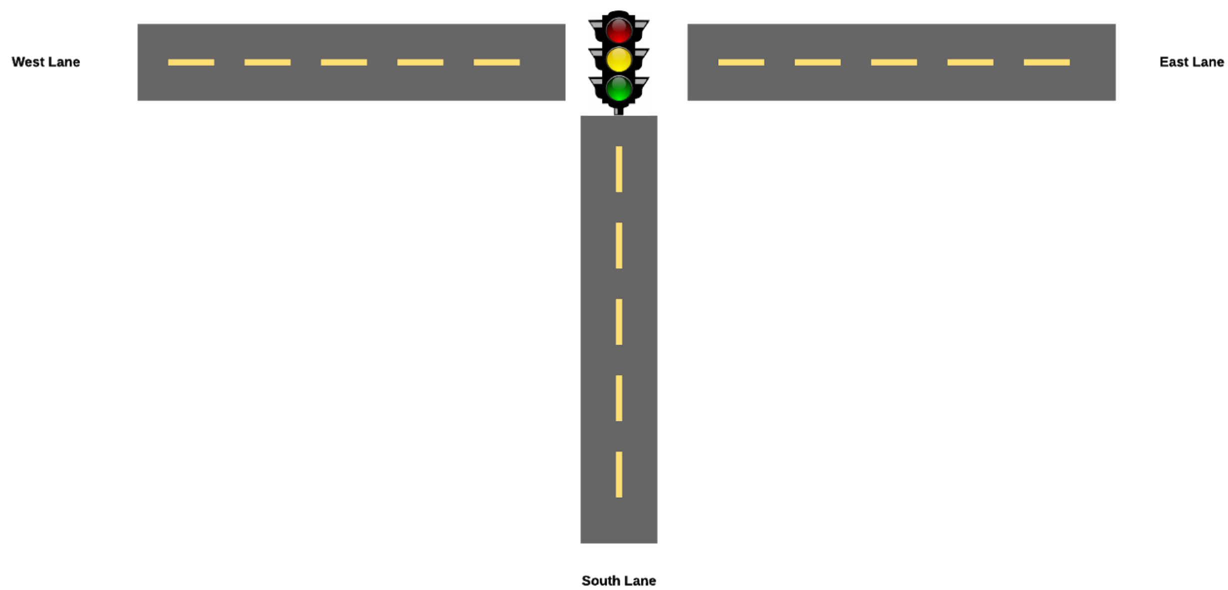
Traffic light intersections are a common pain point for people in life. People just want to travel to their destination with minimal time waiting at an intersection. Traffic intersections, however, experience different traffic patterns throughout the day. Most research into traffic modeling focuses on either the safety of an intersection (minimizing accidents/collisions) or modeling traffic patterns with networks of traffic lights. This paper, however, focuses on a singular intersection.

In order to optimize an intersection's traffic light configuration such that cars are waiting the minimal amount of time, multiple traffic patterns and configurations are needed. This paper will first introduce the model and assumptions, then examine three categories of simulations. The first category looks into moderate traffic that is equal for every lane in the intersection. The second category looks into heavier traffic that is also equal for every lane in the intersection. The last category of simulations look into varying traffic patterns for different lanes.

The Model

The Intersection

For all simulations in this study, the same intersection is used. The intersection consists of three lanes: West, South, and East.



Assumptions & Simplifications

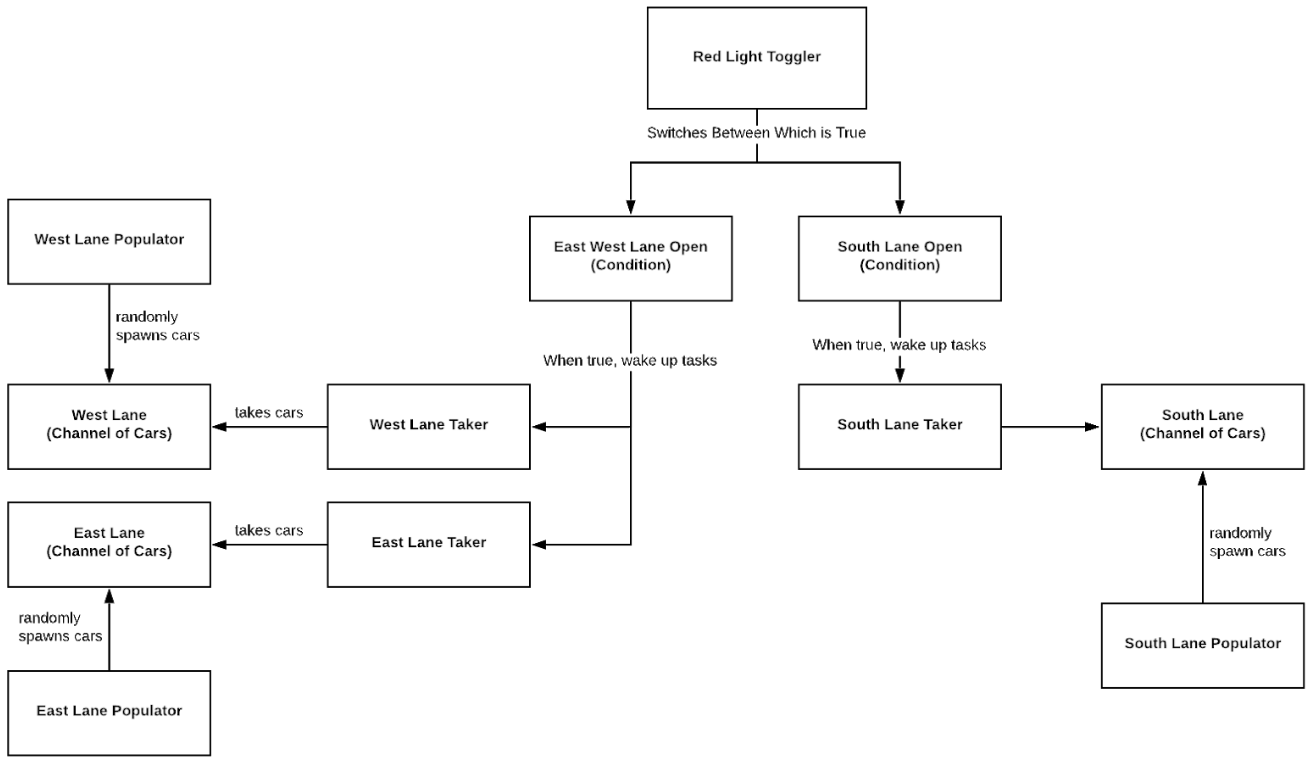
In order to model this study, multiple assumptions and simplifications were made.

Assumption	**Rationale**
All cars respect the signal of the red light	This model does not have any logic for handling accidents, and while red light running does happen in real life, it would complicate the model.
Cars cannot turn on red	This would complicate the model as some cars would be able to make it through the

	light when the light is red.
Cars cannot turn left	This would complicate the model as cars traveling in the same direction would need to signal to each other the lane is clear, or there would need to be a green arrow.
It takes 2 seconds for the light to switch lanes of traffic	No yellow light logic was in the model, so to make up for this, 2 seconds were elapsed when the traffic light switched which lane was open.
Cars accelerate at a constant rate of 0.5 seconds per car	Since the lanes were a shared resource and only know if they can move or not, it would be very difficult to model a non-linear acceleration
At the beginning of the simulation, no traffic exists	This was to simplify the model and given a definite “start” where all spawners/takers/red light tasks start at once
All simulations runs were run on rseed 1	Since there is some inherent randomness with asynchronous functions, the random variable of spawning cars was controlled to seed 1 for all simulations
Per lane direction, there is only one lane of traffic	While this model could be extended to multiple lanes, to simplify the logic and to simplify the interpretation of the results.
The model runs for 10 minutes	This duration gives enough time for traffic to build up, while also giving enough time for the red light to switch lanes enough times

Modeling Concurrency

In order to model this simulation in the Julia Programming Language, multiple tasks were running asynchronously. In order to share resources (such as the cars) between the running tasks, Julia Channels were used. In order to control which lane was open, Julia Conditions were used.



Model Constant

Parameter Name	**How it is Used**
SIMULATION_DURATION	How long the simulation should run. This was set to 600 (10 minutes) for all simulations.
RED_LIGHT_LATENCY	How long no cars can go through the intersection when the light changes. This was set to 2 seconds for all simulations.
TIME_BETWEEN_CARS	How long does it take a car to go through the intersection when the light is green for the given traffic lane. This was set to 0.5 seconds for all simulations.

Model Parameters

Parameter Name	How it is Used
rseed	Which seed to set Julia's random function to. For this model, it was set to 1 for all simulations
east_lane_population_coefficient, west_lane_population_coefficient, south_lane_population_coefficient	These coefficients were used to determine how long it should take for a car to spawn in the corresponding lane. The larger the coefficient, the longer it would take for a car to spawn.
east_west_lane_green_light_time	How long the light stays green for the east/west lanes of traffic (seconds)
south_lane_green_light_time	How long the light stays green for south lane of traffic (seconds)

Results

Moderate Traffic Equal Times for all Lanes

The first few simulations were run to see what impact the duration of a green light had on traffic when all lanes of traffic were being populated with the same coefficient value of 2. A coefficient value 2 represents a moderate level of traffic where, on average, a car is spawned every 1 second per traffic lane.

Model Parameters	Average Time per Car	Total Num Cars Thru
rseed = 1 east_lane_population_coefficient = 2 west_lane_population_coefficient = 2 south_lane_population_coefficient = 2 east_west_lane_green_light_time = 20 south_lane_green_light_time = 20	51.63 seconds	1525
rseed = 1 east_lane_population_coefficient = 2	45.08 seconds	1594

west_lane_population_coefficient = 2 south_lane_population_coefficient = 2 east_west_lane_green_light_time = 40 south_lane_green_light_time = 40		
rseed = 1 east_lane_population_coefficient = 2 west_lane_population_coefficient = 2 south_lane_population_coefficient = 2 east_west_lane_green_light_time = 60 south_lane_green_light_time = 60	46.51 seconds	1619
rseed = 1 east_lane_population_coefficient = 2 west_lane_population_coefficient = 2 south_lane_population_coefficient = 2 east_west_lane_green_light_time = 80 south_lane_green_light_time = 80	53.50 seconds	1628

Heavy Traffic Equal Times for all Lanes

The next round of simulations were run to see what impact the duration of a green light had on traffic when all lanes of traffic were being populated with the same coefficient value of 1. A coefficient value of 1 represents a heavy amount of traffic where, on average, a car is spawned every 0.5 seconds per traffic lane.

Model Parameters	**Average Time per Car**	**Total Num Cars Thru**
rseed = 1 east_lane_population_coefficient = 1 west_lane_population_coefficient = 1 south_lane_population_coefficient = 1 east_west_lane_green_light_time = 20 south_lane_green_light_time = 20	167.44 seconds	1561
rseed = 1 east_lane_population_coefficient = 1 west_lane_population_coefficient = 1 south_lane_population_coefficient = 1 east_west_lane_green_light_time = 40 south_lane_green_light_time = 40	156.81 seconds	1671
rseed = 1 east_lane_population_coefficient = 1 west_lane_population_coefficient = 1	151.63 seconds	1736

south_lane_population_coefficient = 1 east_west_lane_green_light_time = 60 south_lane_green_light_time = 60		
rseed = 1 east_lane_population_coefficient = 1 west_lane_population_coefficient = 1 south_lane_population_coefficient = 1 east_west_lane_green_light_time = 80 south_lane_green_light_time = 80	149.61 seconds	1780

Different Traffic Patterns for Different Lanes

The last set of simulations this model examined were when traffic varied between lanes. In all results below, the traffic coefficients for the east and west lane were 1, meaning on average a car spawned in each lane every 0.5 seconds (on average), and the the coefficient for the south lane was 4, meaning a car spawned in the south lane every 2 seconds (on average).

Model Parameters	**Average Time per Car**	**Total Num Cars Thru**
rseed = 1 east_lane_population_coefficient = 1 west_lane_population_coefficient = 1 south_lane_population_coefficient = 4 east_west_lane_green_light_time = 40 south_lane_green_light_time = 40	115.03	1414
rseed = 1 east_lane_population_coefficient = 1 west_lane_population_coefficient = 1 south_lane_population_coefficient = 4 east_west_lane_green_light_time = 80 south_lane_green_light_time = 40	89.66	1860
rseed = 1 east_lane_population_coefficient = 1 west_lane_population_coefficient = 1 south_lane_population_coefficient = 1 east_west_lane_green_light_time = 160 south_lane_green_light_time = 40	60.68	2115
rseed = 1 east_lane_population_coefficient = 1 west_lane_population_coefficient = 1	71.71	2063

south_lane_population_coefficient = 1 east_west_lane_green_light_time = 80 south_lane_green_light_time = 20		

Conclusions

Moderate Traffic Equal Times for all Lanes

As shown by the data, a lower average time per car can be achieved by increasing the time a given traffic direction has a green light. At first this seemed counterintuitive, however given that every time the light switches, there is time where no cars make it through the intersection. Therefore, when the lane has been open for long enough, the time is minimized where no cars go through. This effect, however, does reach diminishing returns, as shown by the light times of 60 and 80 seconds. Both of these show increasing average car times. This makes sense as if you have cars waiting for long enough, traffic backs up, and the benefit from having a flow of traffic is outweighed by the cost of traffic in the other lane backing up.

Heavy Traffic Equal Times for all Lanes

A similar effect is shown with the moderate traffic simulations, where more time open per green light leads to less car time in a lane. This effect is stronger when the traffic is heavier (cars are spawning more frequently). This makes sense as with heavier traffic, a longer flow of traffic makes more cars go through. Again, this does see a diminishing return as the green light time increases.

Different Traffic Patterns for Different Lanes

The first simulation run in this section was to provide a base. When the east/west direction is populating 4x more frequently than the south direction, yet all lanes have the same green light time, the average car time is the highest and the least amount of cars go through the intersection. The other simulations in this set gave more time to the heavier traffic direction, which as expected, resulted in less car time average and more cars going through. The more time favored to the heavier trafficked lanes shows more cars going through and less car time averages. This again is expected. One interesting point in this data set is comparing the last two rows. They both have the same proportion of green light time (160/40 and 80/20). With that said, the 160/40 timing showed more cars going through and less car timing on average. This could be explained by the effect examined in the first two data sets, where more green light time leads to more cars going through (as red light switches where no cars are going through is minimized).

References

As mentioned in the introduction, most traffic modeling research was mostly focused on collision prevention or a network of traffic lights. For those reasons, this paper did not reference any existing modeling research.

This paper did however use the Julia Programming language to run the models. Julia can be found and downloaded at https://julialang.org/

Appendix Items

Sensitivity Analysis Runs

In order to analyze the sensitivity of the model, a few simulations were run with modified base parameters.

Modifying SIMULATION_DURATION

When the simulation was run for just 1 minute, rather than 10 minutes, the model results were heavily dependent on which lane was first opened. This is because the simulation did not have enough time to switch back and forth between lanes.

Modifying RED_LIGHT_LATENCY

When the simulation was run with a RED_LIGHT_LATENCY of 0.1, rather than 0.5, the impact of the traffic lights was not seen as heavily. This is because as soon as the lane opens, almost all of the cars go through it.

Modifying TIME_BETWEEN_CARS

Modifying the time between cars can cause the simulation to go into a race condition, where the lane could be open to two different directions at once. As long as TIME_BETWEEN_CARS is greater than the RED_LIGHT_LATENCY, the model will not hit this condition.