Modelling, Simulation, and Optimization for Traffic Control

Modelling, Simulation, and Optimization
Continous Assessment - 1
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Project Report

***Abstract*—This paper represents the project report for the module Modelling, Simulation, and Optimization. The project consists of the traffic control mechanism where the vehicle data was operated. The two specific types of roads were joining and forming a crossing structure over a scenario given to avoid the intersection. In this paper, the simulation study, the statistical significance of the results as well as the vehicles study were discussed. Moreover, the vehicle's parameters were taken as assumptions to reach the aim of the project. The vehicle crossing behavior, driver's behavior, inter-arrival time, the distance between two vehicles, the overall time taken for the simulation, and most important the vehicle's speed were also observed. On this basis, the overall simulation was done by making such a traffic control so that the vehicles on the national road and on the crossroad pass successfully. Also, multiple simulations were implemented in the project to investigate the factors like statistical significance, the effect of speed, action on the hypothesis, and so on.**

***Index Terms*—Simulation, vehicle's speed, parameters, statistical significance, road crossing, traffic control, Baseline simulation, and Simulation studies.**

I. Introduction

An intersection between two major segments is the main factor for completing the task of joining two segments so that the formation of a structure will be accomplished. The base structure for joining two intersection points as a means of crossroad was the main issue as a part of avoiding an accident. The whole scenario is based on the situations that are mentioned above. In this project, the village is located near a national road which is slightly busy, as a lot of vehicles are traveling on the road. On the East side of the national road, there is a school and on the West side, there is a village. In short, the national road is a road that separates the village from the school.

According to the scenario, every morning children in the village travel to the school by a crossroad which is in an East-West direction whereas, the national road is in the North-South direction respectively. There is a small by-pass which is constructed in between the village and school intersecting the national road. The start time of school is 9 am as a lot of parents travel to school from the village to drop their children and head back to the village. Every morning the 50 cars make their way to school and get back again as the rush hour on the road is around half an hour before 9 am.

To avoid the large waiting time at the crossing section the parents leave their home and start traveling on 8.30 am. Therefore, an actual rush time is from 8.30 to 9 am and so on. Based on this situation the overall simulation time of the project is 30 minutes. As there is no interference from the school traffic in the evening hours the traffic flow is slightly slower in the evening as zero school traffic.

On the north section of the road, there is construction happening on an estate which directly affects the traffic flow and the waiting time on the crossroad might increase. According to the results, these terminologies will be discussed in this paper.

The base structure of a road is shown in the figure below. There are a lot of cars coming towards the main street at

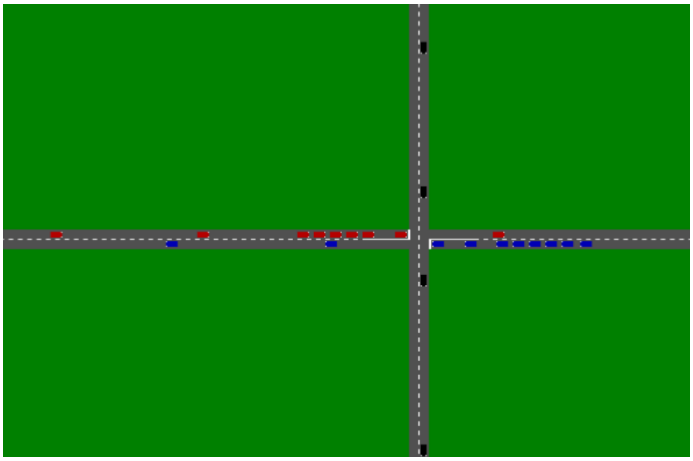

Fig. 1. Basic road and vehicle structure

the crossing bypass point. The crossing was done only on the East-West crossing road there will be no stopping for the North-South directional national road.

The problem statement for this project has two sections. first is to run a simulation model for crossing under the assumption as the vehicle speed on the crossroad should be 50 km/h, The exponential distribution should be followed for the cars in both directions, Simulation time should be 30 minutes and the cars speed on the national road should be of 100 km/h.

The second section of the problem statement consists of creating a framework of multiple simulations to verify results which takes time of 30 minutes each. To check the statistical significance, the average time is taken to travel from one point to another, and the effect of speed on the national road.

II. Literature Review

All of the necessary values required methods, and the flow of the model was referenced from the study material available on Moodle. Other than this the project code was referenced from the Jupiter notebook files available on Moodle, namely, a starting point.ipynb, Project block 1.ipynb, project block 2.ipynb, simulating stop and crossing.ipynb [1].

Other than this, in this research paper, [2] the author worked on the traffic simulation as a part of modeling pedestrian road crossing behavior, where the traffic simulation was done in a part of china. The time gap distribution was extracted from the videotape used to determine the behavior of the road crossing. Additionally, the use of traffic lights was observed in this research.

In this research [3], The microscopic traffic flow simulation was done based on behavior-based multi-purpose traffic flow. It also consists of a wide variety of urban and highway applications. The movement of vehicles on longitudinal and multilane streets was also been observed. and other techniques related to core traffic flow were discussed briefly.

Jamming transition in the traffic flow model with the two-level crossing was demonstrated in this research paper, also cellular automation was used for the traffic flow. [4] When the fraction of c is larger, the jamming transition can be avoided as a part of the result included in the research. According to the results of this paper, the jamming transition occurs when there is a high density of cars which was observed mostly in the two-level crossing.

The simulation of a traffic flow at a signalized intersection was done using a traffic addictive scheme with a number of traffic lights to demonstrate the variations after that [5]. To establish the model characteristics the exclusive Monte-Carlo simulation was carried out and the dependency of the signalized traffic flow was investigated.

For reconstructing, the traffic flow a survey on various simulation models was done in this research[6]. The state-of-the-art techniques were implemented with additionally, the various data-driven animation techniques, including existing data collection methods, used.

III. Methodology

This section will briefly give an explanation of the sequence and the stages which are undertaken to develop the complete simulation model and to solve the two problem statement sections mentioned earlier.

A. Baseline Simulation

In the very first stage, the assumptions on which the simulation model is based are the number of vehicles on the school-village road, which is fixed at 50. Moreover, the speed of the vehicle on the national road is 100 km/h, 100/3.6 [m/s]. Cars on the old school road were limited to 50 km/h and both have an exponential distribution for the inter-arrival time of cars. The default time for a simulation is of 90 minutes but here in this stage, the time allocated for the simulation is of 30 minutes, [1800 seconds] respectively.

The exponential distribution follows the memory-less property, by which an entire procedure will be carried out without disturbance to the current output or the process which is being carried out. Following the exponential distribution which is a part of the continuous probability distribution is used to generate the random numbers of cars on the national road in both directions as well as both directions for the crossroad which is the school-village road. By using the inverse sampling technique, the random variables or values can be generated by using exponential distributions. Setting R = F(X) and solving an equation in terms of R.

For the first simulation which is the baseline simulation, as mentioned earlier the car numbers were randomly generated. The inter-arrival time has spaces in between two vehicles on the East side road and for the national road, the traffic flow was between 200 veh/h and 300 veh/h respectively. The exact traffic flow where the simulation runs is 170 veh/h. Meanwhile, the average travel time for the vehicle to complete the whole section was of 2.75 minutes. whereas, the overall waiting time for the vehicle was around 3.1 to 3.2 minutes. As per the instructions, the random seed value is 21145024 for each of the simulations and it is used for the indexing purpose [1].

The input parameters for the baseline simulation consist of the emergency brake deceleration, average deceleration when it's regenerative braking, and the maximum acceleration depending on the car class. In this section by using the normal values the simulation does not work as expected, there were a lot of car crash situations that occurred. Eventually, instead of using normal values, the slightly high values were used to run the simulation. For example, the brake deceleration value was -10.0 (m/s). For the average deceleration, the value used was -1.0 (m/s). Similarly, for the maximum acceleration, the value was 3.5 (m/s). (baseline simulation.ipynb).

B. Simulation Study

There were three simulation study models were implemented as per the assumptions and the parameters mentioned below.

For the simulation study, the run time of a simulation was of 30 minutes each. Therefore, the time span of each of the simulations was of 1800 seconds. Similar to the baseline simulation model the random seed value is 21145024 mentioned in the jupyter file (Simulation study.ipynb). For comparison between the normal traffic flow and the higher anticipated traffic flow initially, the normal traffic flow was around 280 to 300 veh/h. Whereas, the higher traffic flow was between 400 and 600 veh/h. The jupyter file simulation study1.ipynb consists of this traffic flow. Additionally, for the simulation run with other parameters as input parameters, official assumptions were undertaken.

For the first simulation study, the overall parameters were to specify and deal with the input data of the vehicle. The time span of the simulation was set for 1800 seconds, other than that the average travel time and the waiting time both were measured. Before that, the other assumptions such as the speed of the vehicle, acceleration, deceleration, and the average of

the vehicle. The speed main was 20 and the speed cross was 15 and the IAT main was 8 and IAT cross was 15.

For the first model in the simulation study, the vehicle speed for the national road is 60 kilometers per hour and the cross-road speed is nothing but on the school road was 50 kilometers per hour. There was a statistically significant effect on the simulation of the assumed speed, and the other parameters. The three main assumptions undertook as a few values changes through the deceleration as -10.0 acceleration of -1.4 and the average was of 3.5 meters per second square. (simulation study 1.ipynb).

As a result of these assumptions and according to the assumptions of the simulations the north and south national road is accurately managed but the cross-road junctions observed the car crash behavior and declared this sample as failed in the road crossing for the north-south and east-west directions.

For the second model, because of the unexpected results from simulation model 1, the input parameters were slightly changed and the assumptions were managed for getting the expected results. Moreover, the flow of the code was similar to the simulation study 1 the variables such as speed, deceleration, acceleration average, the timing were set to 30 minutes and the random seed value was 21145024.

The second Jupiter notebook, (simulation study2.ipynb) has clearly stated the assumptions and the other variables as the deceleration, acceleration, and the average values were -10.0, -2.4, and -2.5 meters per second square. The speed of vehicles on the national road was 80 kilometers per hour and for the cross-road, as per the previous results in expecting a proper cross, the speed of vehicles on the old school road was 40 kilometers per hour. Even though, the variations in assumptions and as well as the speed of the vehicle, average travel time, and waiting time the car crash situation occurred at the crossroad after which on the national road from the north-south direction and south-north direction the vehicles are clearly passing. The speed main for the second simulation study model was 80 and the speed cross was 40. The vehicle's maximum speed was changed to 80 and the vmax cross was 40.

For the third simulation study model, due to unexpected results in the first two models the values and the assumption were changed a bit. for the third simulation model (simulation study 3.ipynb) an inter-arrival time for the main was 20, and the inter-arrival time for cross-road was 15. the Vmax main was 80 and Vmax cross was assumed 45 meters per second.

Similarly, for the vehicle's assumptions for the third simulation study model, the deceleration was -8.0 and acceleration was -0.4 and the average was 1.5 meters per second square respectively.

IV. Results and Interpretations

In this section, the results based on the simulation model include the graphs, traffic flow results also, recorders plot, density plots, and the comparison between the two simulation studies.

A. Baseline Simulation

The baseline simulation model is the primary simulation model in which the simulation was done as per the parameters and the assumptions mentioned above in the methodology. The results of the baseline simulation are as follows: As shown

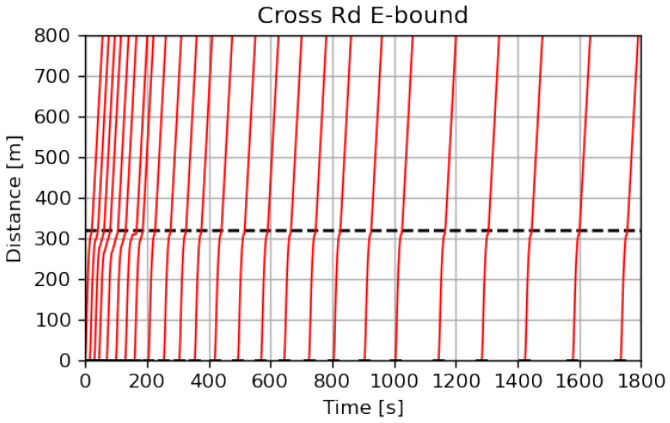

Fig. 2. Baseline simulation

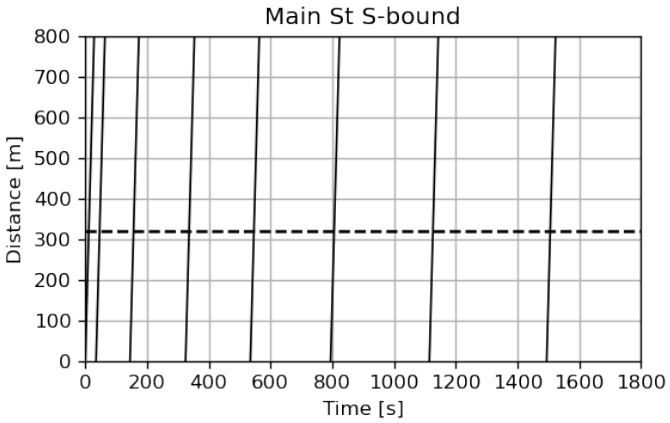

Fig. 3. Baseline simulations

in figures 2,3, and 4 the clear cross-road structure can be observed on both the north-south national road and the east-west crossroad.

B. Simulation study

The results obtained from the simulation study for each model out of three as per the parameters set in it also stated at the three ipnyb files. As shown in the figures in simulation studies 5, 6, and 7 the first two simulation models resulted in the car crash scenario. But other than that the third model was representing the car flow and the car crossings were carried out without fluctuation in it, The dark red marks represent the reason for rejecting the model as a point of comparison. Therefore as shown in the figure simulation study 3 the third model is the final model.

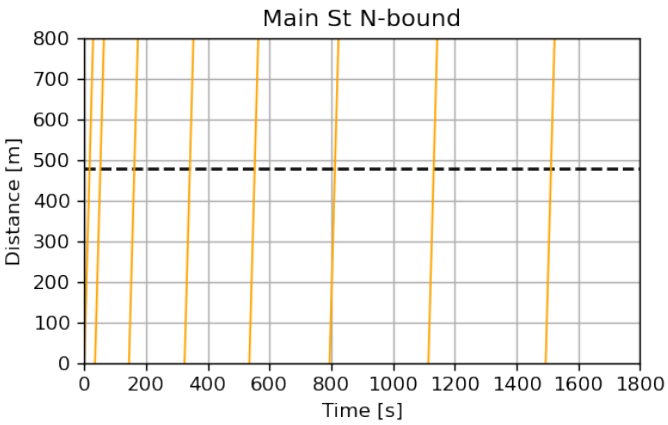

Fig. 4. Baseline simulation

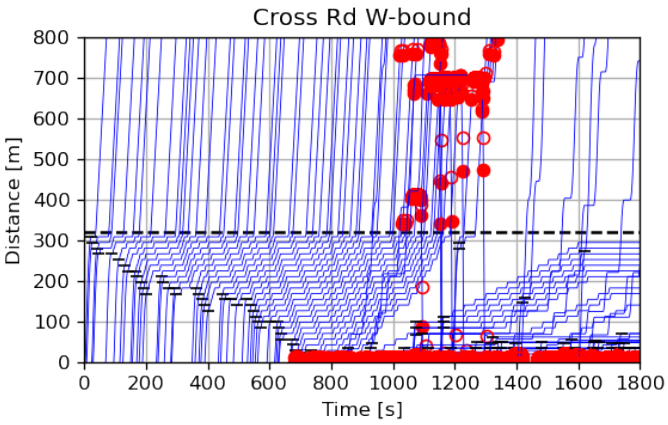

Fig. 5. Simulation study 1

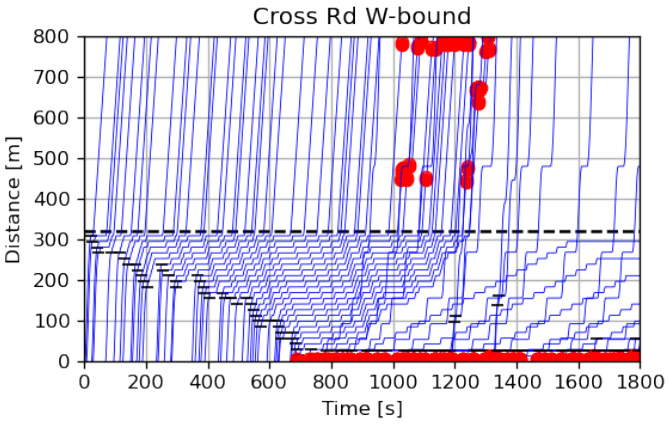

Fig. 6. Simulation study 2

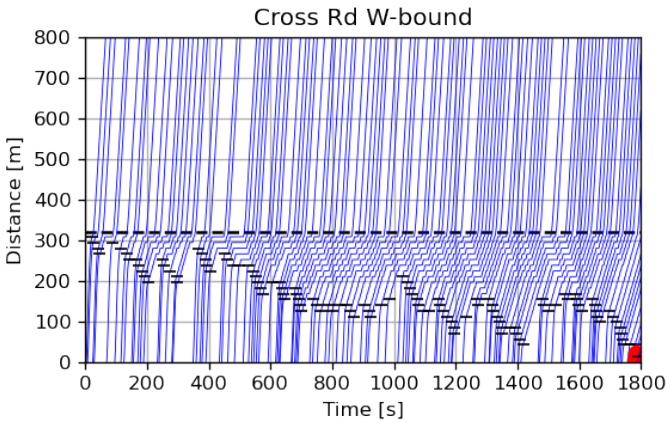

Fig. 7. simulation study 3

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N-bound Flow:   478.9veh/h  expected flow:   450.0veh/h
S-bound Flow:   466.0veh/h  expected flow:   450.0veh/h
E-bound Flow:   147.9veh/h  expected flow:   240.0veh/h
W-bound Flow:   137.7veh/h  expected flow:   240.0veh/h
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Fig. 8. simulation study 1 traffic flow

Figures 8, 9, and 10 show the variations in the traffic flow of the three simulation models.

The average travel time for the first simulation study model was 258.5 s whereas the average travel time for simulation models 2 and 3 were 388 and 207 seconds. The wait time for all three models was 567, 927, and 360 seconds respectively. as stated above according to the traffic flow, average travel time, and maximum waiting time simulation model 3 is the final model for the simulation study. Figures 11, 12, and 13 show the vehicle's behavior at the crossroad.

And figures 14, 15, and 16 show the main street northbound of the vehicles.

V. Reflections and Future Work

For the traffic simulations, while developing the model for traffic control the various lanes can be added to the sections while crossing the roads and national roads intersecting. More

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N-bound Flow:   478.9veh/h  expected flow:   450.0veh/h
S-bound Flow:   466.0veh/h  expected flow:   450.0veh/h
E-bound Flow:   111.1veh/h  expected flow:   240.0veh/h
W-bound Flow:   111.6veh/h  expected flow:   240.0veh/h
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Fig. 9. simulation study 2 traffic flow

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N-bound Flow:   213.2veh/h  expected flow:   180.0veh/h
S-bound Flow:   189.3veh/h  expected flow:   180.0veh/h
E-bound Flow:   194.2veh/h  expected flow:   240.0veh/h
W-bound Flow:   208.6veh/h  expected flow:   240.0veh/h
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Fig. 10. simulation study 3 traffic flow

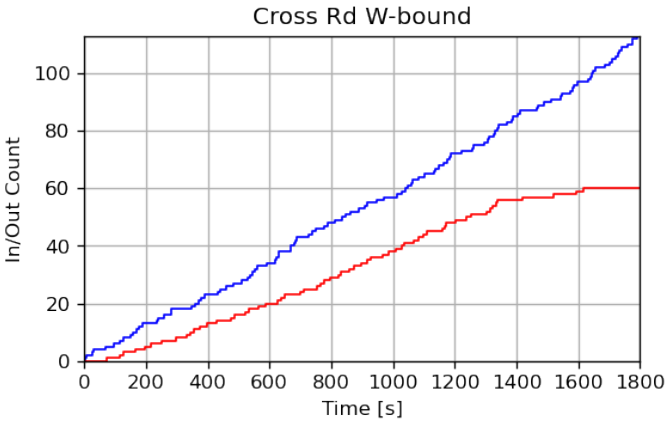

Fig. 11. Vehicles behavior on cross roads

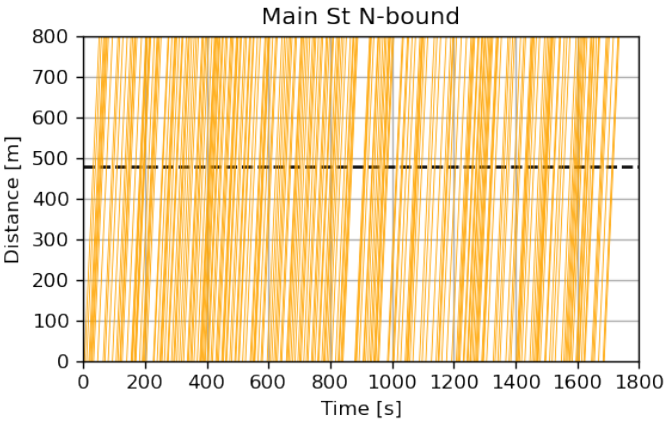

Fig. 14. Main street N Bound

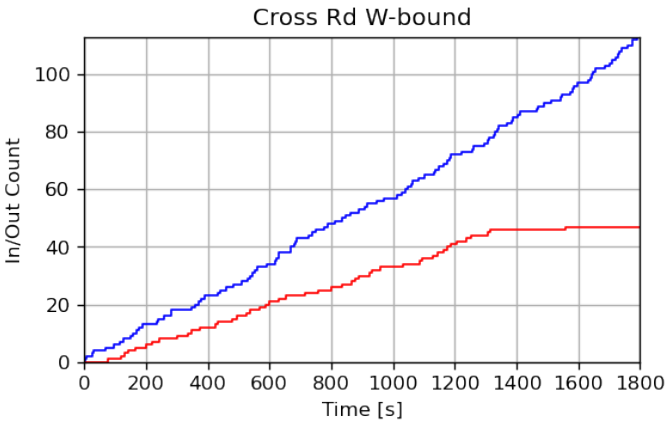

Fig. 12. Vehicles behavior on cross roads

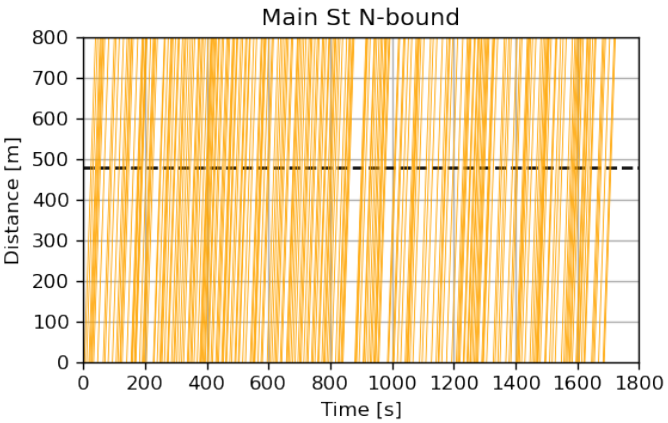

Fig. 15. Main street N Bound

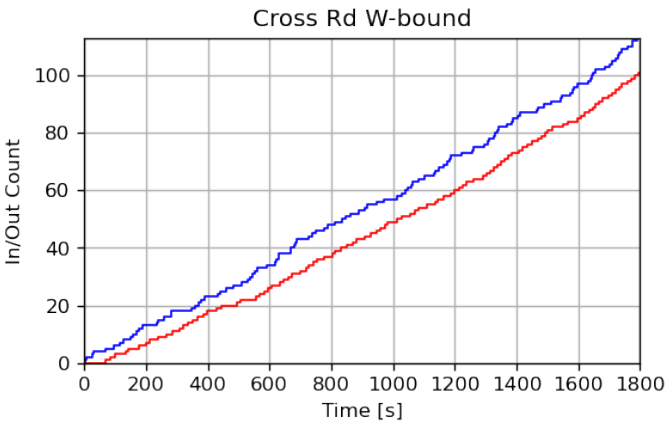

Fig. 13. Vehicles behavior on cross roads

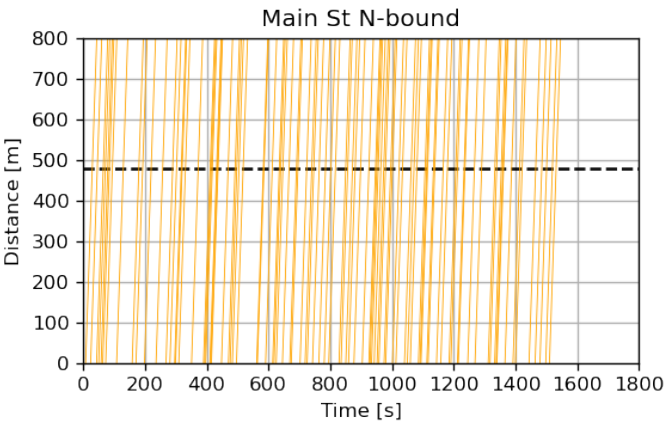

Fig. 16. Main street N Bound

number of lanes can include the more number of vehicles in the picture so that complexity can be increased.

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