Traffic Simulation For Rural Crossing Of a National Road And Local Road

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***Abstract*— The expansion of road infrastructure has resulted in intersections between local and national roads. Traffic flow at intersections can determine congestion and waiting times. The intersection of a national road running north-south and a municipal road running east-west is simulated for the purposes of this study. For the old school and national roads intersection several traffic flow scenarios are simulated, including vehicle and driver behavior, inter-arrival time, and speed of vehicles. Python combined with simply library is used for this study's simulation. To ensure a smooth and trouble-free flow of traffic on both roads, analysis and optimization are carried out based on statistical factors such as the distribution of all vehicle's waiting times, the mean travel time, and the queue length.**

Keywords—Intersection, Python, Class, Simulation.

I. INTRODUCTION

The need for road infrastructure projects has increased significantly due to population growth and the rise of metropolitan areas. Some of these projects are aimed at boosting capacity and enhancing existing infrastructure. One of the major parts of a road infrastructure network is the intersection of two or more roads at a given location. At road crossings, several traffic problems involving bicyclists, pedestrians, and cars arise.

Techniques for traffic simulation are being more frequently utilized to improve intersection problems. It becomes a crucial resource for analysing and resolving the traffic issue. Through the use of cutting-edge computer technology, traffic simulation studies the characteristics of a practical traffic system that might reoccur in order to find the best solution to a real-world traffic issue.

This study implements a simulation system of the crossing intersection of a national road and village road. The introductions of national roads should not effectively impact the daily commute of villagers. The impact of various scenarios of the national road on the average travel time, average wait time, queue length of cars in the old school road is analysed. Python programming language is used for simulation owing to its powerful tools and simpler coding.

II. LITRATURE REVIEW

This study [1] initially discusses the benefits of integrating VISSIM and Synchro to enhance the simulation, as well as the function of microscopic traffic simulation in optimizing organization. The technique system for intersection optimization simulation is then proposed in this paper using a mix of data analysis and microscopic traffic software. The best course of action can be determined by making comparisons between average wait time, average queue length, remaining capacity, and density. Combining the two processes makes simulation and optimization easy, convenient, and eliminates the hassle of manual computations [1].

The research paper [2] assessed the results of lowering the speed limit in a section of Budapest, Hungary, taking into account the connection between urban roads and motorways. The assessment is performed by combining the emission model COPERT with VISSIM. An appropriate speed limit value is created for the upstream road section of the crowded portion by using the variable speed restriction system, taking into account the traffic performance measured at the congested location. The outcomes demonstrate a significant decrease in traffic delays and pollutant emissions.

The authors of [3] created a simulation model for congested areas to calculate driving time and queue length, two essential components of intersection effectiveness. To examine and assess current and future traffic patterns, traffic data from Can Tho's (Vietnam)key intersection was acquired during rush hours. The congestion problem model was developed and applied using the ARENA simulation tool. The tool generated findings by using the gathered data to generate several case study scenarios. They also found that the model used in this study can be used to test out different traffic scenarios before putting them into practice [3].

This research [4] uses simulation modeling to address a transportation issue. To decrease the number of vehicle cycles and waiting times at roundabout intersections, various types of models are studied utilizing repeated iterations. While ARENA software is utilized for data analysis and computations, discrete event simulation (DES) is performed to test the base model over two alternatives. According to the results, the lone roundabout option (alternative 2) is the best one in terms of cycle time, waiting time, and the number of cars shifted out of the system. Findings can help the flow of traffic at intersections like these, where commuters frequently experience significant wait times at peak hours.

III. METHODOLOGY

The simulations of traffic flow at the intersection of the national road and old school road are done using Python

3.9.12 and the simpy package [5]. The whole development is carried out in various stages, which are as follows:

- Initially a background was created for simulation. The road networks are integrated after, with intersection for the national and old school road.
- The model was improved further to replicate the movement of cars down a road while considering parameters such as average speed, braking, direction and acceleration.
- The simulation was created for different values for vehicles per hour, inter-arrival time, and speed to analyse the impact of increasing the number of cars on the national road.
- The multiple scenarios of the simulation were assessed using graphs and metrics for average travel time, queue length and waiting time for vehicles traveling on the old school road.

A. *Simulation Model*

1.Model of Intersection

Each attribute of the intersection was implemented by different classes in python. The different classes created in the code is discussed briefly below:

Class Road: The class road is created to establish direction of cars either in north-south or east-west. The class contains various functions to show attributes such as name, road segment, length, and, distance. The assumptions used in class road is shown in below table:

Road Attribute	Value
Lane Width	6m
Keep Clear Line	20m
Time Tolerance	5 sec

Class Intersection: This class is used to construct the intersections of the two roads. The class contains functions to simulate the stopping, queueing, crossing of cars at the intersection.

Class Road Segment: This class is used to develop the road segment parameters and flow of cars from one road segment to another.

Class Road Network: For the simulation, a road network is built using this class. The road network has various characteristics, among them name, width, and height of the roads. The dimensions of the vehicle, the safety line distance, and lane width of the road can be altered using this class. Techniques for acquiring intersection data and expanding the road network are also part of this class. The assumptions considered in this section is shown below:

Road Network Attribute	Value
North-South road length	1000
East-West road length	1000

2.Model Vehicle and Driver Behavior

The vehicle and driver characteristics are developed in the below mentioned class.

Class Vehicle: The class vehicle is responsible for estimating vehicle and driver behaviour by setting parameters such as speed, acceleration, position and deceleration. In order for the vehicle to respond to various situations, numerous components have been developed. The class contains functions for stop, move, adjust velocity, crossingTime, emergency braking, and crossing time . In order to address the various real-world occurrences that vehicles may encounter, braking and other measures have been developed. The parameters that were used to simulate the driver's actions are shown in the table below. In doing this research, we presumed that the pace was constant. Most of the time, drivers change their vehicles' speeds in response to a range of factors, such as an empty road, a shortage of time, and the state of the vehicle. The assumptions of this class is shown below:

Vehicle Attribute	Value
Emergency Deceleration	-4.0 m/s^2
Engine Braking	-0.6 m/s^2
Max Acceleration	2.5 m/s^2
Vehicle Length	4 m
Vehicle Width	3 m

Driver Behaviour Attribute	Value
Speed of Car	100 km/hr
No More Tolerance	2 sec
Time Tolerance	5 sec

3.Data Collection:

To construct sample population data, a range of input variables and seed values of last four digits of student id were used. Tmax, Vmax, and IAT (Inter Arrival Time), among other factors, were changed in order to generate the input for the simulation. The class specified below is used to report the simulation's results.

Class Recorder:

The Recorder class is used to record each and every simulation occurrence. Start time, stop time, and step time are three attributes of this class that, respectively, define the simulation's beginning, ending, and time step.

IV. RESULTS AND INTERPRETATION

Part 1. Baseline Simulations

All of the assumptions covered in the previous section were used while running the Baseline simulation. The conclusions and the simulated baseline questions are as follows:

IATmain_North	30
IATmain_South	18
IATcross	18
VMAXmain	100 kmph
VMAXcross	50kmph

The simulations parameters are listed below:

- The seed value is 4
- The vehicles on the national road travel at a speed of 100kmph
- The vehicles on the old school road travel at a speed of 50kmph
- The inter arrival time of cars on both the roads are exponentially distributed
- The number of cars traveling every morning at rush hour on the old school road is 50.
- The simulation time period is 30 mins.

The simulation for 200veh/hr and 300 veh/hr are executed separately and the obtained results are shown below.

Simulation model results for 200 veh/hr

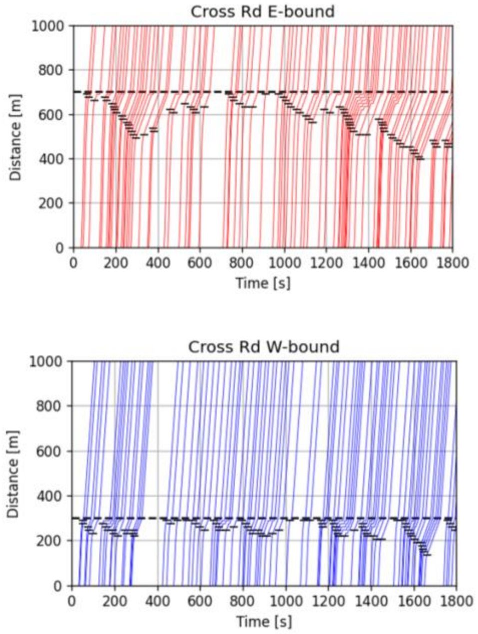
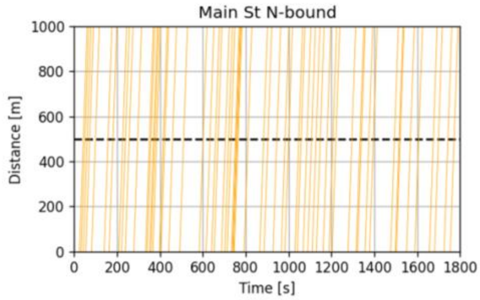


Fig.1.Travel time of vehicles on East-West road (cross road) with IAT



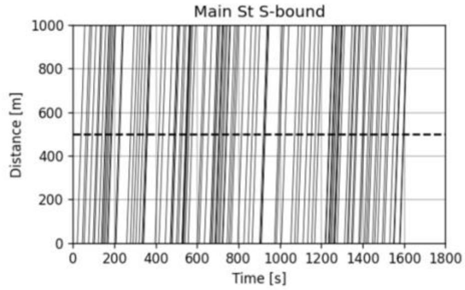


Fig.2. Travel time of vehicles on North-South road (main road) with IAT

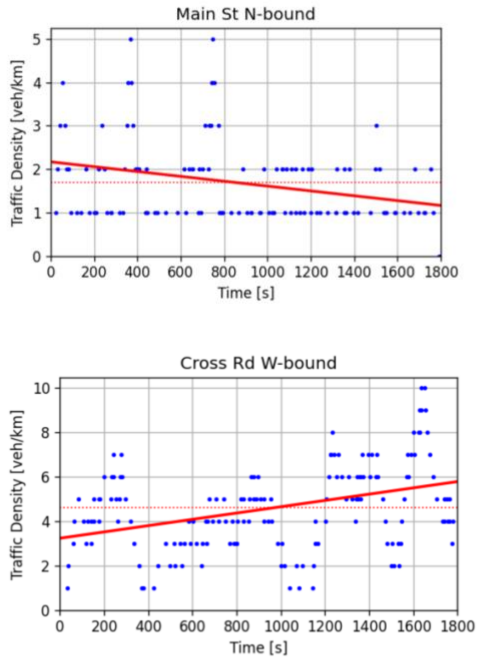
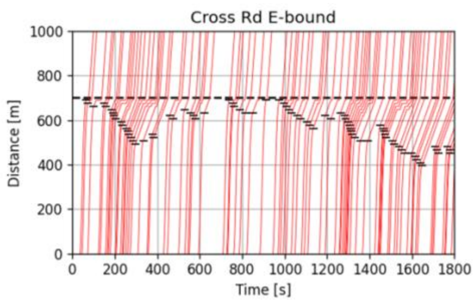


Fig.3.Traffic density plot - cross road and main road

The significant statistical values for 200 veh/hr flow in the cross road are shown in the below table (in seconds):

Average travel time	**98.46**
Maximum travel time	**162.28**
Maximum queue length	**21**
Maximum wait time	**115.68**

Simulation model results for 300 veh/hr



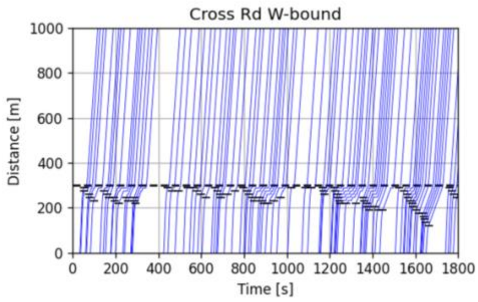


Fig.4. Travel time of vehicles on East-West road (cross road) with IAT

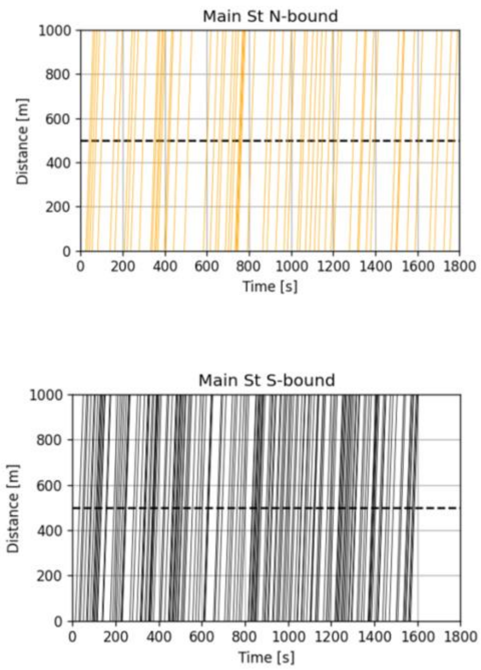
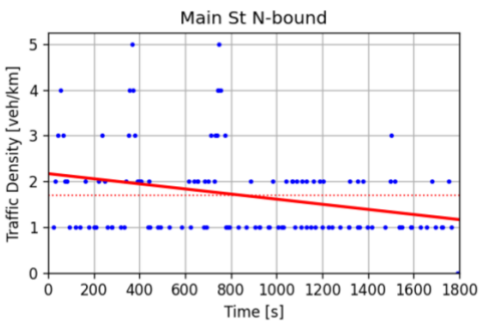


Fig.5. Travel time of vehicles on North-South road (main road) with IAT



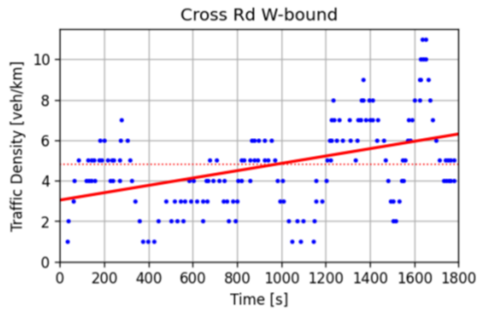


Fig.6. Traffic density plot - cross road and main road

The significant statistical values for 200 veh/hr flow in the cross road are shown in the below table (in seconds):

Average travel time	**102.7**
Maximum travel time	**166.17**
Maximum queue length	**21**
Maximum wait time	**116.04**

Part 2. Simulation Study

The simulation study is done with increasing the inter arrival time from 300 veh/hr to 400 veh/hr and 600 veh/hr.

IATmain_North	**18**
IATmain_South	**18**
IATcross	**18**
VMAXmain	**60 kmph**
VMAXcross	**50 kmph**

The simulations parameters are listed below:

- The seed value is 8494
- The vehicles on the national road travel at a speed of 60kmph
- The vehicles on the old school road travel at a speed of 50kmph
- The inter arrival time of cars on both the roads are exponentially distributed
- The number of cars traveling every morning at rush hour on the old school road is 50.
- The simulation time period is 30 mins.

The simulations are performed for N=8 times for 300 veh/hr, 400 veh/hr and 600 veh/hr. The results obtained are shown below:

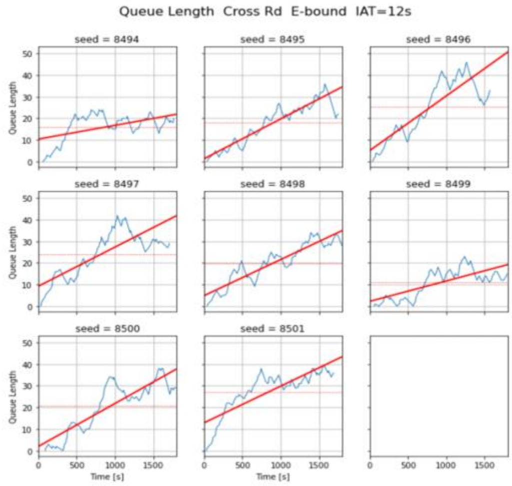


Fig 7. Queue length -cross road for 300veh/hr

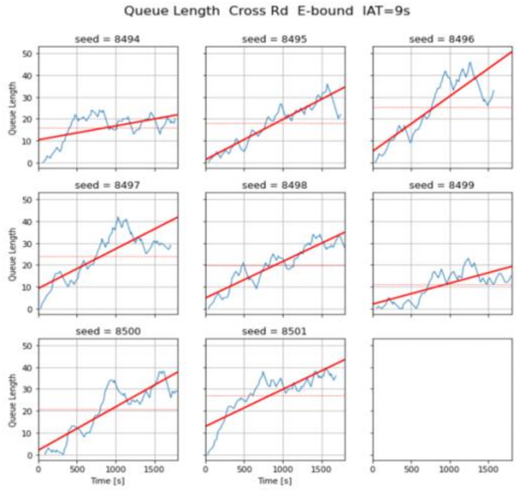


Fig 8. Queue length -cross road for 400veh/hr

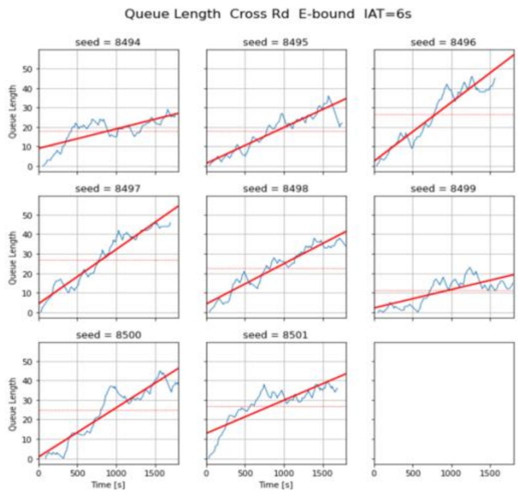


Fig 9. Queue length -cross road for 600veh/hr

In this study, the first hypothesis is

H0: The change to 400 veh/hr has significant change in the average wait time and average queue length ($p<0.01$)
H1: The change to 400 veh/hr has no significant change in the average wait time and average queue length.

Parameter	p-value
Average wait time	4.00E-05
Average queue length	0.018

From the p-values for average wait time and average queue length we can conclude that there is a significant change for queue length but not wait time. So, we cannot reject null hypothesis.

The second hypothesis is,

H0: The change to 600 veh/hr has significant change in the average wait time and average queue length ($p<0.01$)
H1: The change to 600 veh/hr has no significant change in the average wait time and average queue length.

Parameter	p-value
Average wait time	2.00E-05
Average queue length	0.00391

From the p-values for average wait time and average queue length we can conclude that there is no significant change for queue length and wait time. So we reject null hypothesis.

V. Reflections and Future Work

The simulations done in this study showed significant results in analyzing changes in traffic flow parameters . Python programming language and simpy library were used to simulate the different scenarios. The simulation effectively demonstrates how queue length and waiting period significantly grow as traffic density rises and how these parameters vary when speed changes. In the future, this code can be modified to run simulations on a larger scale with longer highways, more diverse vehicle types, additional overtaking scenarios, and more side roads than the proposed intersection.

VI. References

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