Modelling, Simulation and Optimisation for Baseline and Traffic signals of the Road

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***Abstract*— In today's scenario, there were many accidents and collision occurring between the vehicle due to certain conditions such as vehicle repair, old emission vehicle and non-maintained vehicles. There were lot of congestions happening around the world due to misleading of rules and regulation setup for the particular road either it is important or less movement area. Another worst thing is happening around is not following the traffic rules and even traffic is not setup in certain area which leads to many accidents and delay in the travel time to the destinations. To overcome this problem, we need to build the simulation of road and vehicles with the traffic signals. With this we can optimize the overall result of the simulation built. In this project, we simulate the two-road type such as main, cross road using Python's Simpy package. The vehicle parameter, driver's behavior, speed and traffic flow on both the roads with the addition of traffic light signals. The model result also shows the performance of car, average waiting time and non-zero waiting time on both roads.**

Keywords—accidents, congestions, travel time, traffic signals, simulation, Simpy, vehicle parameter, driver's behavior and waiting time.

I. INTRODUCTION

In this study, the implementation of baseline and traffic simulation has been taken through the python code. we will do certain modification in the simulation to get better results and optimization. In this section, we will look into the motivation, objective of the research paper and the research questions involved in this project.

A. Motivation and Objective of the Research Paper

The main aim of this research is to facilitate the better road crossing of the vehicle from local and main road through baseline simulation. Then to facilitate the better flow of vehicles without any delays in the newly developed area, traffic light simulation has been adopted. This project will be modulated based on the use cases provided below as research questions.

B. Research Questions

The below mentioned points are the use cases which is provided as a project requirement. This research question facilitates to drive the projects smoothly.

1) How maximal traffic flow we can accommodate on the main road which still make space for the required traffic flow on the local road.

2) How long should be the different colour of traffic light stay to facilitate maximal traffic flow on the main road

3) Average waiting time and the non-zero waiting time for the main and local road traffic.

The following sections will provide further details about the project such as related work was done earlier in this domain, methodology, simulation model, result and interpretation, conclusion and future work.

II. LITERATURE REVIEW

G. A. Trunfio [1] has developed a model with comparison of trends in modelling and simulation with machine learning model. When compared to ML models, the modelling and simulation technique can provide, in principle, a more solutions of the program's dynamics further than the bound established by observed historical behavior when it is based on a good theory of the system's working. Despite the conceptual gap between the ML and M&S techniques, a new and promising research trend focuses on their synergistic integration for improved data-driven simulation models. Their study explores to the changes and perspectives for modelling and simulation techniques based on advanced Machine learning based on an examination of recent and updated scientific literature. N. Moretto et al [2] has proposed the appropriate level and expert mix of treatments necessary to meet patient demand have really been determined through simulations. The objective and effectiveness of simulation modeling in service planning are yet uncertain. The goal of this research was to look into the adoption, context, and costs of employing modeling advice to help with service delivery.

H. Ugale [3] used the object-oriented programming to create his work. In the simulation model, the simulator offers a visual and pictorial explanation of several traffic parameters. The study proposed a basic mathematical model of automobile traffic at crosswalks. Object-Oriented Process which involves are then used to program this mathematical model as various simulations. After that, the suggested simulator is utilized to simulate various load scenarios at city crossroads. The paper includes a brief description of the process's step-by-step process. M. Chen [4] introduced a genetic algorithm-based VISSIM parameter modification approach. Finally, the suggested algorithm's usefulness is demonstrated by experimental findings. Simulation code and reference materials has been accessed for our model [5]. D. Esmaeili Aliabadi [6] has created a upper side and lower side modeling technique that is presented in the context of energy marketplaces, along with its benefits and drawbacks. Then, in entrenched markets, we look at many modeling strategies. Finally, we show how expanding local power systems have specific design issues that should be addressed.

III. METHODOLOGY

The simulation model has been constructed and implemented through python code using Jupyter Notebook. This section is the useful for developing the whole simulation

from scratch. The methodology of this research shows the building of road segments and network which has roads, intersection, road segments, road networks and traffic lights. The vehicle section shows the vehicle parameter and its features. Recorder which contains all the information which are useful to visualizes the data. It acts as function which holds all the data which is needed for simulation. Last part of this section is showing the building process of simulation through cross road and traffic lights.

A. Road Network

A national main road goes straight which is along with north-south direction. Then the road gets divided into two parts, eastern old town and western new town. In the national main road, the traffic flow of the vehicle. There is a basic model of creation of baseline road, intersection of each road, making traffic signals in between them.

First it has the module of global constants indicating main and local directions. Then the construction of roads happening based on the height, width, adding segments, length, intersection, crossroad, intersection point, its distance and vehicles. Intersection of road consists of cross road, queue length, request, release, spot request and deadlock. This will make sure to avoid the deadlock occurs in the crossing and reduce the queue length.

This road network model gave the exact distance of the road, possible intersection between both the roads to allow the vehicle flow smoothly.

B. Vehicles Characteristics

Vehicles are modulated in a way to make the best simulation with flawless. Here are some characteristics of vehicles such as emergency brake deceleration, average deceleration when using engine braking and its regenerative braking, maximum acceleration depending on car class. The acceleration and deceleration of vehicle should be fixed as how fast it do this thing. The velocity changes over the period of time as the adjusting velocity, continuous the vehicle at same speed, accelerate and cruise, interrupting a sub process will be modelled in the vehicle portion.

C. Recorder parameters

Recorder is the event which is setup to run the animation and also the simulation for making the results and statistics easier. It has the list of all currently running vehicles and known one which is going to start or if they are already stopped it. This module comprises all the statistics parameters such as average travel time across the different roads, average speed in km/h of vehicles travelling on the different road and in the given direction, flow of the traffic and the density in vehicles in different roads per time and distance. Then it would be useful to produce the plots and the figures for visualization.

D. Simulation

Simulation has been used in a variety of industries, including government sectors, information technology, and healthcare. In the realm of operations management, simulation is the second most often employed device. Traffic simulation has emerged into a useful approach for identifying the primary goals of transportation design and prediction. Simulation is possible to simulate the complexity of a real-world transportation system. Simulation is defined as a dynamic and powerful depiction of a process in the real world that is achieved by building a computer simulation and moving it all through time. Traffic simulation has shown to be a valuable and cost-effective way to supply real-time traffic information to aid in incident detection and reporting. The following section will portray the detail analysis of undergone simulation in this project.

IV. The Simulation Model

By employing statistical representations of the activities involved, simulation models attempt to recreate the functioning and logic of a genuine system. This simulation is developed by a python module which is simpy to create a baseline and traffic light simulation. This makes vehicle to pass in distributed system without any disturbance. This can be useful to run the car in the lane with any number of durations. Traffic light simulation created to accommodate flow of traffic in the roads due to newly grown real estates in the north of the village.

A. Model of the street crossing

The street crossing is the method which allows the vehicle to pass from one cross road to another cross road or one main road to another main road. This can be achieved by the different parameters such as Tmax, VMAXmain, VMAXcross, IATmain_North, IATmain_South, IATcross and the location.

Vmax is the maximum vehicle allowance which states that which side of road acting and color of the vehicle and the plan of the certain vehicle in the particular crossing. For example, if the vehicle from east and west of cross road is to stop and cross to give way for the vehicle from the main road.

The generation of random seed is used to make different strands for not to use number for our analysis. This road crossing method will call the recorder function to execute the road network, adding road for all 4 roads and road segments to provide the movement of vehicle in the baseline by distributed manner. This method consists of 3 segments which are described as follows.

- Simulation crossing through road on morning peak hours
- Simulation crossing through road on normal day time
- Simulation crossing through road on evening peak hours

1) Simulation crossing through road on morning peak hours

The baseline simulation has designed in a way to allow the traffic flow from all direction. Traffic flow is based on the certain circumstance it might get less or more in the roads. In this project, there will be high crowd in rush hours and the traffic flow will be high in that time. In morning, 7:30 am to 9:15 am the vehicle flow to south direction would be 300 veh/h whereas the vehicle flow to north direction would be 200 veh/h. The cross has the flow of 200 veh/h in school

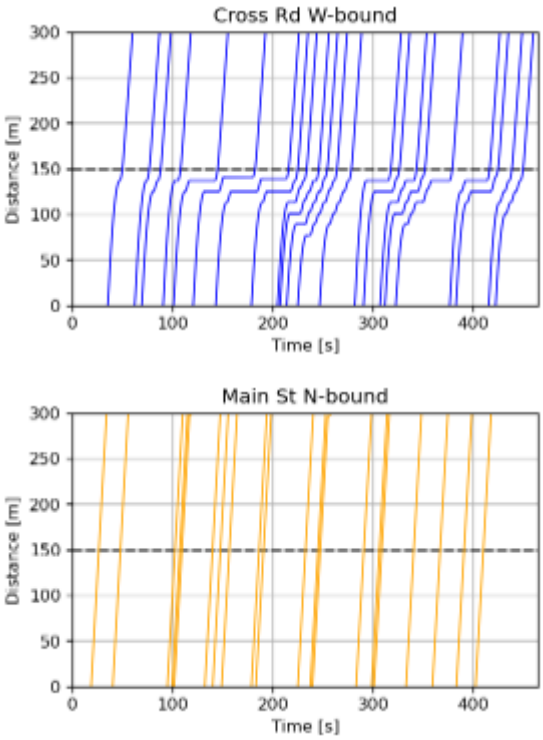

Fig 4.1.1 Traffic flow on morning peak hours in west and north road

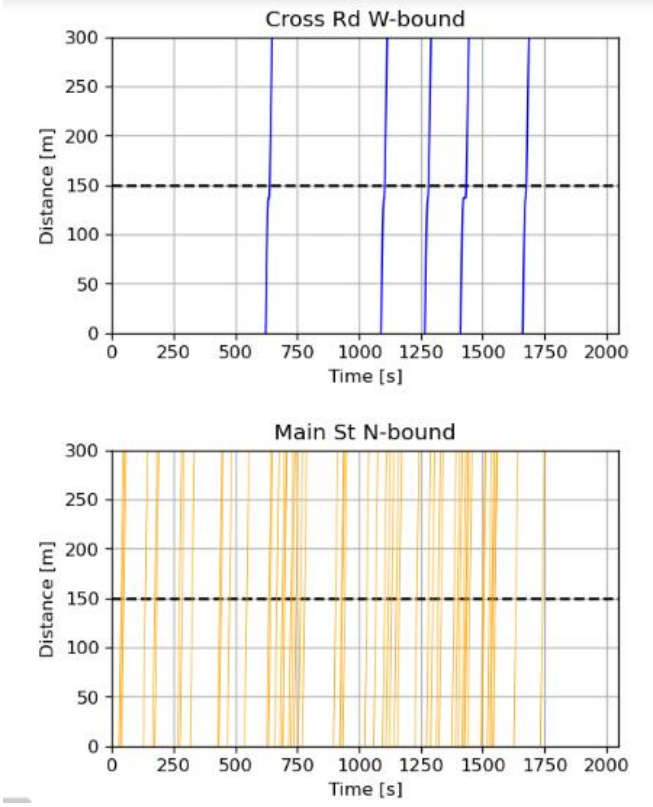

Fig 4.1.2 Traffic flow on normal time in west and north road

opening hours. We need to make changes in the interarrival time of both directions to produce the higher traffic flow in this direction. IAT of north direction is fixed as 18, IAT of south direction is 12 and the IAT of cross directions is 18, vmax of main road is marked as 70/3.6 and 55/3.6 in cross road. The figure 4.1.1 shows the traffic flow in west and north direction in morning hours. Tmax is set to be 400 since the IAT of both direction is less. So, the lesser Tmax would facilitate to produce more traffic flow in shorter period.

2) Simulation crossing through road on normal day time

In normal day time, the vehicle flow from both south direction and north direction would be 100 veh/h. In cross road, flow is 10 veh/h on both directions. We have changed from parameters to produce less traffic flow in this period. IAT of main road is 36 and the IAT of cross directions is 360, vmax of main road is marked as 65/3.6 and 55/3.6 in cross road. The figure 4.1.2 shows the traffic flow in west and north direction in normal hours. Tmax is set to range of 2000 to 2500.since the IAT of both direction is more. So, the Tmax would be higher to facilitate to produce more traffic flow in that period.

3) Simulation crossing through road on morning peak hours

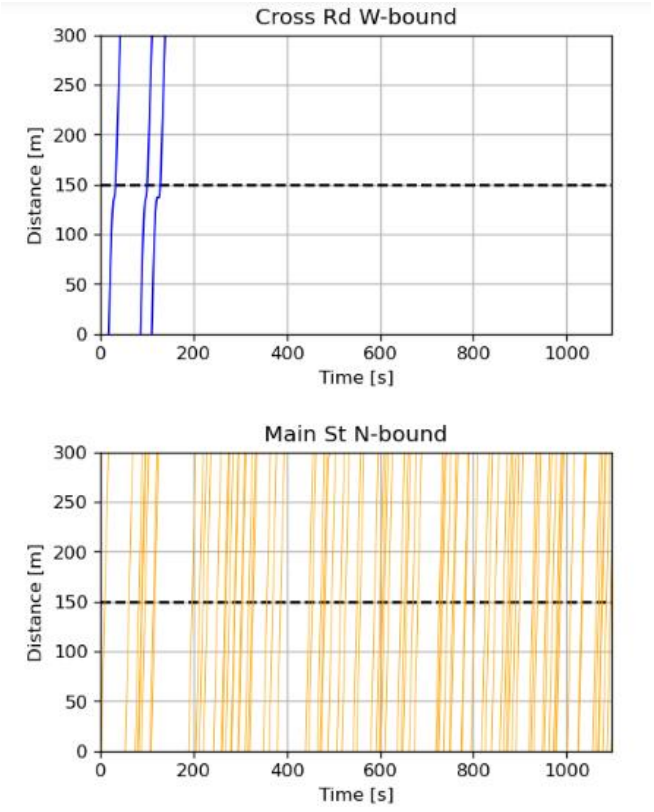

Fig 4.1.3 Traffic flow on evening hour in west & north road

In evening rush hours, the vehicle flow would be opposite to the morning hours such that the south direction flow would be 200 veh/h whereas the vehicle flow to north direction would be 300 veh/h. The vehicle flow in the cross region is 10 veh/h. We need to make changes in the interarrival time of both directions to produce the higher traffic flow in the main

direction and lesser in cross region. IAT of north direction is fixed as 12, IAT of south direction is 18 and the IAT of cross directions is 360, vmax of main road is marked as 70/3.6 and 55/3.6 in cross road. The above figure 4.1.3 shows the traffic flow in west and north direction in evening rush hours. Tmax is set to be 400 to 1800. since the IAT of main direction is less and more in local road, the average Tmax of this range would facilitate to produce more traffic flow in that time duration.

B. *Model Vehicle and Driver Behaviour*

There are two types of cars have selected for this study. One is latest model with high configurations and another vehicle set is old one with less configuration. For baseline simulation, we use the higher end version to facilitate the better observation between the rush hours and normal day. This vehicle has set the parameter of -7 m/s^2 for emergency breaking, of -1.2 m/s^2 for their engine brake system and 3.7 m/s^2 for maximum acceleration. In this driver behavior would be normal as the vehicle act upon the traffic smoothly based on its higher acceleration and deceleration parameters.

For traffic light simulation, the vehicle parameter has been picked as a normal default one and the driver behavior would be little worse than the latest car holder. The below table 4.2 shows the detailed vehicle parameter set for both baseline and traffic light simulation.

	Simulation on	
Vehicle Attributes	Baseline (m/s^2)	Traffic light (m/s^2)
Emergency Break	-7	-4
Engine Break	-1.2	-0.6
Max Acceleration	3.7	2.5

Fig 4.2 Vehicle Parameter

C. *Model for statistical analysis*

The statistical part of the project illustrates the various mathematical approaches which will be useful for our results. The approaches include average travel time, average speed, density, flow and certain plots are stored in the recorder. These all parameters are having certain formula and make them defined in the recorder class and then after simulation it called the function to get the results. The below mentioned are the formula for some of the statistics.

- flow = (len(df)-1) / (df.t.max()-df.t.min()) * 3600
- avgspeed = return round(3.6*road.getLength() / t, 2)
- avgwaittime = return round(sum(times) / len(times), 2)
- maxWaitTime = return round(max(times),2)
- maxQueueLength = data.ql.max()
- nonzerowtime = round(sum(times)/ moving_cars,2)

D. *Generation of traffic signals*

The traffic lights are generated in the road crossings to facilitate the flow of traffic in comfortable way. Concept behind the traffic light is to maximize the traffic movement in the main road because of the growing real estates in the north part of the village. The traffic signals have 3 colors which includes red, green and yellow. Our aim is to allow more traffic in the main region. So, it has been simulated as less red signal and more time for green, orange signals. In similar way, red in the local region is more compared to other lights. In main road, IAT is given as 20 for north and 18 for south. In local, IAT is provided as 36 and the Tmax is set as 800 sec to give some space for more vehicle in graph.

E. *Data Collection*

Data collection is the part for storing the logs in the recorder function which ease the work for providing the required result for accomplishing our use cases. There are various new functions built in addition to the traffic flow, speed and waiting time. The recorder function is the data storer for all we required for analysis. Simulation run can be making use of it and extracted the features from the recorder data such as velocity, IAT, Tmax, density and the flow of the vehicle. Then the plots are fascinated to show the outcome from the simulations.

V. Results and Interpretation

The collection of data has been done through the simulation then the resultant logs are stored to perform analysis through below visualizations.

A. Maximal traffic flow that can accommodate on the main road.

```
local traffic 10 veh/hr.
 Main road traffic 100veh/hr
N-bound Flow:  101.4veh/h  expected flow:  100.0veh/h
S-bound Flow:   98.8veh/h  expected flow:  100.0veh/h
E-bound Flow:    6.9veh/h  expected flow:   10.0veh/h
W-bound Flow:   13.2veh/h  expected flow:   10.0veh/h
local traffic 10 veh/hr.
 Main road traffic 500veh/hr
N-bound Flow:  468.9veh/h  expected flow:  500.0veh/h
S-bound Flow:  484.1veh/h  expected flow:  500.0veh/h
E-bound Flow:    7.4veh/h  expected flow:   10.0veh/h
W-bound Flow:   25.7veh/h  expected flow:   10.0veh/h
local traffic 200 veh/hr.
 Main road traffic 300veh/hr
N-bound Flow:  245.9veh/h  expected flow:  300.0veh/h
S-bound Flow:  232.3veh/h  expected flow:  300.0veh/h
E-bound Flow:  131.1veh/h  expected flow:  200.0veh/h
W-bound Flow:  212.8veh/h  expected flow:  200.0veh/h
```

Fig 5.1.1 Traffic flow in each directions

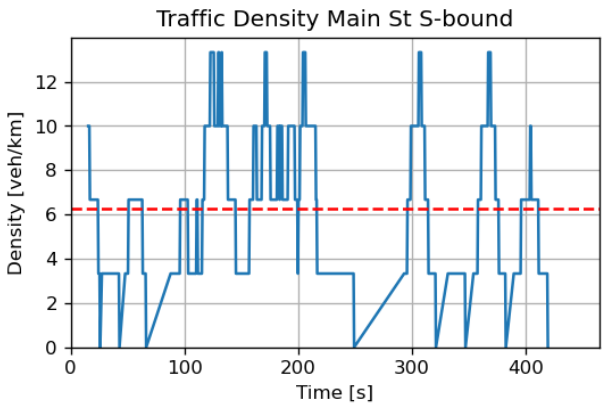

Fig 5.1.2 Density of traffic in south directions

The maximal flow of vehicle in the main road is around 500 veh/h which would still not disturbing the flow in the local road on 10 veh/h. If the flow of local road is raised to 200 veh/hr then the maximum allowed vehicle in main road would be around 300 veh/hr. The above figure 5.1.1 shows the maximal traffic flow in all the direction. Here the south side traffic flow accommodates more compared to another road and its density of traffic flow is shown in figure 5.1.2.

B. Duration facilitate for different traffic light to process maximal traffic flow on the main road

The below shown figures 5.2.1 to 5.2.4 states the traffic signals and the flow of traffic in all the four directions.

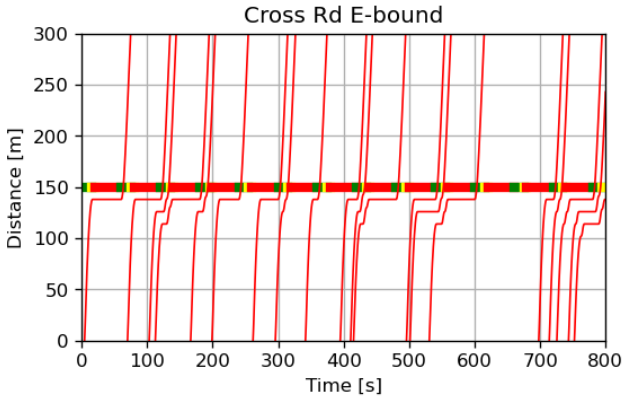

Fig 5.2.1 Traffic Lights in East Direction

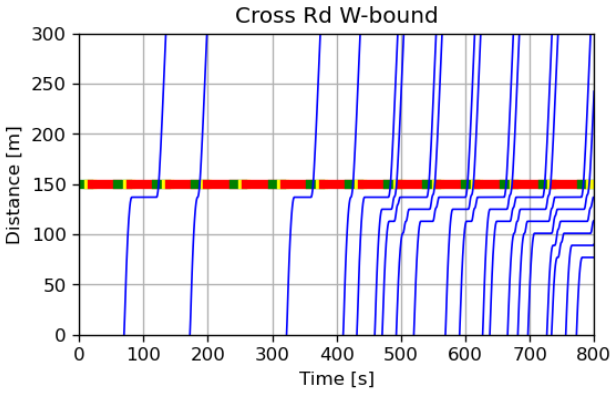

Fig 5.2.1 Traffic Lights in West Direction

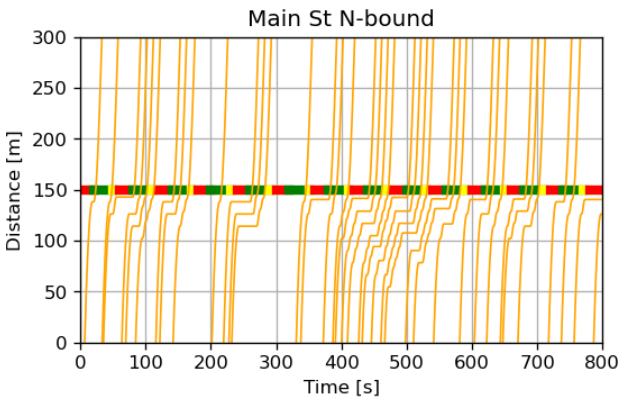

Fig 5.2.1 Traffic Lights in North Direction

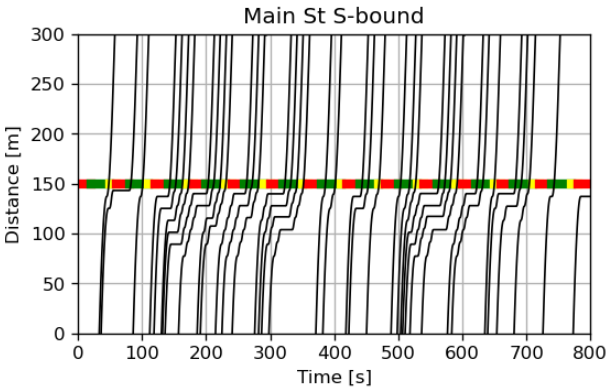

Fig 5.2.1 Traffic Lights in South Direction

The red signals in the local roads are higher and lesser in the main road and vice versa for the green and yellow lights in each direction. This makes the traffic flow in main road is much higher and the IAT of the main road also less compared to the cross road.

C. Average waiting time and the non-zero waiting time for the main and local road traffic.

Here all the statistics about the mean travel time, average speed, maximum queue length, maximum wait time and the total cars with zero wait time of both the roads in baseline and traffic lights simulation are shown below.

```
Mean Travel Time on Main Road -   20.0
Mean Travel Time on Local Road -   27.33

Average Speed on Main Road -   54.0
Average Speed on Local Road -   39.52

Max Queue Length on Local Road -   0
Max Queue Length on Main Road -   0

Max Wait Time on Main Road -   0
Mean Wait Time on Main Road -   0
Total cars with zero wait time on Main Road -  (0, 0,

Max Wait Time on Local Road -   8.39
Mean Wait Time on Local Road -   1.39
Total cars with zero wait time on Local Road -  (0, 0,
```

Fig 5.3.1 Statistics of the baseline simulation

```
Average Travel Time on the Main Road -   50.1
Average Travel Time on the Local Road -   60.01

Average Speed on the Main Road -   21.56
Average Speed on the Local Road -   18.0

Max Queue Length on the Local Road -   5
Max Queue Length on the Main Road -   7

Max Wait Time on the Main Road -   61.59
Average Wait Time on the Main Road -   25.28
Total cars with zero wait time on the Main Road -  (75, 8, 28.3)

Max Wait Time on the Local Road -   88.4
Average Wait Time on the Local Road -   35.44
Total cars with zero wait time on the Local Road -  (35, 2, 37.59)
```

Fig 5.3.2 Statistics of the traffic light simulation

The waiting time for the vehicle is cleared illustrated by the distribution plot shown below. This shows the waiting time is more in initial stages and evenly distributed when the duration moves further.

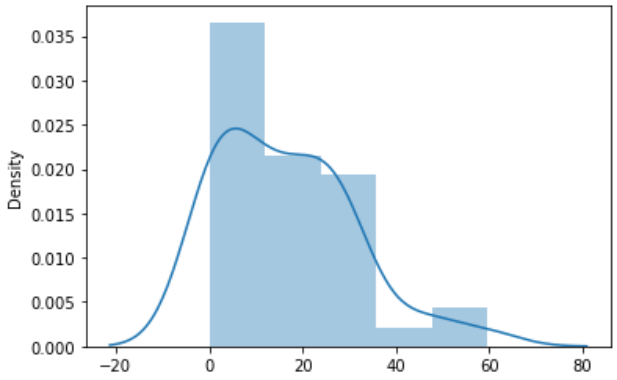

Fig 5.3.3 Distribution plot for the morning hours waiting time

D. Overall summary of an simulation

The travel time, speed of the vehicles is more in traffic light simulation and the wait time also less in that field. The summary of the simulation shows the traffic flow is more after implementing the traffic lights in the road. There is almost 60 percent growth in the travel speed and the time between the baseline and traffic light simulation. The below table 5.4 shows the overall statistics between the baseline and traffic light simulation in morning peak hours.

Road Type	Peak (Morning / Evening) Statistic Approach on Vehicle (km/h)	Simulation on Baseline	Simulation on Traffic Light
Main (Average of N & S)	Average Travel Time	19.44	50.1
	Average Speed	55.56	21.56
	Max Queue Length	0	7
	Max Wait Time	0	61.59
	Average Wait Time	0	25.28
	Total cars with zero wait time	0, 0, 'No'	75, 8, 28.3
Local Road	Average Travel Time	41.96	60.01
	Average Speed	25.74	18
	Max Queue Length	5	5
	Max Wait Time	59.6	88.4
	Average Wait Time	16.54	35.44
	Total cars with zero wait time	0, 0, 'No'	35, 2, 37.59

Fig 5.4 Overall performance of simulation

VI. Conclusion and Future Work

This research has simulated the standard national road with the traffic light in each crossing on the two-way lane in all the four directions. This simulation is applied to the flow of the traffic and density of the baseline simulations. This study also reports the waiting time for vehicles when crossing the main road. This estimates the traffic, speed based on the interarrival time of the road. This encapsulated the vehicle parameters with the behavior of driver in this approach. The color of the vehicle has been differentiated to predict the better result.

The overall statistics shows that the traffic light implementation is better to accommodate the maximal traffic flow and minimal waiting time when crossing the road. When the IAT of the road is less than the waiting time will be more and worst. So, the IAT is increased for local road to above waiting for vehicles coming from the main road. The plot of this simulation makes the better understanding of the simulation caried out in the project.

In future, the multilane road would be picked to investigate the simulation to the next level with the more varieties of vehicles with different type such as fuel, electric, manual and automatic to predict the better vehicle for multilane simulation. There will be complexity in the traffic signals duration the multilane implementation. So, it would be interested to perform such type of simulations in further studies.

Reference

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