INDIAN INSTITUTE OF ENGINEERING SCIENCE AND TECHNOLOGY

Mini-Project Report

For 2nd year(4th Semester) in Bachelor of Technology, Computer Science and Technology

Under the supervision of -
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submitted by:-

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To
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PREFACE

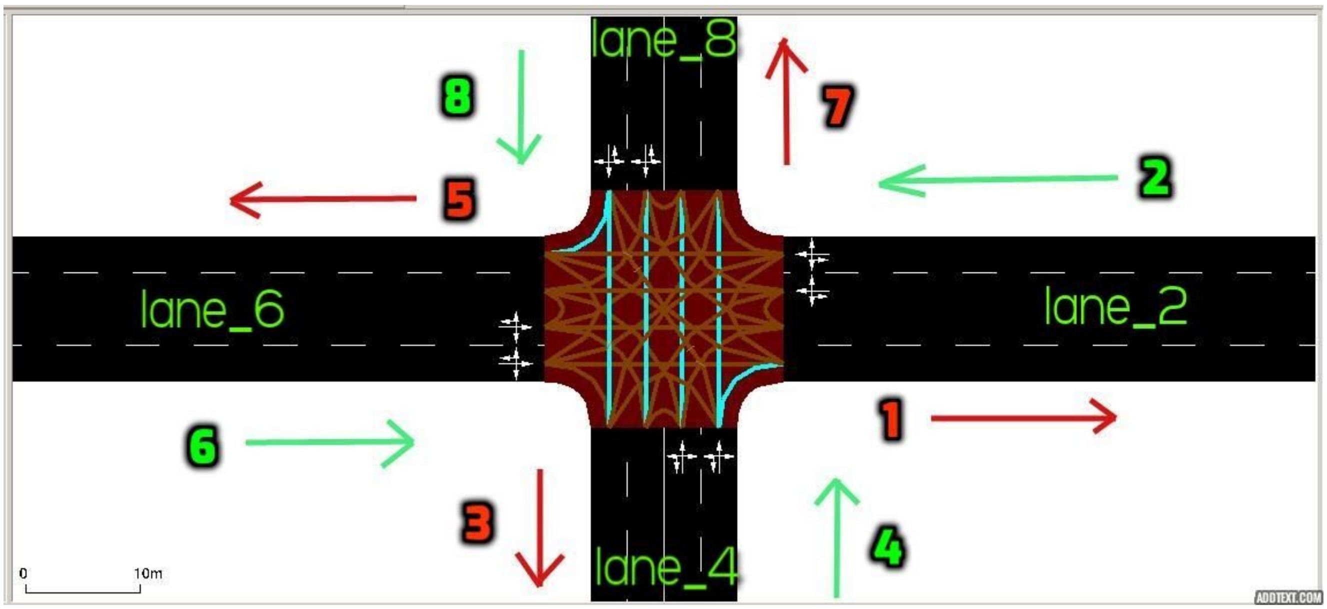
The given project is aimed at improving intersection traffic congestion by using feedback from statistical parameters computed per cycle. Here we have used two sets of algorithms to solve the problem.

Moreover, our model will help to achieve certain goals like reduction in waiting time of vehicles, reduction in total time for entire cycle, reducing delays which may result in late arrival for employment, meetings, and education, resulting in lost business, disciplinary action or other personal losses, increasing ability to forecast travel time accurately, traffic improvisation of the area, less emission of gases due to less traffic congestion and waiting time, reduced fuel wastage, reduced wear and tear of vehicles which occurs as a result of idling in traffic and frequent acceleration and braking, reducing chances of collisions and reducing spillover effect from congested main arteries to secondary roads and side streets as alternative routes are attempted ('rat running'), which may affect neighborhood amenity and real estate prices.

Part 1 -

Simulation Setup -

The intersection is simulated in SUMO and the network is edited in NETEDIT. Using TraCI api the simulation is run in SUMO. The green arrows denote incoming lanes and red arrows denote the outgoing lanes. The brown and teal lines in the intersection denote all the possible routes a vehicle can take in the intersection.



$lane_2$,$lane_4$,$lane_6$,$lane_8$ are incoming lanes, $lane_1$,$lane_3$,$lane_5$,$lane_7$ are outgoing lanes across the intersection.

Algorithm -

wt_k= Total Waiting time of vehicles in the four incoming lanes across the intersection up to k^{th} cycle

$wt_k=\mu_{k-1}*(k-1)+\delta_k$

Where μ_{k-1} is the mean waiting time of the vehicles up to $(k-1)^{th}$ cycle.
δ_k= (Waiting time of the vehicles in the k^{th} cycle)/(Total no. of vehicles in incoming lanes in the k^{th} cycle)
$\mu_{k-1}*(k-1)$ = Total Waiting time of the vehicles up to $(k-1)^{th}$ cycle.
$\mu_k = \frac{wt_k}{k}$ = Mean waiting time up to k^{th} cycle
$v_k = \delta_k - \mu_k$ = Variance up to k^{th} cycle
$\sigma_k = \sqrt{\frac{{v_k}^2}{k}}$ =Standard deviation up to k^{th} cycle

Compute $X = \mu_{k-1}+c(>=6.3)*\sigma_{k-1}$

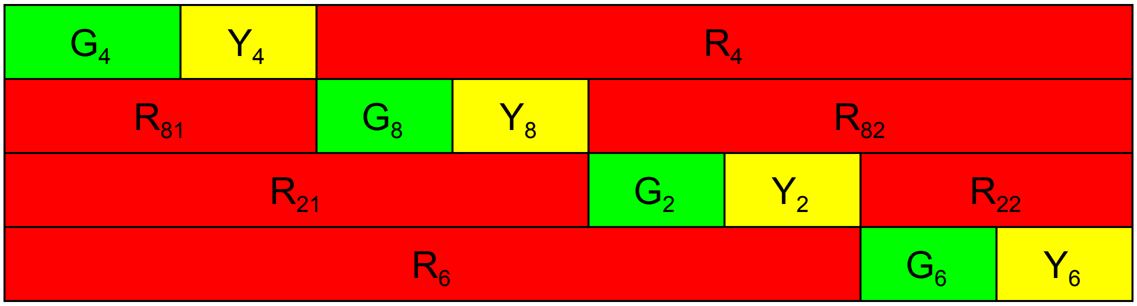
<u>Recomputation of the green signal duration of the four incoming lanes in $(k+1)^{th}$ cycle</u>

G_{jk+1}= Green signal duration in j^{th} incoming lanes(j=2,4,6,8) in $(k+1)^{th}$ cycle
G_{jk}= Green signal duration in the j^{th} incoming lane in the k^{th} cycle
δ_{jk}=Waiting time of vehicles in the j^{th} lane in the k^{th} cycle
wt_{k-1}=Total Waiting time of vehicles in the four lanes across the intersection up to $(k-1)^{th}$ cycle.

$G_{jk+1}=G_{jk}+ \frac{\delta_{jk}}{\Sigma\delta_{jk}}(\delta_k - x)$ for j=2,4,6,8
$G_{2k+1}=G_{2k}+ \frac{\delta_{2k}}{\delta_{2k}+\delta_{4k}+\delta_{6k}+\delta_{8k}}(\delta_k - x)$

<u>Determination of the green signal sequence to the lanes in $(k+1)^{th}$ cycle</u>

1. $\delta_{2k},\delta_{4k},\delta_{6k},\delta_{8k}$ are the waiting time of the vehicles in $lane_2,lane_4,lane_6,lane_8$ respectively in the k^{th} cycle.
2. Arranges $\delta_{2k},\delta_{4k},\delta_{6k},\delta_{8k}$ in descending order in a list to determine the sequence of green signal to the lanes in $(k+1)^{th}$ cycle.
3. Let the list is $(\delta_{4k},\delta_{8k},\delta_{2k},\delta_{6k})$. So in $(k+1)^{th}$ cycle, $lane_4$ becomes green first then $lane_8$ then $lane_2$ and $lane_6$. So the $(k+1)^{th}$ cycle becomes as follows:



G_2, G_4, G_6, G_8 are the green signal duration of $lane_2$,$lane_4$,$lane_6$,$lane_8$ in $(k+1)^{th}$ cycle

Duration of $(k+1)^{th}$ cycle = $G_4+Y_4+G_8+Y_8+G_2+Y_2+G_6+Y_6$

Y_2, Y_4, Y_6, Y_8 are the yellow signal duration of $lane_2$,$lane_4$,$lane_6$,$lane_8$.

Implementation -

Project Structure -

```
├── intersection
│   ├── default.view.xml
│   ├── intersection.net.xml
│   ├── routes.rou.xml
│   ├── sim.sumocfg
│   ├── tls.xml
│   └── trips.trips.xml
├── main.py
├── results
├── SimRunner.py
└── TrafficGenerator.py
```

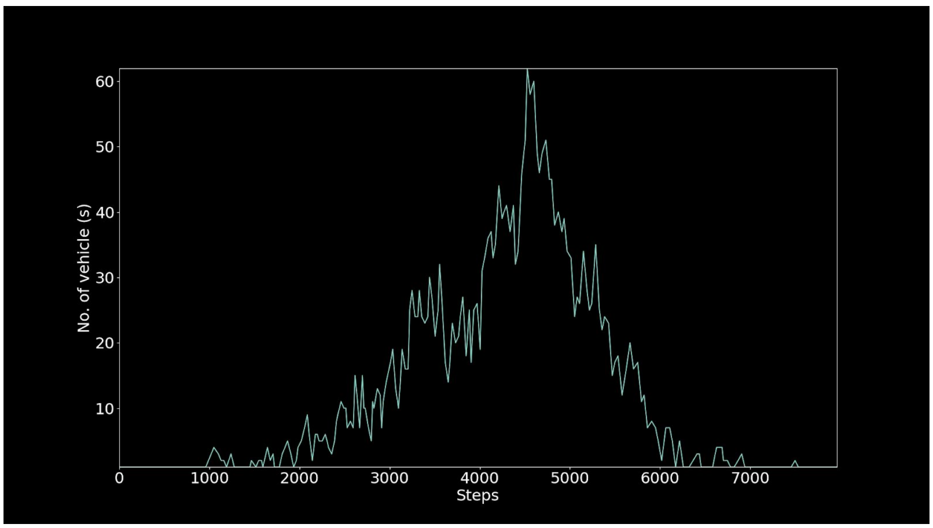
1. intersection :
   a. default.view.xml : contains view information for SUMO
   b. intersection.net.xml : contains network/intersection information created in NETEDIT
   c. routes.rou.xml : contains route information for vehicles.
   d. sim.sumocfg : SUMO configuration file
2. TrafficGenerator.py : Generates the vehicles and routes (the

routes.rou.xml file) for simulation. The arrival time of vehicles follows Poisson Distribution.

3. SimRunner.py : The main algorithm is implemented here.
4. main.py : Entry point for our program. Runs the SUMO simulation

Results -

1. No. of vehicles vs no. of simulation steps -

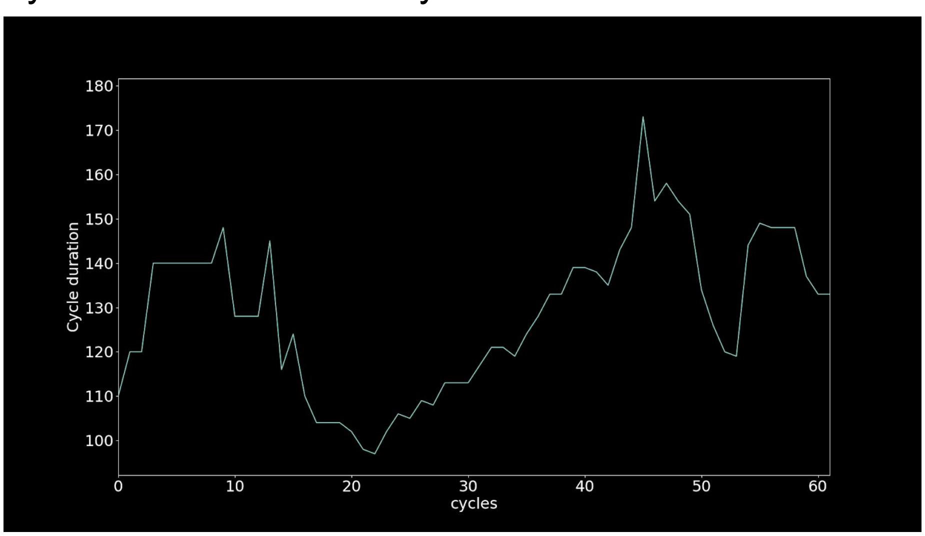


Since the arrival time of vehicles in the simulation follow Poisson Distribution

$P(x; \mu) = (e^{-\mu} \mu^{x}) / x!$ for $x=0,1,2,\cdots$

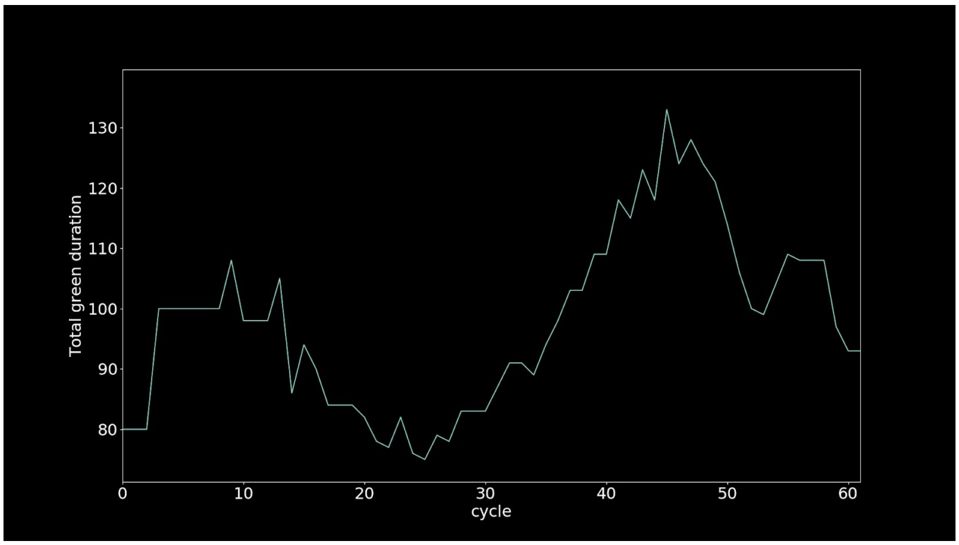
The graph peaks at around the μ set for the simulation.

2. Cycle duration vs no. of cycles -



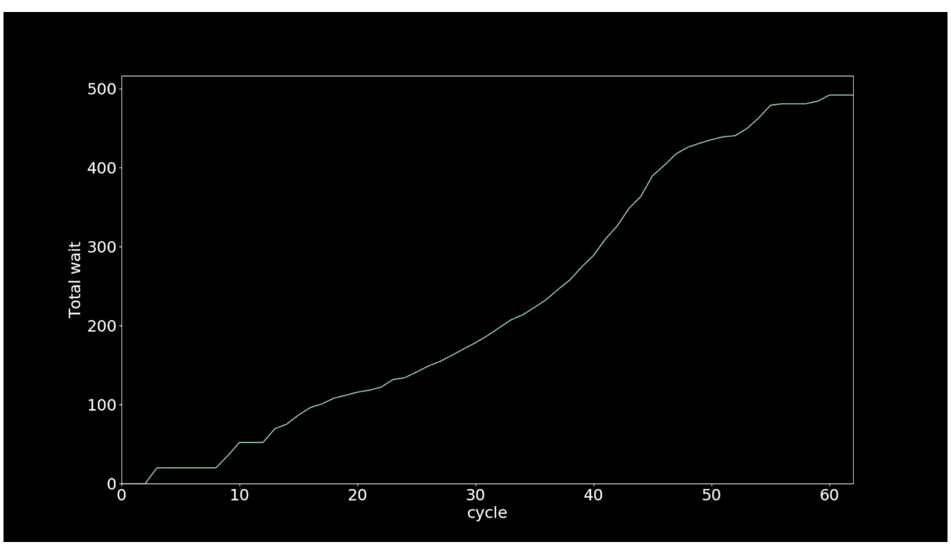
The traffic management agent which implements the algorithm reduces cycle duration whenever it reaches 140 - 160 range. This means whenever the congestion accumulates the algorithm increases the green duration appropriately decreasing the congestion but cycle duration Increases. The subsequent cycles the cycle duration decreases as no. of vehicles in intersection decreases.

3. Green Duration vs no. of cycles -



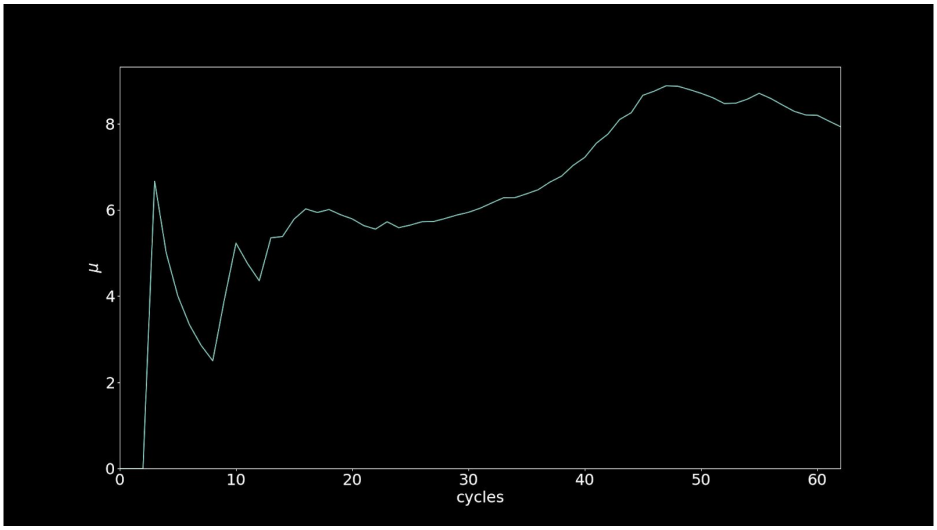
The plot follows the same pattern as cycle duration vs no. of cycles as yellow light duration is same for all cycles and only green duration is computed. Thus cycle duration depends on green duration.

4. Total Wait vs no. of cycles -

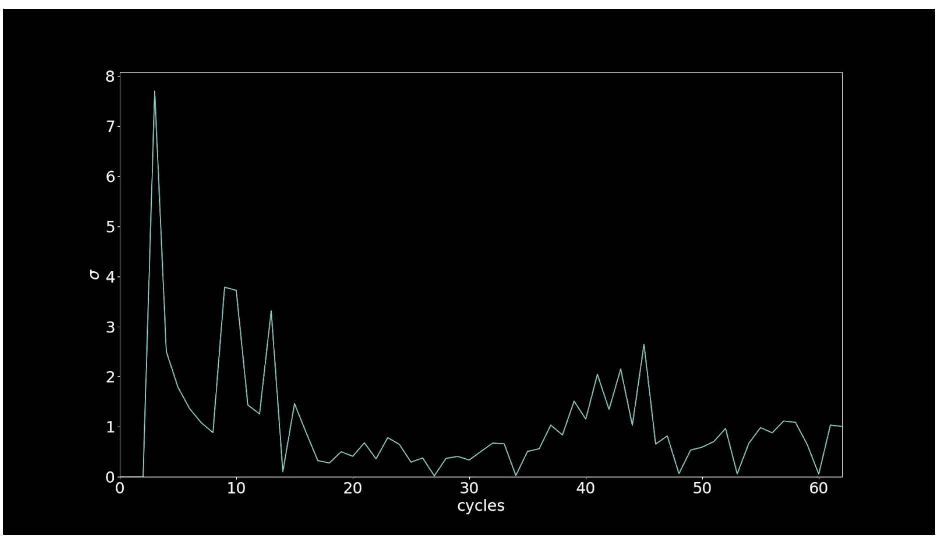


The total wait plateaus as the congestion levels decreases. The total wait has a steep increase in middle due to that coinciding with the ‘rush hour’. But the slope is gentle when compared to the sudden increase in traffic as shown by no. of vehicles vs simulation step curve.

5. Plot of μ vs no. of cycles -

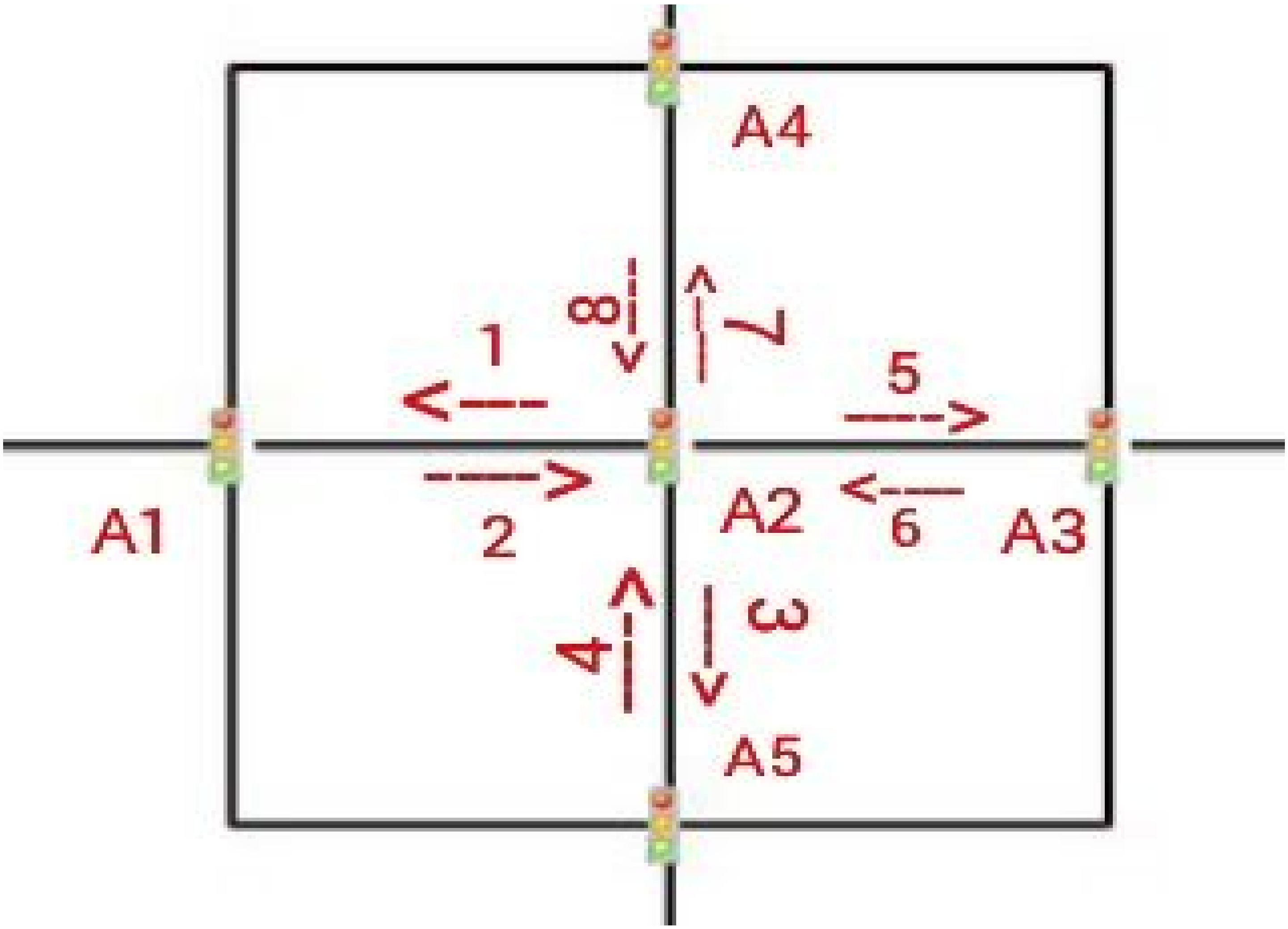


6. Plot σ vs no of cycles -



Part 2 -

Simulation Setup -



A_1,A_2,A_3 are the three agents at the three successive intersections and 2,4,6,8 are incoming lanes and 1,3,5,7 are outgoing lanes for the intersection A_2.

Algorithm -

In the first cycle the sequence of green signals for the four lanes is $lane_2$,$lane_4$,$lane_6$,$lane_8$, and green light duration is 10 seconds.

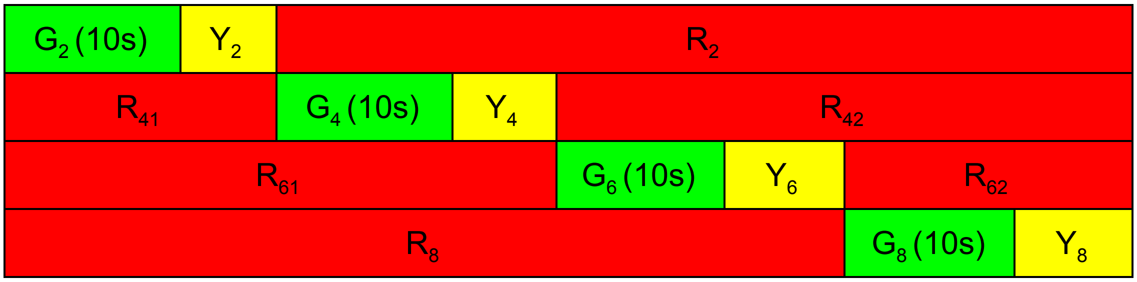


Diagram for 1st cycle

Duration of 1st cycle = $G_2 + Y_2 + G_4 + Y_4 + G_6 + Y_6 + G_8 + Y_8$

$= 40 + Y_2 + Y_4 + Y_6 + Y_8$

Let,

δ_{21}= Waiting time of vehicles in $lane_2$ for 1st cycle
δ_{41}= Waiting time of vehicles in $lane_4$ for 1st cycle
δ_{61}= Waiting time of vehicles in $lane_6$ for 1st cycle
δ_{81}= Waiting time of vehicles in $lane_8$ for 1st cycle

So total waiting time for 1st cycle in the four lanes across the intersection is
$wt_1 = \delta_{21} + \delta_{41} + \delta_{61} + \delta_{81}$

The program is executed for 10 cycles.

Calculating the following:

Total waiting time of the vehicles in the four lanes across the intersection up to 10 cycles=wt_{10}

Mean waiting time of the vehicles up to 10th cycle = $\mu_{10} = \frac{wt_{10}}{10}$

Waiting time of the vehicles in the four lanes at 10th cycle = δ_{10}

Variance at 10th cycle $v_{10} = \delta_{10} - \mu_{10}$

Standard Deviation at 10th cycle $\sigma_{10} = \sqrt{\frac{V^2{}_{10}}{10}}$

Compute X as $\mu_{10} + c*\sigma_{10}$

Compute waiting time of the vehicles up to 11th cycle = δ_{11}

If δ_{11}>X

Recompute the green signal duration of the four lanes for the 12th cycle

Else

The Green signal duration of the four lanes in the 12th cycle remains identical to the green signal duration of the four lanes in the 11th cycle.

Recomputation of the green signal duration of the four incoming lanes in the 12th cycle

Let,

The green signal duration of the $lane_2$ for 12th cycle = $G_{2_{12}}$

The green signal duration of the $lane_2$ for 11th cycle = $G_{2_{11}}$

Total waiting time of the vehicles in the four lanes across the intersection up to 11th cycle = wt_{11}

Total waiting time of the vehicles in the four lanes across the intersection up to 10th cycle = wt_{10}

Waiting time of vehicles on $lane_2$ at 11th cycle = $\delta_{2_{11}}$

Waiting time of vehicles on $lane_4$ at 11th cycle = $\delta_{4_{11}}$

Waiting time of vehicles on $lane_6$ at 11th cycle = $\delta_{6_{11}}$

Waiting time of vehicles on $lane_8$ at 11th cycle = $\delta_{8_{11}}$

Then

$$G_{2_{12}} = G_{2_{11}} + \frac{\delta_{2_{11}}}{\delta_{2_{11}} + \delta_{4_{11}} + \delta_{6_{11}} + \delta_{8_{11}}} * (wt_{11} - wt_{10})$$

Similarly for the other incoming lanes,

For $lane_4$:

$$G_{4_{12}} = G_{4_{11}} + \frac{\delta_{4_{11}}}{\delta_{2_{11}} + \delta_{4_{11}} + \delta_{6_{11}} + \delta_{8_{11}}} * (wt_{11} - wt_{10})$$

For $lane_6$:

$$G_{6_{12}} = G_{6_{11}} + \frac{\delta_{6_{11}}}{\delta_{2_{11}} + \delta_{4_{11}} + \delta_{6_{11}} + \delta_{8_{11}}} * (wt_{11} - wt_{10})$$

For $lane_8$:

$$G_{8_{12}} = G_{8_{11}} + \frac{\delta_{8_{11}}}{\delta_{2_{11}} + \delta_{4_{11}} + \delta_{6_{11}} + \delta_{8_{11}}} * (wt_{11} - wt_{10})$$

Determination of the green signal sequence to the lanes in the 12th cycle

If $\delta_{2_{11}}$, $\delta_{4_{11}}$, $\delta_{6_{11}}$, $\delta_{8_{11}}$ are the waiting time of the vehicles in $lane_2$, $lane_4$, $lane_6$,$lane_8$ in 11th cycle arrange the waiting times in decreasing order which will determine the sequence of the green signal on the 4 lanes.

Suppose the list in decreasing order is $(\delta_{2_{11}}, \delta_{6_{11}}, \delta_{8_{11}}, \delta_{4_{11}})$ then $lane_2$ is first made green for $G_{2_{12}}$ time duration, then $lane_6$ is made green for $G_{6_{12}}$ time duration, then $lane_8$ is made green for $G_{8_{12}}$ time duration and finally, $lane_4$ becomes green for $G_{4_{12}}$ time duration.

The subsequent cycles are calculated in the same way.

Implementation -

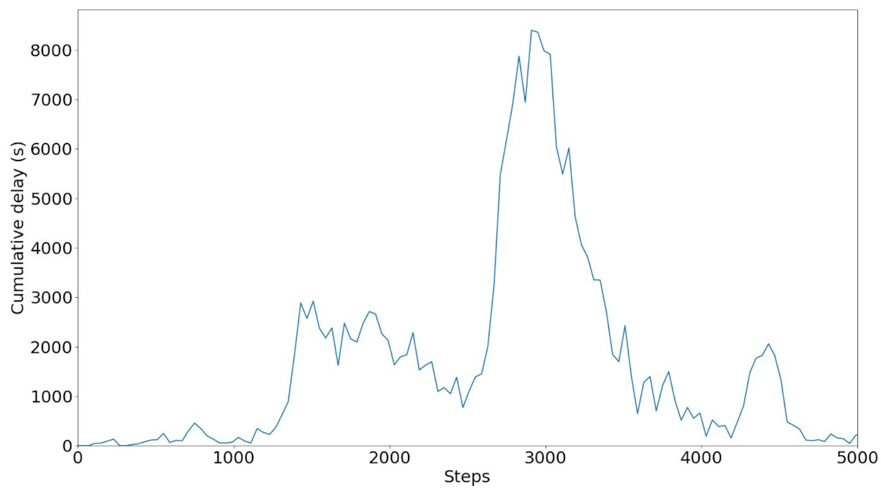
Project Structure -

```
.
├── main.py
├── network
│   ├── default.view.xml
│   ├── grid.net.xml
│   ├── routes.rou.xml
│   ├── sim.sumocfg
│   └── tls_c.tls
├── results
├── SimRunner.py
└── TrafficGenerator.py
```

1. network :
   a. default.view.xml : contains view information for SUMO
   b. grid.net.xml : contains road grid network information created in NETEDIT
   c. routes.rou.xml : contains route information for vehicles.
   d. sim.sumocfg : SUMO configuration file
   e. tls_c.tls : contains initial traffic light sequence for all the agents
2. TrafficGenerator.py : Generates the vehicles and routes (the routes.rou.xml file) for simulation. The arrival time of vehicles follows Poisson Distribution.
3. SimRunner.py : The main algorithm is implemented here.
4. main.py : Entry point for our program. Runs the SUMO simulation

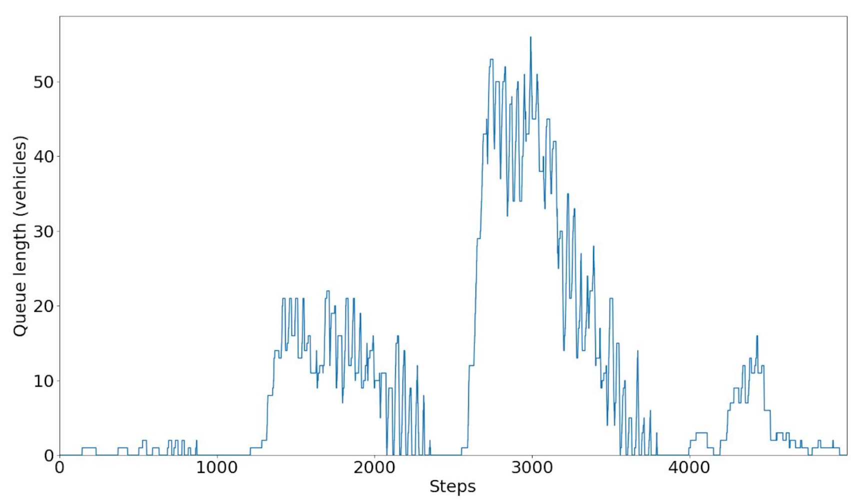
Results -

1. Cumulative Delay vs no. of Cycles -



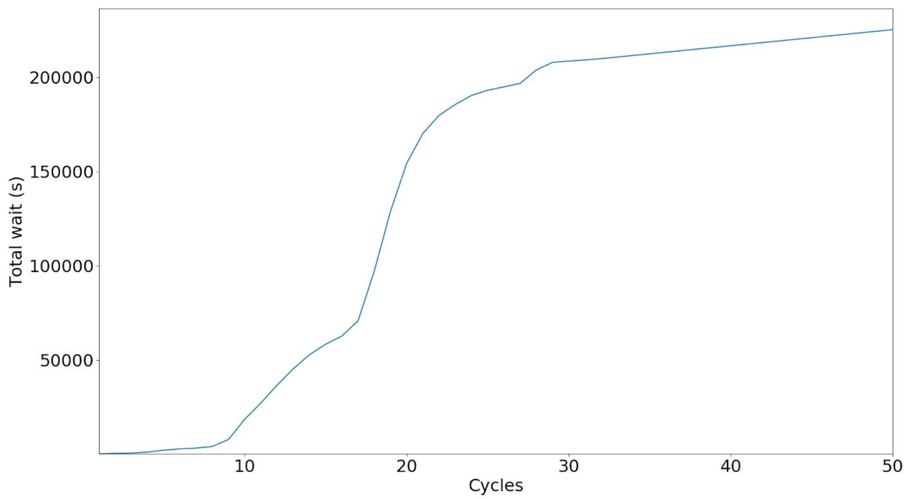
The traffic management agents on the intersections work to reduce cumulative delay whenever there is a sudden spike. The middle spike corresponds to the ‘rush hour’ traffic.

2. Cumulative queue length in intersections vs cycles -



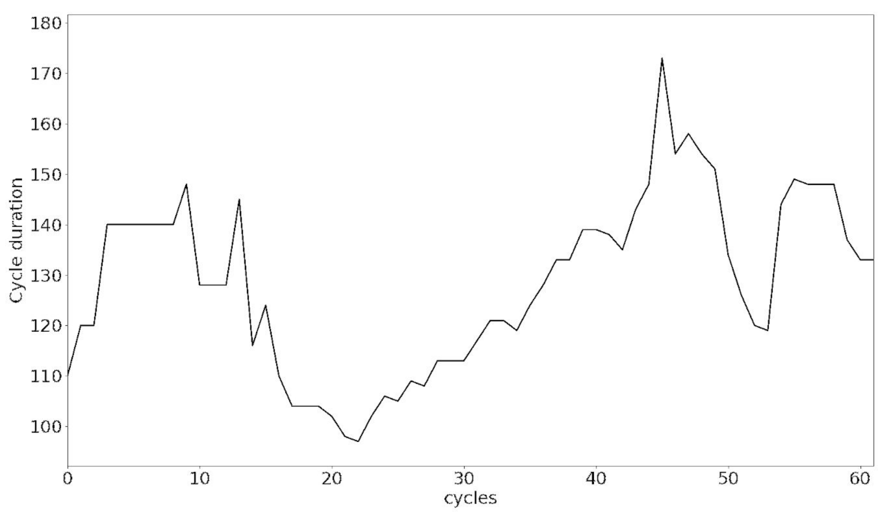
The plot is similar to the previous one as cumulative delay is directly proportional to the ‘congestion’ levels or cumulative queue length. The agents work together to reduce congestion by letting the larger queues go first.

3. Total wait vs no. of cycles -



The total wait plateaus as the congestion levels decreases. The total wait has a steep increase in middle due to that coinciding with the ‘rush hour’. But the slope is gentle when compared to the sudden increase in traffic as shown by queue length vs no. of cycles curve.

4. Cycle duration vs no. of cycles -



The cycle duration has 3 peaks corresponding to the three surge in congestion as seen in the queue length plot. The cycle duration computed by the algorithm(by recomputing green duration in each cycle) increases due to increase in green duration to accommodate for increase in congestion.