5. Experiment

5.1 Aim of the Experiments

The aim of the experiments is to improve the performance of the node. The experiments are conducted to see if the Average waiting time in the node and the average number of vehicles waiting in each signal can be reduced.

The whole Experiments Milestone task is divided into the following sub-tasks

- Analysis of initial simulation
- Performing Experiments
- Results summary
- Recommendations

5.2 Analysis of initial Simulation

After observing the initial simulation Program, we have discovered some important factors to initiate the experiment. These factors can play a major role in improving the performance of the entire node. The observed factors are:

Traffic loads in each of the roads

In Ebendorferstraße & Gerhart-Hauptmann straße, the traffic loads are much higher compared to other remaining roads. Some methods are required to balance the load of traffic on these roads.

Signal Patterns

At occasions, signals turned back to red from green even before all the waiting cars exited the road. That causes an additional delay for vehicles waiting at the signal.

Pedestrians crossing the streets

Multiple times, cars had to wait for some crossing pedestrian before entering the destination road because the signal turned green for vehicles before the pedestrians completely crossed over the road.

Vehicle Routes

Vehicles moving to Gerhart-Hauptmann straße had to go into Olvenstedter Straße and enter from the half arm and that led to an additional delay.

5.3 Performing Experiments

For the Experiments, we have considered two quality measures,

- Average queue length
- Average time in Node

The experiments were done in two sections to check for results:

- Existing traffic metrics with 10 repetitions
- Increased traffic flow upto 5 times the current recorded traffic load

The traffic variance graphs show the parameter in focus (queue length or average time in node) in the y axis and the traffic load in the x axis. Traffic load starts with 1 which denotes the existing traffic scenario. The experiment will increase the load upto 5 times the current flow and test the system against it.

We ran the traffic variance for the existing setup to analyse how it would react and found the below points:

- Ebendorfer Str. and Gerhart-Hauptmann Str. see steep increase in queue length with increased traffic flow. But gradually slow down as the load increases.
- Olvenstedter Str. West and Herder Str. see a gradual increase in the queue lengths.
- Olvenstedter Str. South does not get impacted until the traffic load is 3 times the current value but after that shows a sharp incline in its queue length.

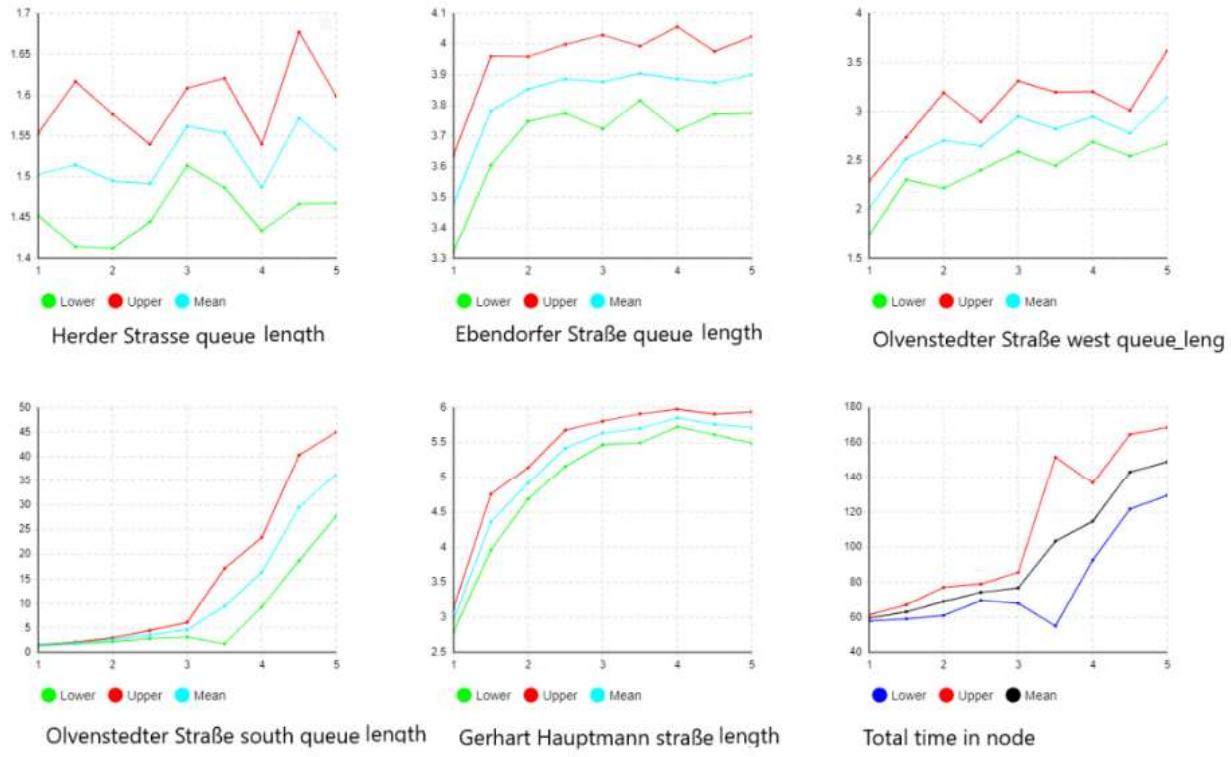

Figure 32: Traffic Variance Graphs for the average queue length of each road and average time spent in the node

5.4 Experiment 1: Increase the number of lanes in Ebendorferstraße

Ebendorferstraße saw most numbers of inter-arrivals and currently has one lane on each side of the road, the experiment is to Increase the number of lanes in Ebendorferstraße leading into the intersection, from one to two.

Variable	Real World Value	Validated CI (99%)	Experiment CI (99%)
Average Queue Length	3.55	3.509 - 3.589	4.967 - 5.137
Avg. time in node (Secs)	58	53.23 - 58.651	54.833 - 57.377

Table 20: Differences made by Experiment 1.

Other streets are unaffected by this change along with a similar time spent in the node. Hence only the queue length of Ebendorferstraße is considered as an impacted parameter. This experiment increases the queue length in Ebendorferstraße from around 3.5 to approximately 5 after adding one additional late to it. That means, now there are more vehicles waiting at the signals.

Traffic variation:

This experiment withstands increased traffic to an extent. While the initial load of traffic produces a mean of around 7.6 queue length at Ebendorferstraße. Increasing it to 5 times the existing traffic load ends up producing queue length of about 8.2. Thus this experiment will withstand higher load of traffic without creating any significant concern.

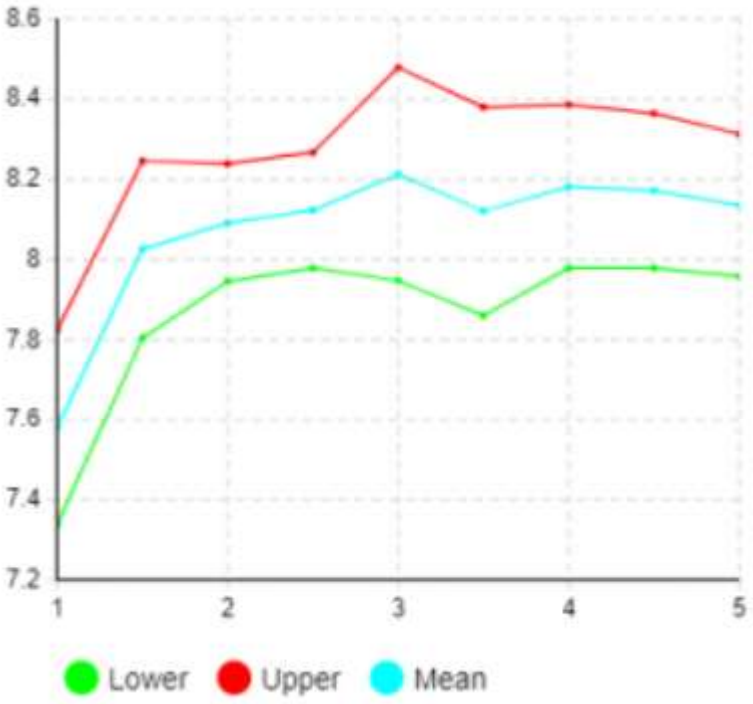

Figure 33: Traffic variation effect on Ebendorfer Str. after implementation of Experiment 1.

5.5 Experiment 2: Signal optimization

Changing of signal phases is not in the most optimal order. Changing the signal from red to green at the same time for Gerhart-Hauptmann Str. and Olvenstedter Str. (S) also created a relatively high queue sometimes.

The current Signal denoting stopline for each of the streets is:

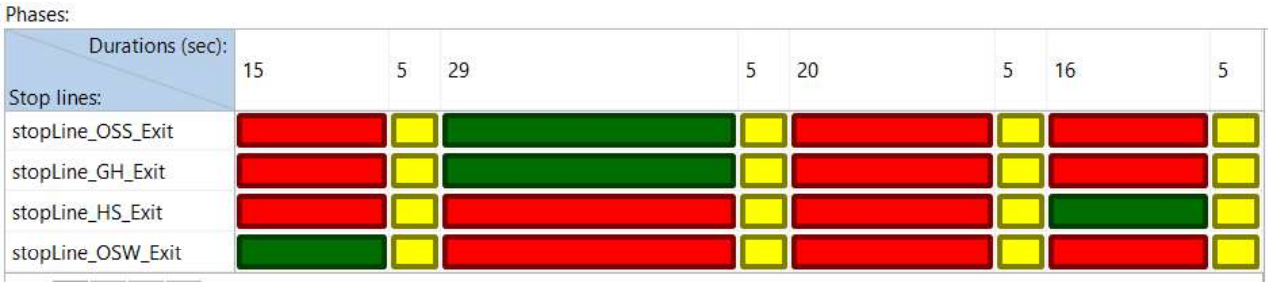

Figure 34: Signal phases (approximate)

Splitting the phase GH/OSS so that GH and OSS have their own phase. In the following order of phases obtain minimal 'average time in node' value.

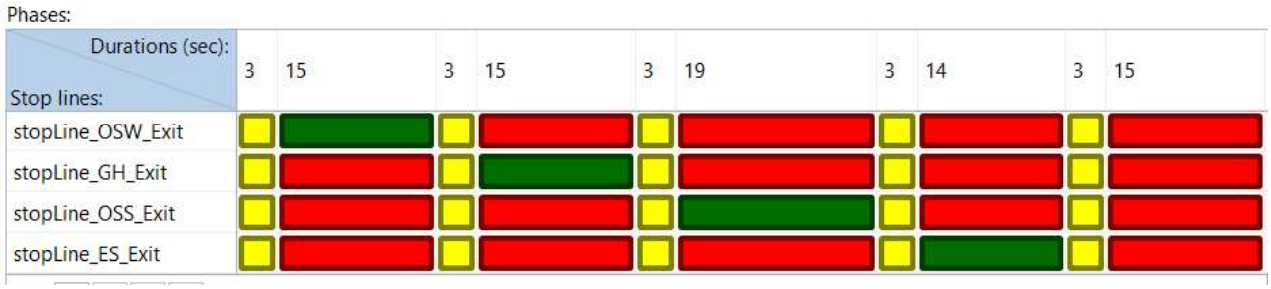

Figure 35: Signal phases after implementing Experiment 2.

Variable	Real World Value	Validated CI (99%)	Experiment CI (99%)
Herder Str. (Av-Que-Len)	1.57	1.556 - 1.593	1.554 - 1.595
Ebendorfer Str. (Av-Que-Len)	3.55	3.509 - 3.589	3.131 - 3.199
Olvenstedter Str.-W (Av-Que-Len)	2.0	2.01 - 2.152	1.679 - 1.822
Gerhart-Haupt. Str. (Av-Que-Len)	3.13	2.974 - 3.156	2.91 - 3.093
Olvenstedter Str.-S (Av-Que-Len)	1.59	1.468 - 1.632	1.125 - 1.289
Avg. time in node (Secs)	58	53.23 - 58.651	46.584 - 52.001

Table 21: Differences made by Experiment 2

After changing the signal pattern, there is only a slight reduction in average queue length for all the roads in the node. However, there is a significant decrease in average time in the node changing from 58 in the real world to 46.584 - 52.001 in the experiment. That means a vehicle requires at least 6-12 seconds less to travel through the node.

Traffic variance:

The traffic variance part of the experiment showed that this change will majorly reduce the average time spent by vehicles in the node even with a higher traffic load. There are a few spikes in that value but even those are still less or the same as the current value. Thus no concerns are observed.

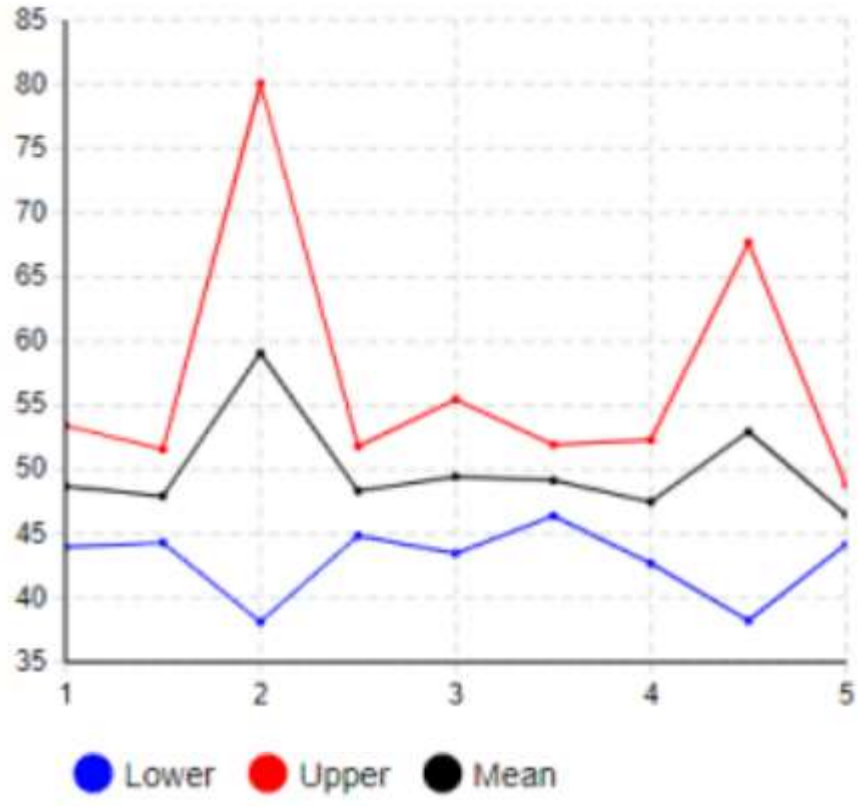

Figure 36: Traffic variation effect on Average time in node after implementation of Experiment 2.

5.6 Experiment 3: Pedestrian over-bridge/Subway

While the Pedestrians are crossing the road, the signal changes to green for the vehicles, making the vehicles wait for an additional time. Hence, increases time spent in the node. An over-bridge can totally remove the pedestrians from the road and allow uninterrupted vehicle movement.

Variable	Real World Value	Validated CI (99%)	Experiment CI (99%)
Avg. time in node (Secs)	58	53.23 - 58.651	43.771 - 44.446

Table 22: Differences made by Experiment 3.

The average queue length does not get affected by removing the pedestrian. The only variable to consider is the Average time in node. The average time in node has decreased to 43.771 - 44.446 from the real-world value of 58.

Traffic Variance:

The average time spent inside the node by vehicles increases constantly with an increase in traffic load. There is a steep increase beyond traffic load of 3 times more than the current system but that is related more to the overall setup of the node than to the experiment in particular.

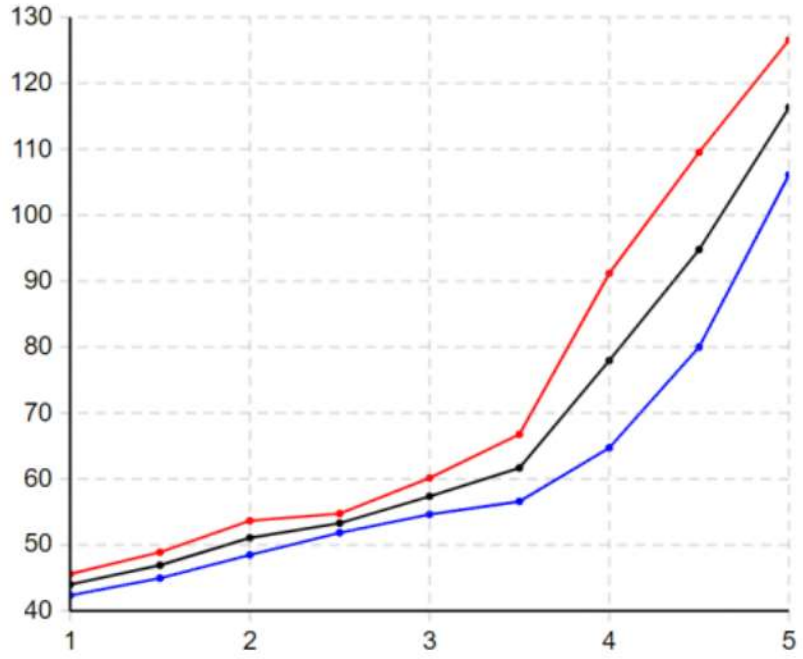

Figure 37: Traffic variation effect on Average time in node after implementation of Experiment 3.

5.7 Experiment 4: Combining the half arm in Gerhart-Hauptmann straße

Vehicles are taking a longer routing coming from anywhere except Olvenstedter strasse (south) into Gerhart-Hauptmann straße. This increases time spent in the node. In the experiment, we are removing the two-way arm into Olvenstedter strasse (south) and converting the one way exit to the intersection into a two-way connection in Gerhart-Hauptmann straße

Variable	Real World Value	Validated CI (99%)	Experiment CI (99%)
Gerhart-Haupt. Str. (Av-Que-Len)	3.13	2.974 - 3.156	1.628 - 1.648
Avg. time in node (Secs)	58	53.23 - 58.651	46.391 - 50.053

Table 23: Differences made by Experiment 4.

After the experiment, there is a significant decrease in both Average queue length and Average time in node. The average queue length and average time in node both have decreased from 3.13 to 1.628 - 1.648 and 58 to 46.391 - 50.053 respectively.

Traffic variance:

The increase in traffic does not seem to bother the result of this experiment in particular. Though the queue length at Gerhart-Hauptmann straße increases in proportion to the traffic load, it still maintains an acceptable level of queues. The queue length of around 4.2 after this experiment is implemented, at 5 times the traffic is almost comparable to the current system's mean of 3.13.

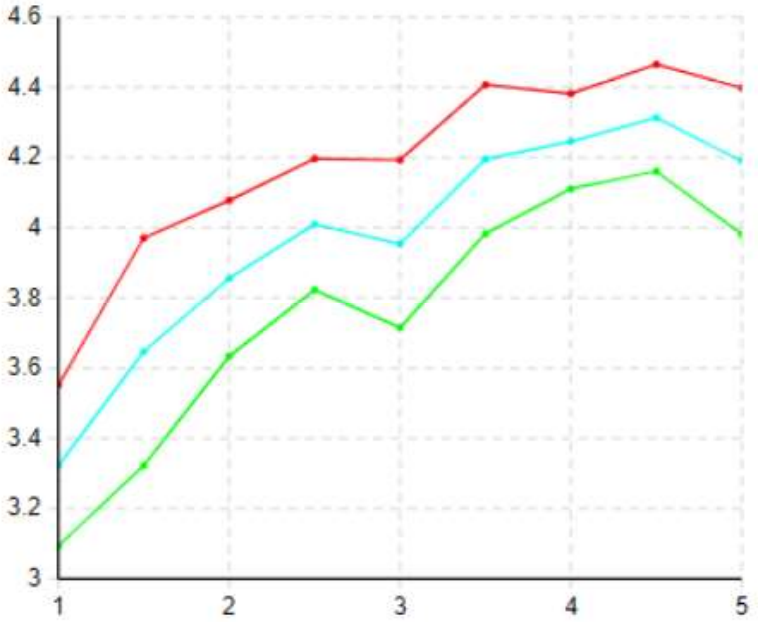

Figure 38: Traffic variation effect on Queue length at Gerhart-Hauptmann Str. after implementation of Experiment 4.

The average time spent in node by the vehicles also sees a gradual increase with the load but still ends up having value of around 60 seconds at 5 times the traffic load of current situation which already sees the value reach upto 58 seconds with the existing setup.

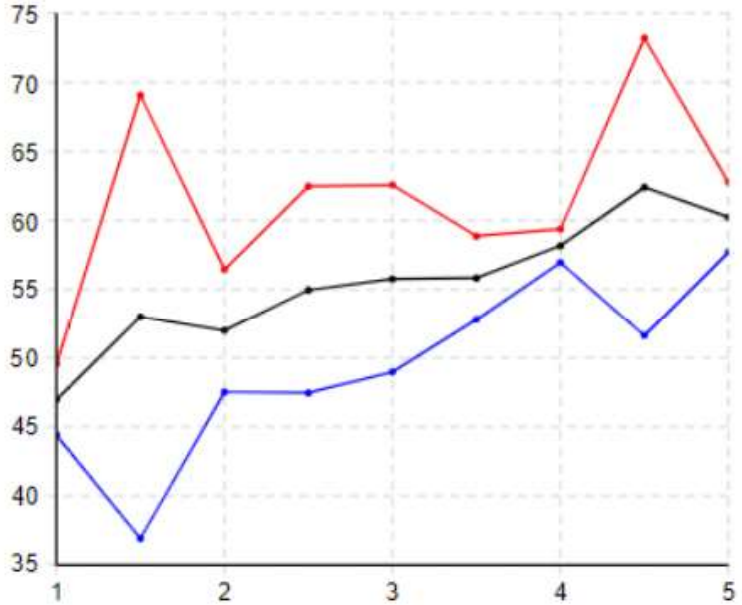

Figure 39: Traffic variation effect on average time spent in node after implementation of Experiment 4.