

Optimization of Traffic lights

Current situation:

1. Green Time Allotted: This refers to the duration for which the traffic light remains green for a particular direction at the junction. It is predetermined based on expected traffic flow patterns.

2. Green Time Used: This is the actual duration for which vehicles utilize the green light to move through the junction. It is recorded to analyze how effectively the allotted green time is being used.

3. Average Saturation: Average saturation measures the proportion of the green time that is utilized by vehicles. It is calculated as the ratio of the green time used to the green time allotted.

$$\text{Average Saturation} = (\text{Green Time Allotted}/\text{Green Time Used}) * 100\%$$

The Average Saturation according to our data is 80.04594774%.

We have data on green time used, green time allotted to the vehicles, and the saturation of the time utilized by the vehicle. This discrepancy arises because when the green time is allocated to a particular junction and there are no vehicles, the software setup takes 5 seconds to verify that there is no vehicle at that junction. The software fully depends on the delay between the two arrivals. If the delay between the two arrivals is more than 4 seconds, the software switches that signal to red. However, this is not the best way to calculate the fitness of the timings since there can be gaps in high-volume traffic. Hence, the actual saturation might be much less than calculated above.

4. Standard Deviation of Green Time Used: The standard deviation measures the variability in green time usage. A high standard deviation indicates inconsistent usage of green time across different cycles.

The standard deviation according to our data is 25.10559175.

Basic Analysis:

The basic analysis of the traffic volume.

From a broader perspective, considering traffic volumes in 10-minute intervals from 13th Jan to 29th Feb:

Approaches	ABC to Bhangagarh	Ulubari to Bhangagarh	Rajgarh to Bhangagarh
Average	75.440452	82.708355	59.366705
Standard Deviation	52.923148	56.737897	44.773497
Min	0	0	0
Max	233	259	299

This broader perspective tells us that traffic volume on the Ulubari approach is the highest and lowest at the Rajgarh approach, with ABC being in the middle. However, as one can clearly see, the standard deviation is too high to make any definitive conclusions.

Hence, we proceed towards a finer analysis. We first decide the factors that can affect the traffic flow. Traffic flow can change according to the time of day. The traffic flow in the morning half may not be the same as in the evening half. Additionally, traffic volume changes on holidays.

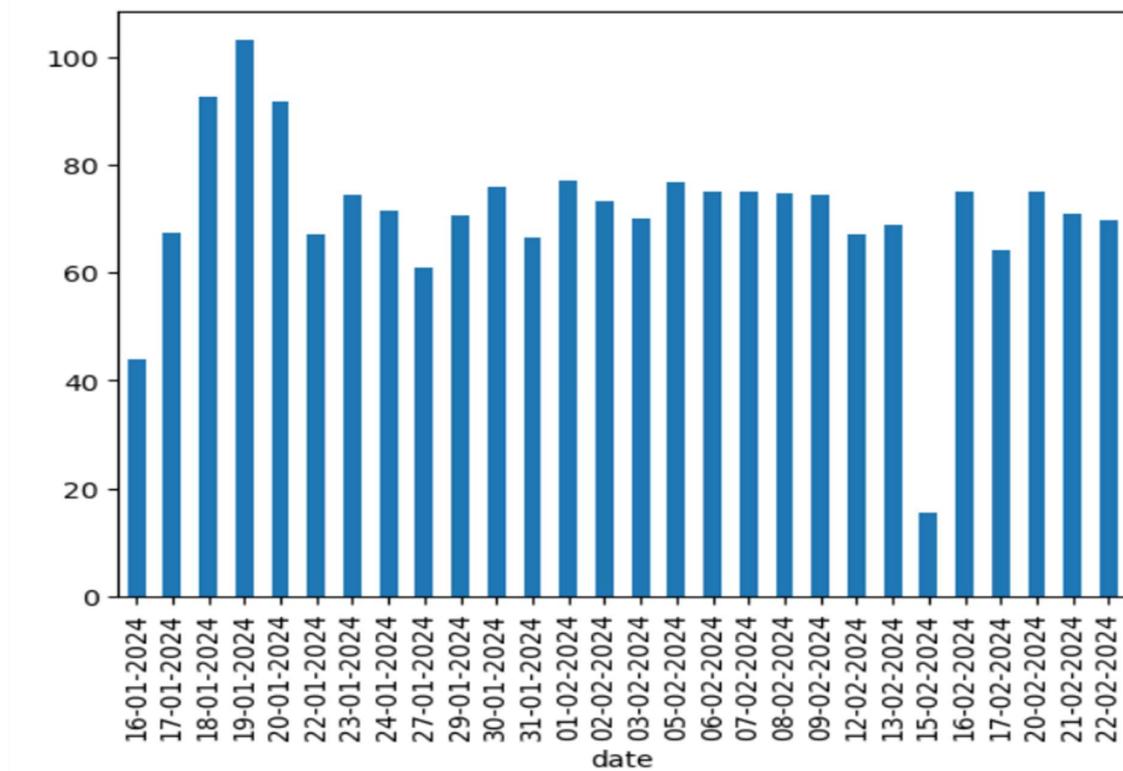
So, we start by removing holidays from the considered data (i.e. 13th jan,2024 to 29th feb,2024) and dividing the traffic volumes in seven parts (i.e. 8AM to 9AM, 9AM to 10AM, 10AM to 11AM,1PM to 2PM,2PM to 3PM,5PM to 6PM,6PM to 7PM).

Analysis of traffic volume (8AM to 9AM):

In the following graphs, x-axis indicates the date, and the y-axis indicates the average number of vehicle arrivals in 10-minute intervals between 8AM to 9AM.

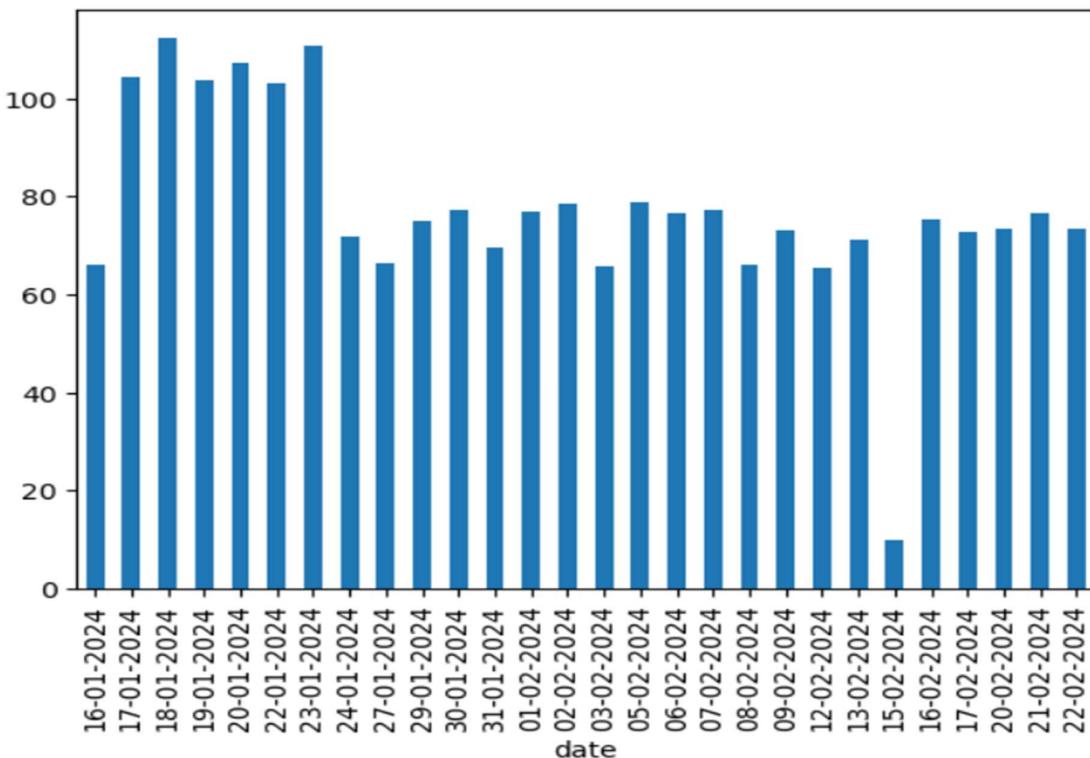
ABC to Bhangagarh:

Total Average: 70.375

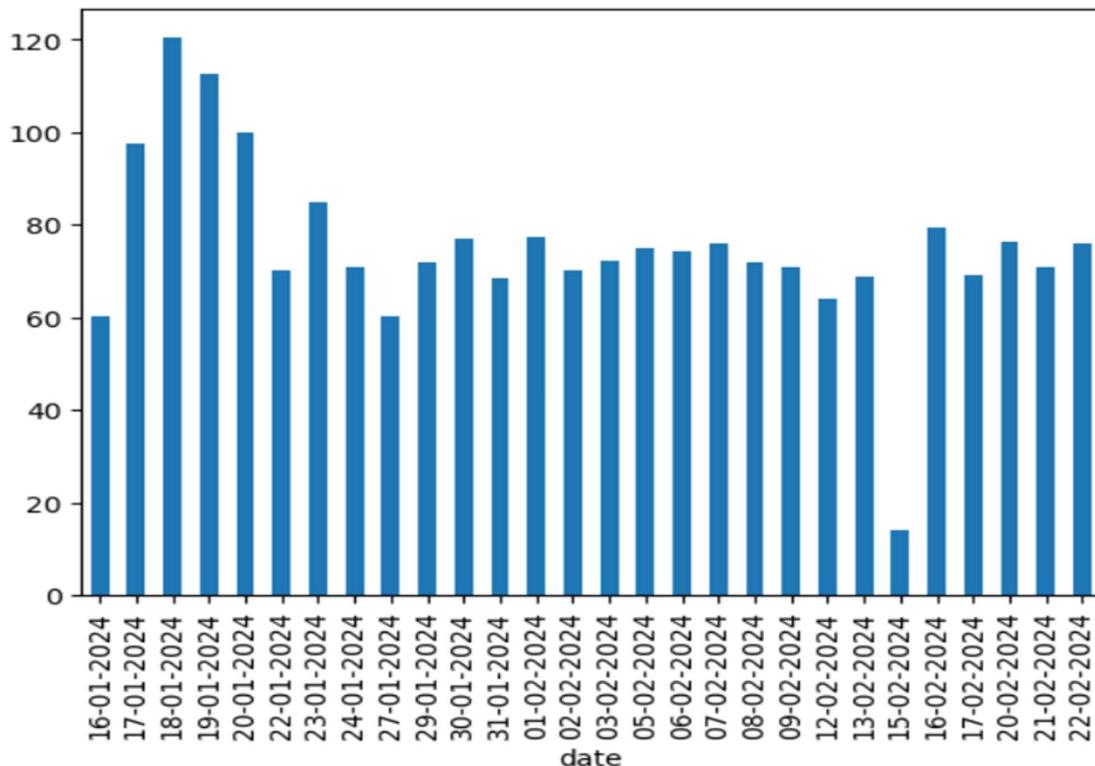


Ulubari to Bhangagarh:

Total Average: 77.78571428571429



Rajgarh to Bhangagarh:
Total Average: 76.5060975609756



As we can see the number of arrivals on a particular day stays within a specific range for each approach.

For example, for the Rajgarh approach, the maximum number of arrivals are in the range of 67 to 77. Additionally, notice that the total averages are not significantly different from each other.

Note: For additional data visualizations and detailed analysis, please refer to *Appendix A*. This section includes supplementary graphs for the time periods of 9-10 AM, 10-11 AM, 5-6 PM, and 6-7 PM, covering all three approaches discussed in this report.

Inferences:

1. If you closely examine the above graphs, except for the first few days, the traffic volume stays within a closed interval. For example, for the Ulubari approach, from 8 AM to 9 AM, the number of arrivals almost stays in the range of 68 to 78.
2. The traffic volume in a particular hour highly depends on the amount of traffic in the previous hour. For example, for the Ulubari approach, the traffic volume from 8 AM to 9 AM from January 17th to January 23rd is around 105 vehicles per 10 minutes, while for the rest of the days, the average is around 65 vehicles per 10 minutes. For the same days, the traffic from 9 AM to 10 AM is around 155 vehicles per 10 minutes, while for the rest of the days, it is around 95 vehicles per 10 minutes. Similar patterns can be observed in other cases.

Note: Since the traffic volumes were unusually high for the first few days, which is not a common occurrence, we will exclude data from January 16th to January 23rd, 2024, in further analysis.

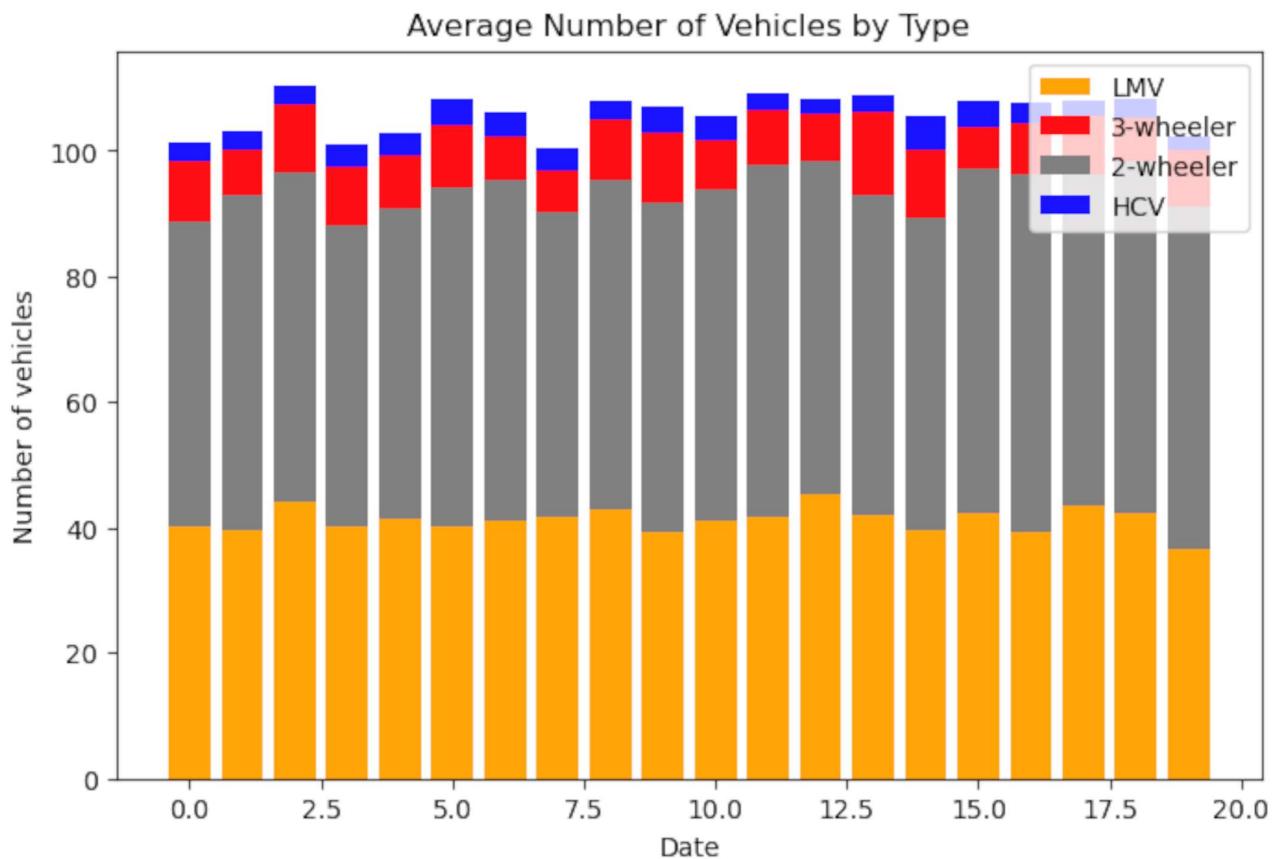
Analysis of Traffic Volume Distribution by Vehicle Type:

Let's delve into the distribution of different vehicle types in the total traffic volume. Cars and two-wheelers dominate the traffic, significantly outnumbering three-wheeler and HCVs (Heavy Commercial Vehicles). To better understand this trend, we'll visualize the traffic volume split across all approaches during three peak time intervals: 9 AM to 10 AM, 1 PM to 2 PM, and 6 PM to 7 PM. This analysis will help identify patterns and peak traffic contributions of each vehicle type.

Visualizing traffic between 9 AM to 10 AM:

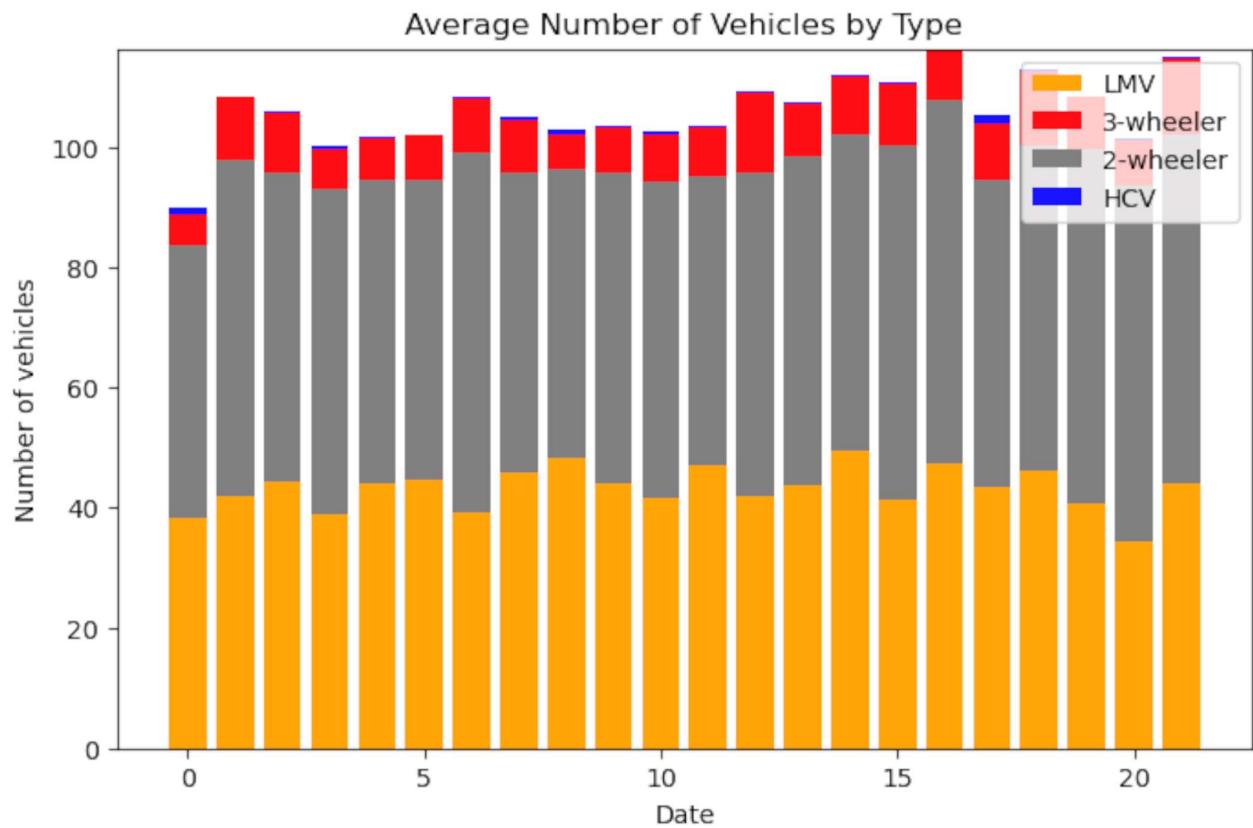
In the following graphs, x-axis indicates the day, and the y-axis indicates the number of vehicles with their types arrived in between 9 AM to 10 AM.

From Ulubari to Bhangagarh:

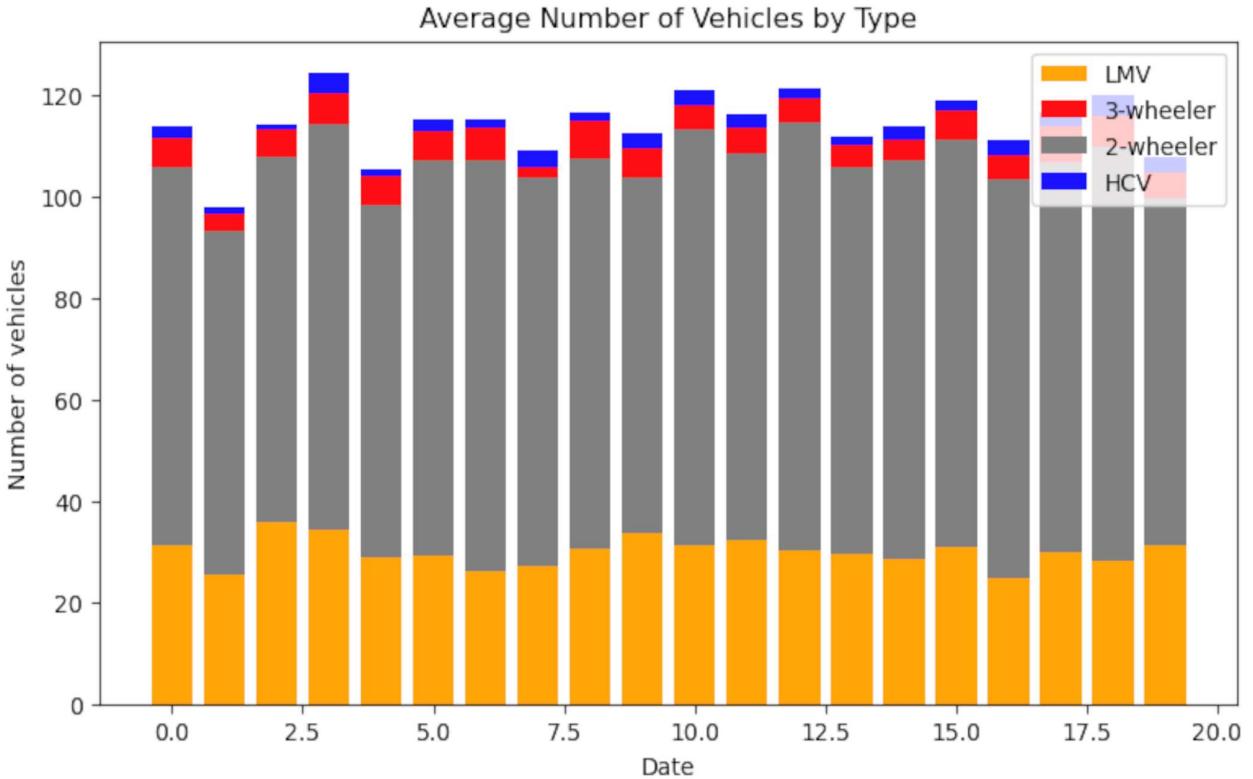


The ratio of two-wheelers , three-wheelers, cars and HCVs is almost constant around 40.7 : 6.4 : 33.5 : 3.2.

From Rajgarh to Bhangagarh:



From ABC to Bhangagarh:



Note: For additional data visualizations and detailed analysis, please refer to Appendix B. This section includes supplementary graphs for the time periods of 1-2 PM and 6-7 PM, covering all three approaches discussed in this report.

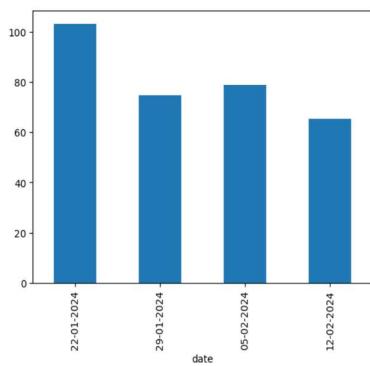
Monday Analysis:

We proceed towards even finer analysis by analysing the traffic volume day-wise. We start by removing holidays from the Mondays (i.e., from January 13th, 2024 to February 29th, 2024) and dividing the traffic volumes into seven parts (i.e., 8 AM to 9 AM, 9 AM to 10 AM, 10 AM to 11 AM).

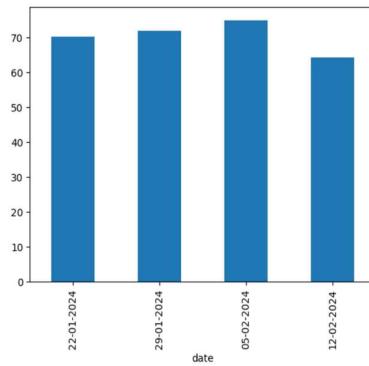
The traffic volume between 8AM to 9AM:

In the following graphs, x-axis indicates the date and the y-axis indicates the average number of vehicles arriving in 10-minute intervals between 8AM to 9AM.

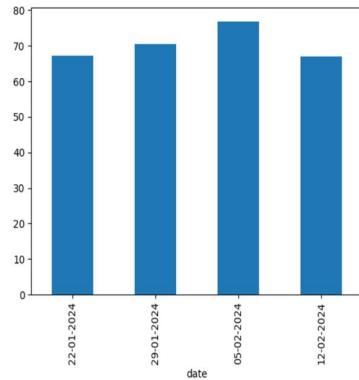
Ulubari to Bhangagarh:
Total Average: 80.54166666



Rajgarh to Bhangagarh:
Total Average: 70.25



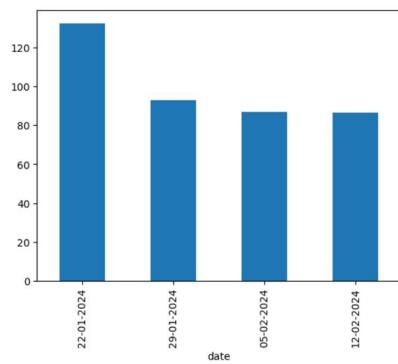
ABC to Bhangagarh:
Total Average: 70.375



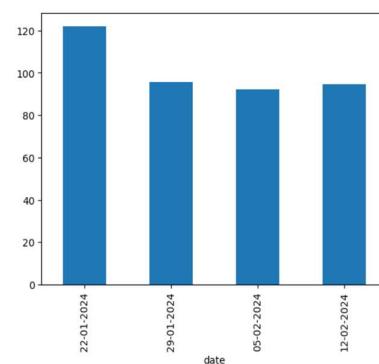
The traffic volume between 9AM to 10AM:

In the following graphs, x-axis indicates the date and the y-axis indicates the average number of vehicles arriving in 10-minute intervals between 9AM to 10AM.

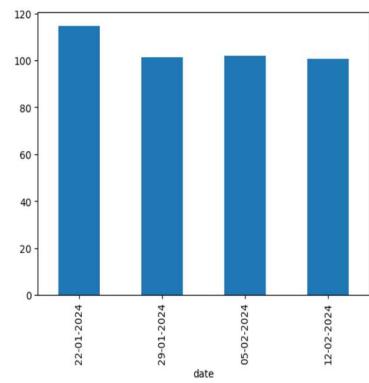
Ulubari to Bhangagarh:
Total Average: 99.5833333333



Rajgarh to Bhangagarh:
Total Average: 101.12500



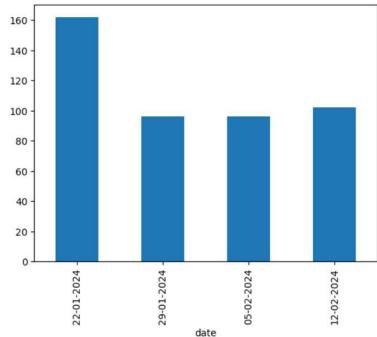
ABC to Bhangagarh:-
Total Average: 104.625



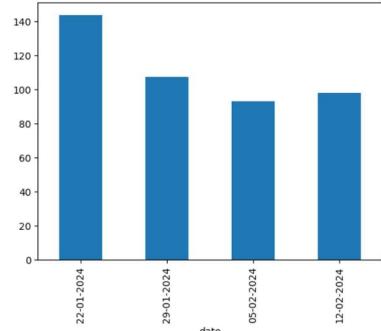
The traffic volume between 10AM to 11AM:

In the following graphs, x-axis indicates the date and the y-axis indicates the average number of vehicles arrival s in 10-minute intervals between 10AM to 11AM.

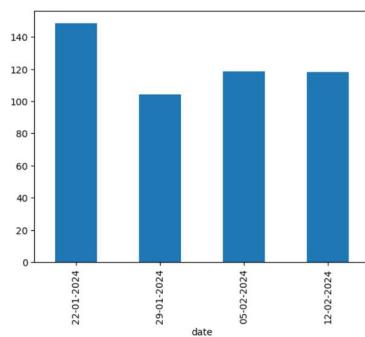
Ulubari to Bhangagarh:
Total Average: 114.125



Rajgarh to Bhangagarh:
Total Average: 110.499



ABC to Bhangagarh:
Total Average: 122.25



The inferences stated above also apply to the Monday analysis. However, this analysis did not provide us with additional insights.

Day-wise Analysis:

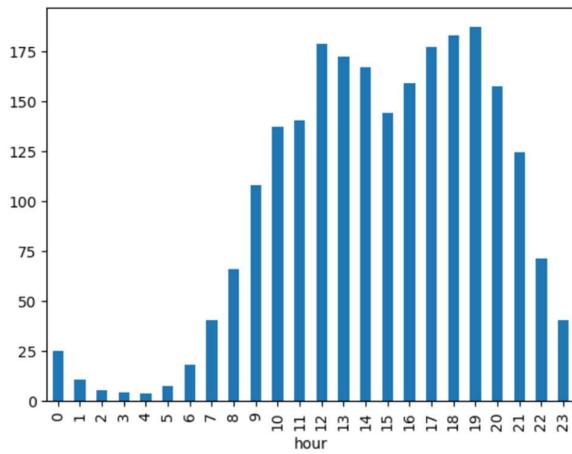
Considering our inferences in the basic analysis, the traffic volume in any interval highly depends on the traffic volume in the previous hour and it belongs to a range.

Hence it becomes important to study the volume distribution of traffic in a day.

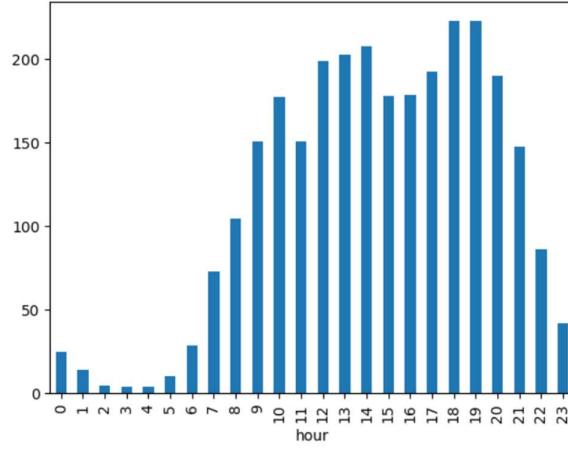
Hence, we plotted the graphs of the average number of vehicles per 10 minutes in an hour.

In the following graphs, Y-axes denote the average number of vehicles in 10 minutes. On X-axes 'n' mean the time interval n to n+1 interval in 24 hour clock.

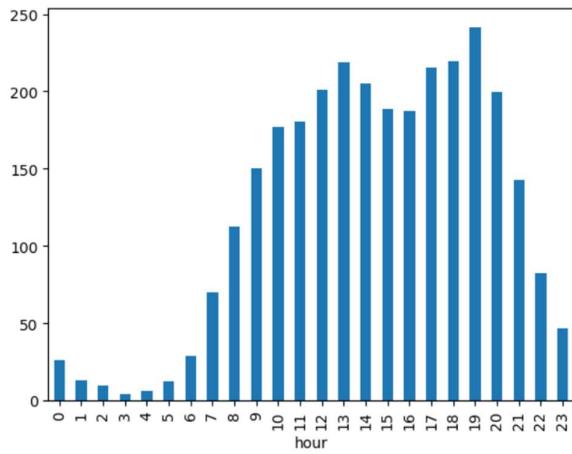
16-01-2024:



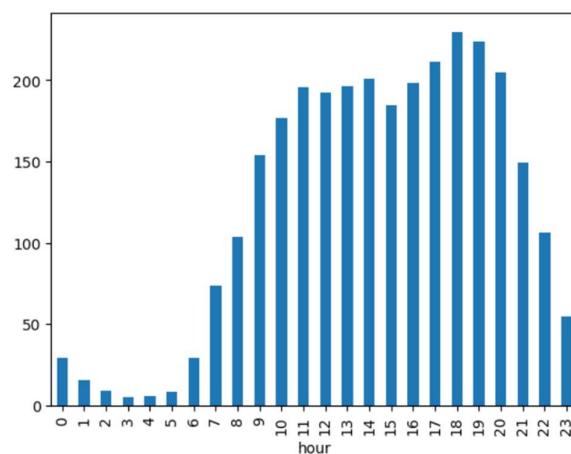
17-01-2024:



18-01-2024:



19-01-2024:



Observations:

Upon observing the graphs, a discernible pattern emerges. Despite changes in scale, the bimodal nature of the graphs remains consistent. This consistency suggests that the traffic volume within any given 10-minute interval is influenced by the average traffic volume during the preceding 1-hour interval.

Note: For further data visualizations and analysis, please refer to Appendix C. While this report includes graphs for [16-01-2024, 17-01-2024, 18-01-2024, 19-01-2024], the appendix contains supplementary graphs for additional dates. This ensures comprehensive coverage of the data for thorough analysis.

Prediction

Our traffic prediction algorithm is based on the following observations from our initial analysis:

1. **Peak Traffic Occurrences:** Traffic volume tends to occur most frequently within a certain range.
2. **Dependence on Previous Hour:** Traffic volume is largely dependent on the volume in the previous hour.

Given these observations, we can infer that the regular daily traffic volume is most likely to fall within a predictable range.

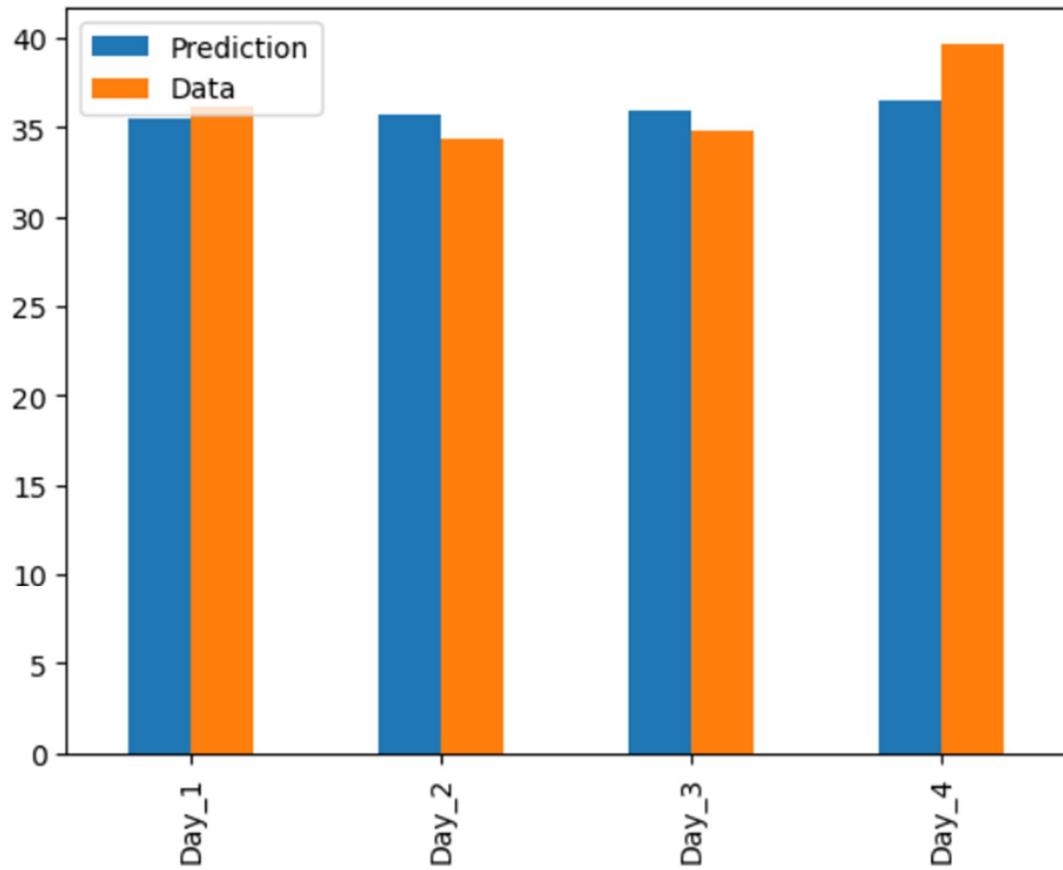
To enhance our prediction, we will employ the moving average method. This involves predicting the average number of vehicles in a given hour based on the traffic volume in the same hour over the last five days.

We tested our prediction results against 4 regular days(i.e. 23rd, 24th, 28th and 29th Feb 2024)

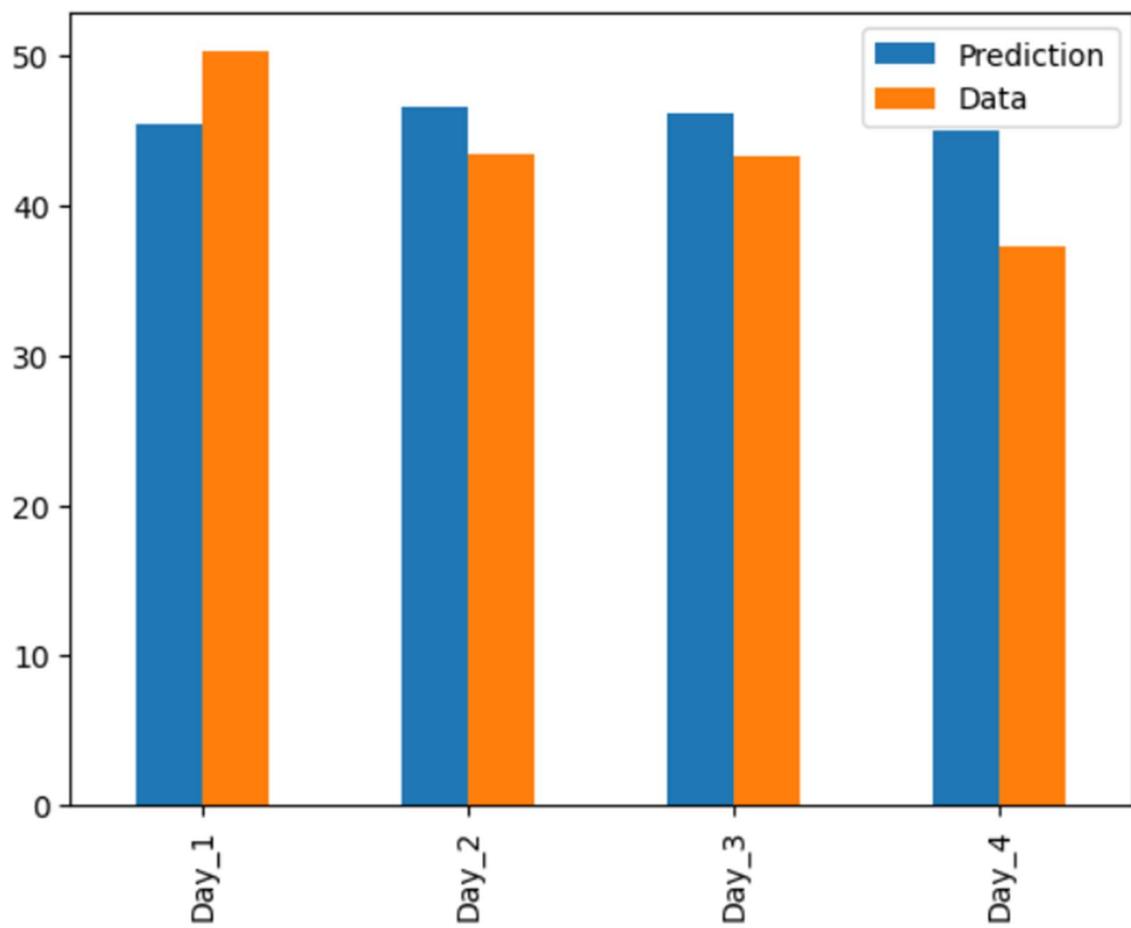
The results for each kind of vehicles is as follows:

For 8AM to 9AM:

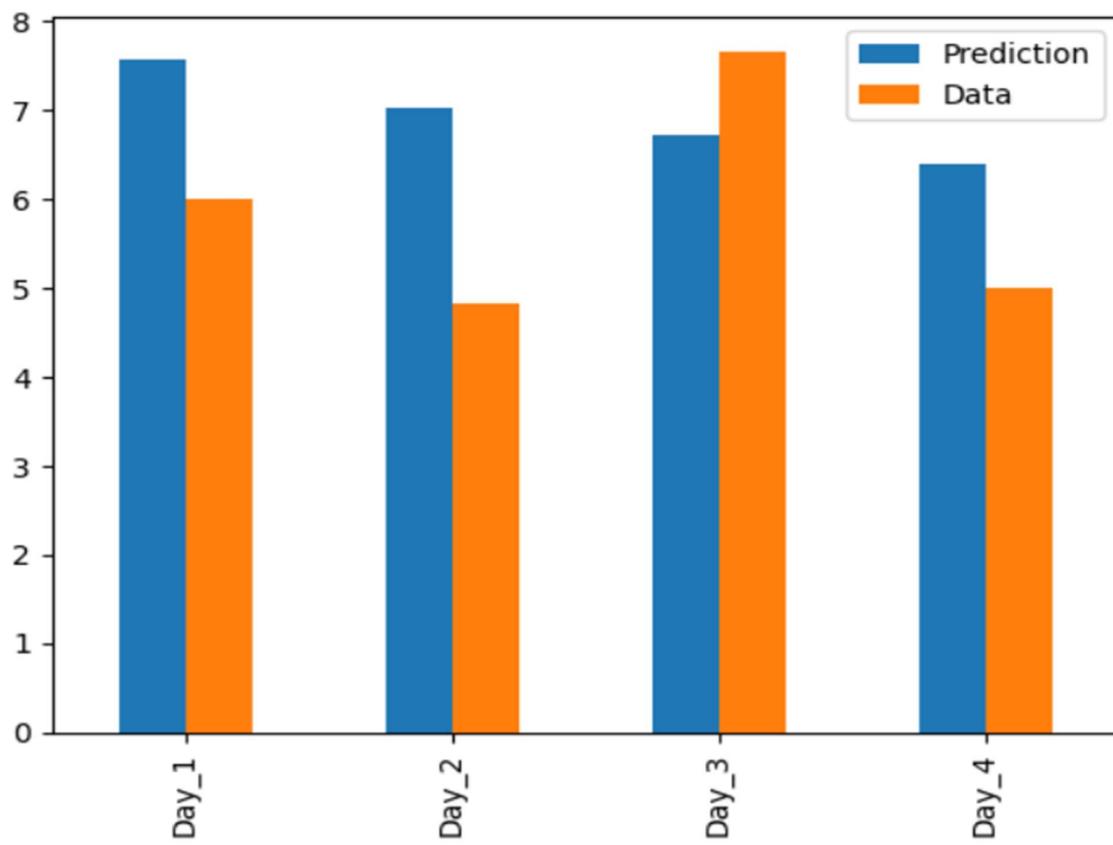
Cars:



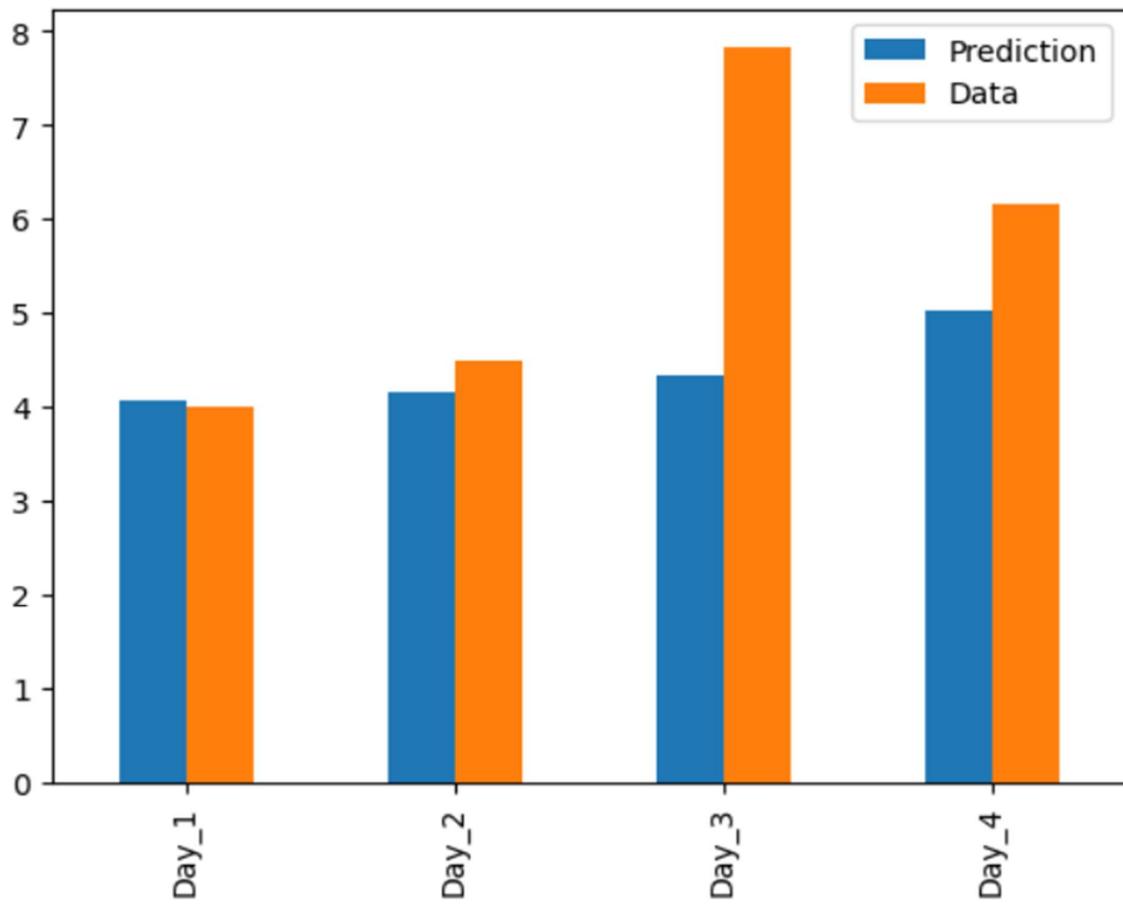
Two Wheelers:



Three Wheelers:



HCVs:



As we can see, the maximum difference between the predicted and actual events is 5, which is reasonable and accurate to within $\frac{1}{2}$ vehicle per minute.

Note: For further data visualizations and analysis, please refer to *Appendix D*. While this report includes graphs for the 8-9 AM time period (covering Two Wheelers, Cars, and Three Wheelers), the appendix contains supplementary graphs for the time periods of 9-10 AM, 10-11 AM, 1-2 PM, 2-3 PM, 5-6 PM, and 6-7 PM. This ensures comprehensive coverage of the data for thorough analysis.

Simulator:

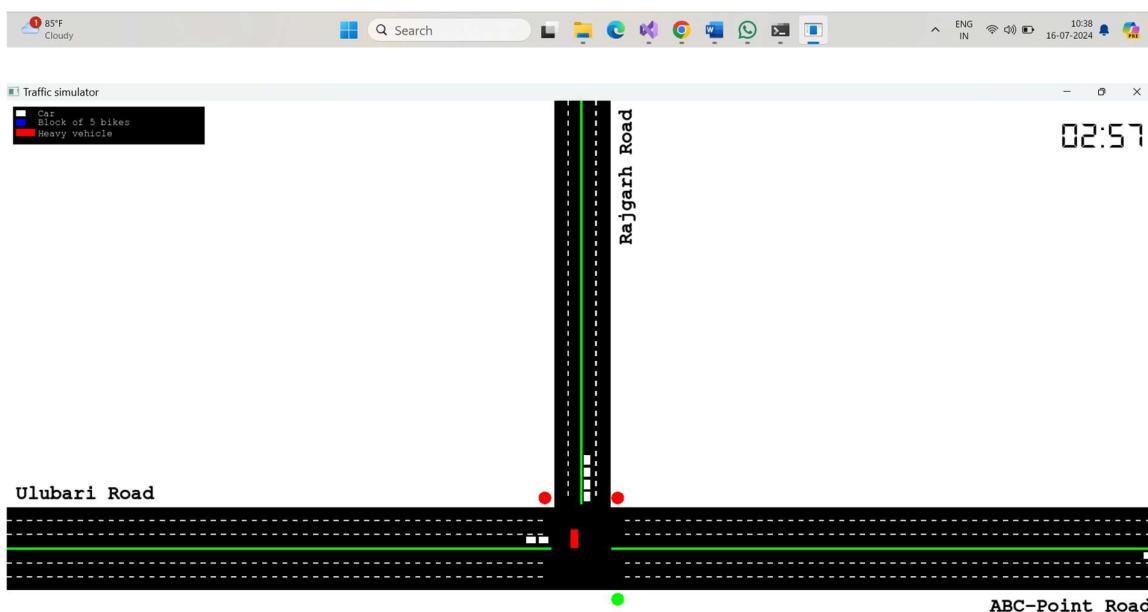
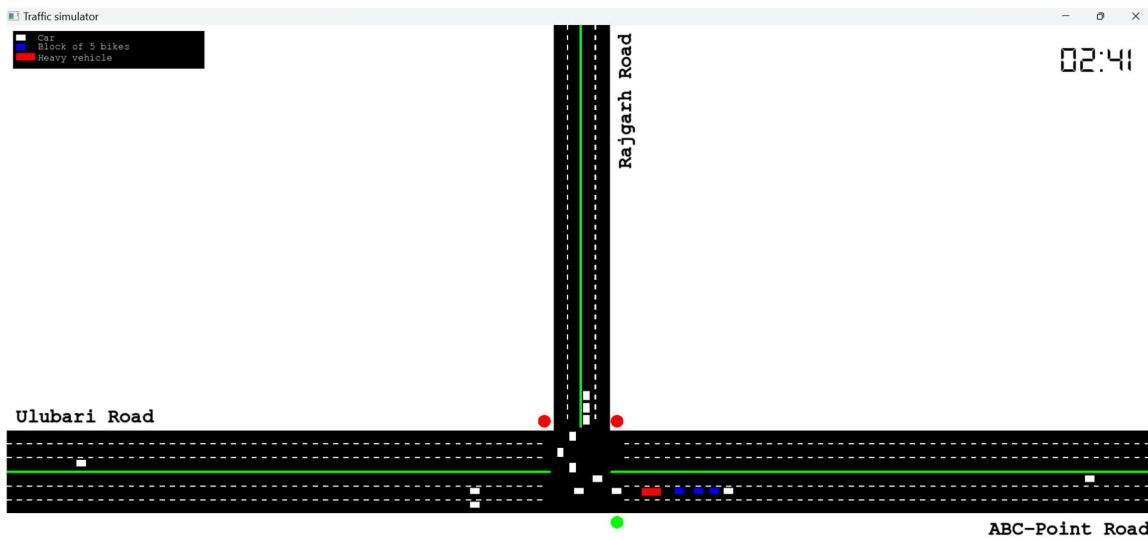
To analyse the performance of intersection timings, it is essential to calculate the waiting time for each vehicle and determine the maximum queue length for each approach. To effectively showcase our results, we have built a highly realistic simulation of the intersection. In this simulator, the speed of each vehicle is dynamically adjusted based on the distance to the vehicle ahead, ensuring that vehicles slow down as they approach closer to others.

In the simulator, vehicles are visually represented using color-coded rectangles for clarity:

- **Cars:** White rectangles
- **Heavy vehicles:** Red rectangles
- **Groups of two-wheelers (five per group):** Blue rectangles

These visual distinctions help in easily identifying different types of vehicles within the simulation.

Below are some snapshots of the simulator in action, illustrating its detailed and lifelike design



APPENDIX

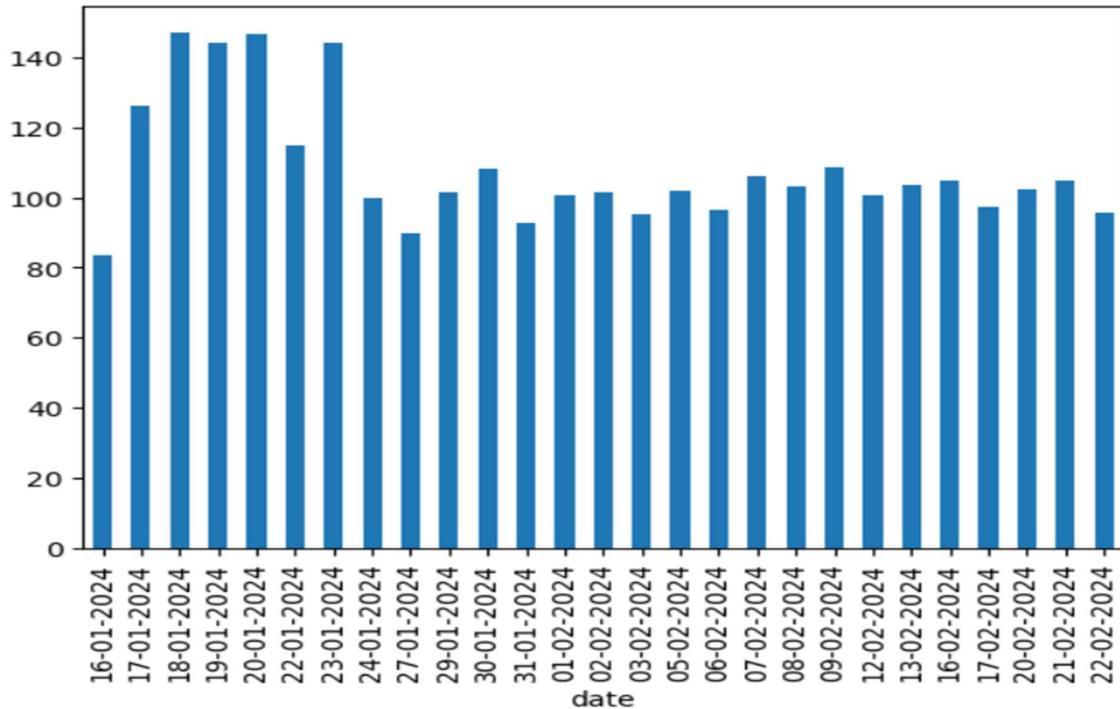
Appendix-A

The traffic between 9AM to 10AM:

In the following graphs, x-axis indicates the date and the y-axis indicates the average number of vehicles arrivals in 10-minutes interval between 9AM to 10AM

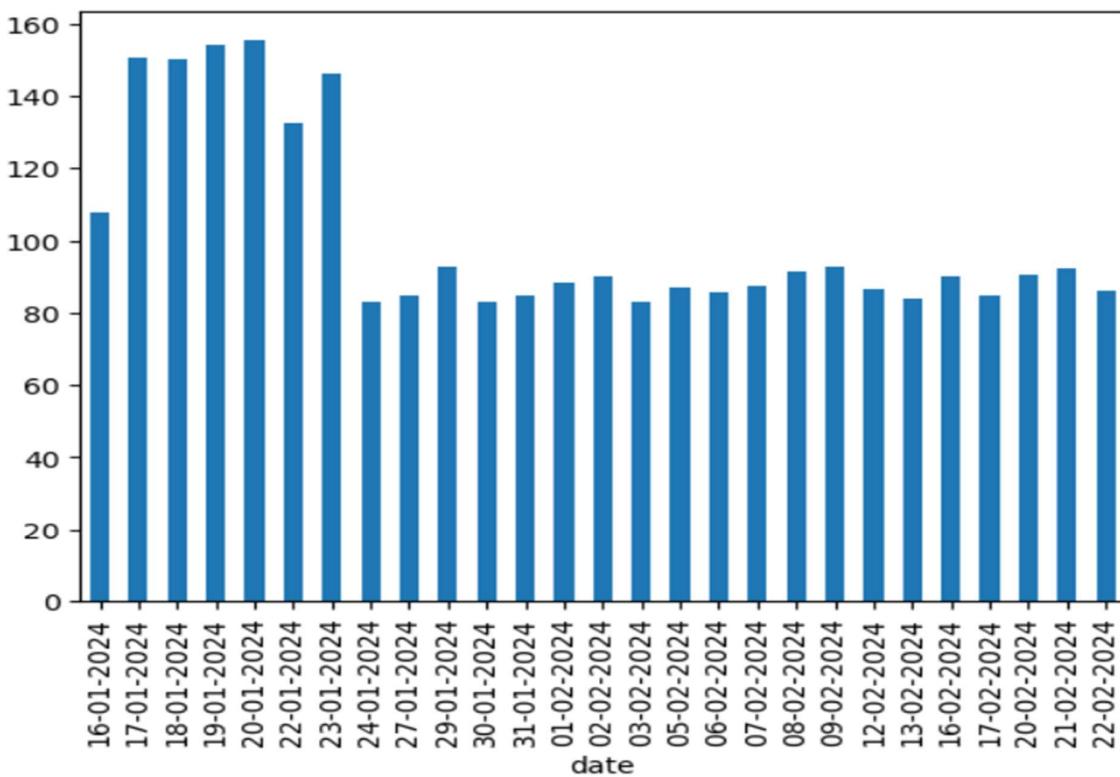
ABC to Bhangagarh:

Total Average: 108.17283950617283



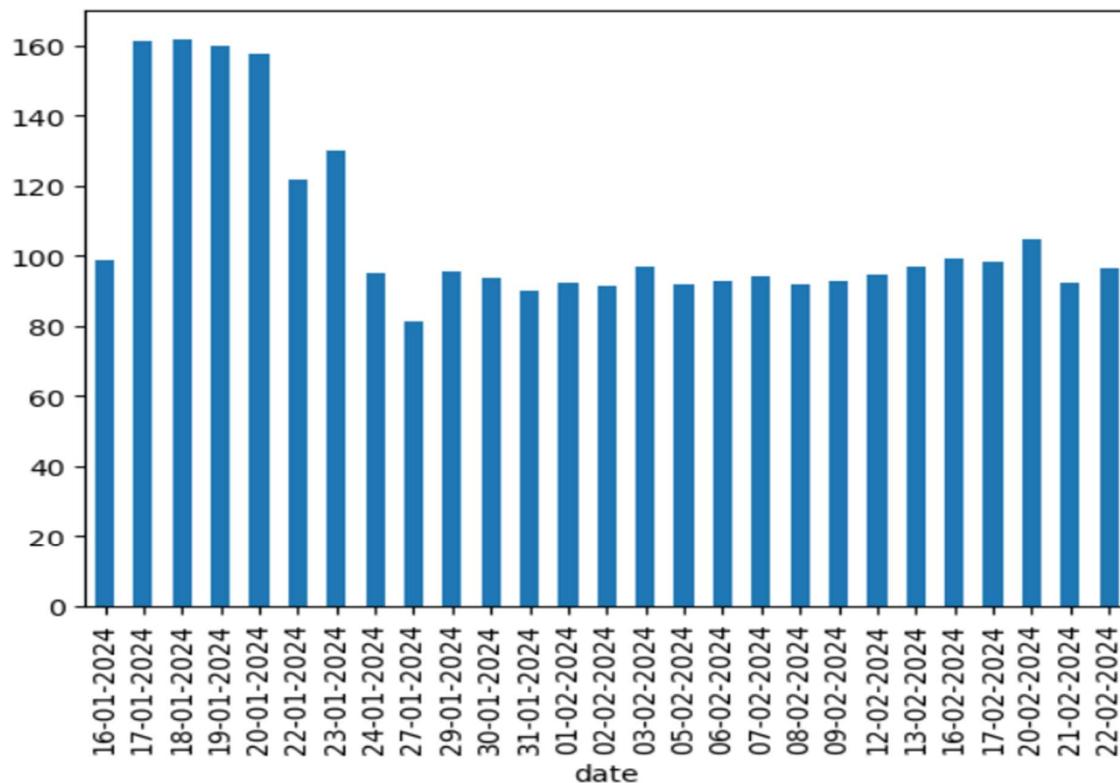
Ulubari to Bhangagarh:

Total Average: 101.65432098765433



Rajgarh to Bhangagarh:

Total Average: 106.51234567901236

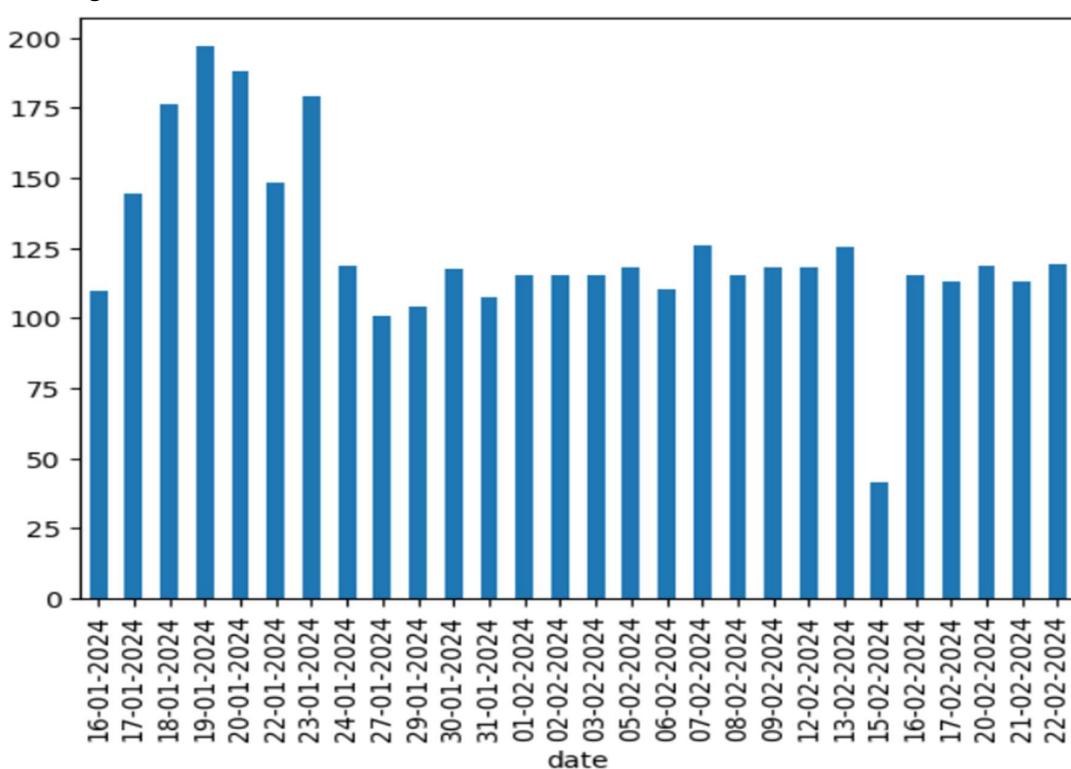


The traffic from 10 AM to 11AM:

In the following graphs, x-axis indicates the date and the y-axis indicates the average number of vehicles arrivals in 10-minute intervals between 10AM to 11AM.

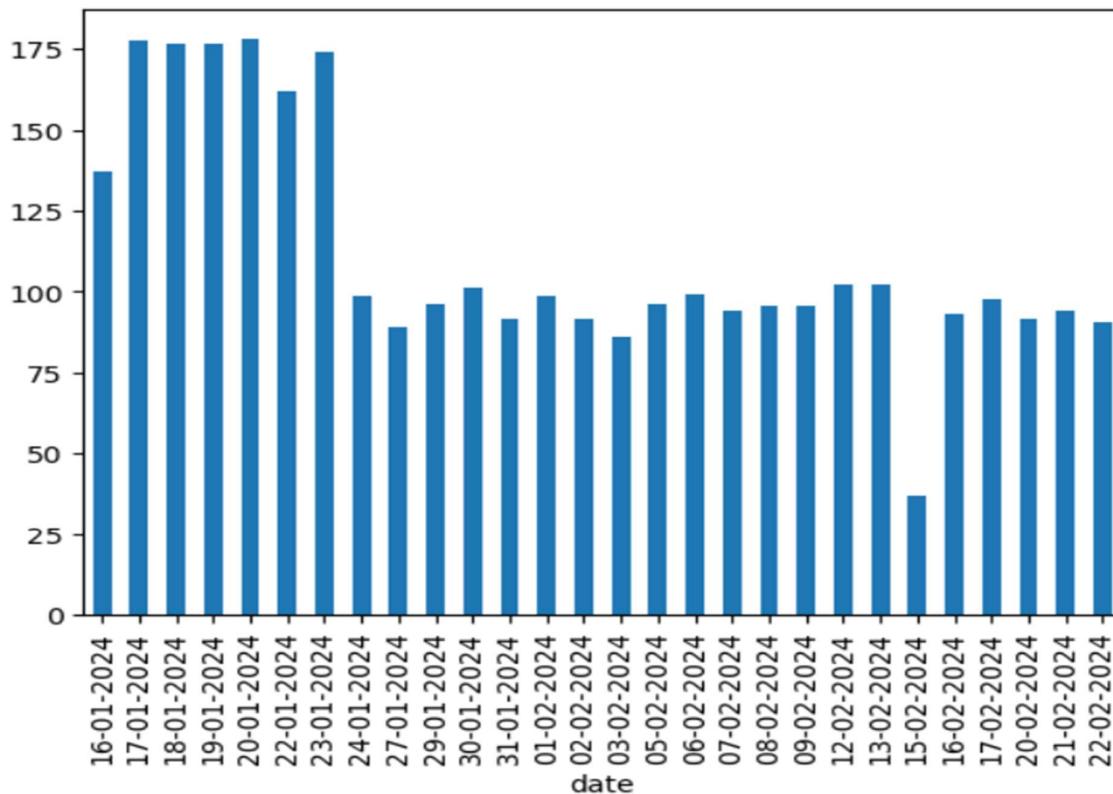
ABC to Bhangagarh:

Total Average: 124.62500000000001

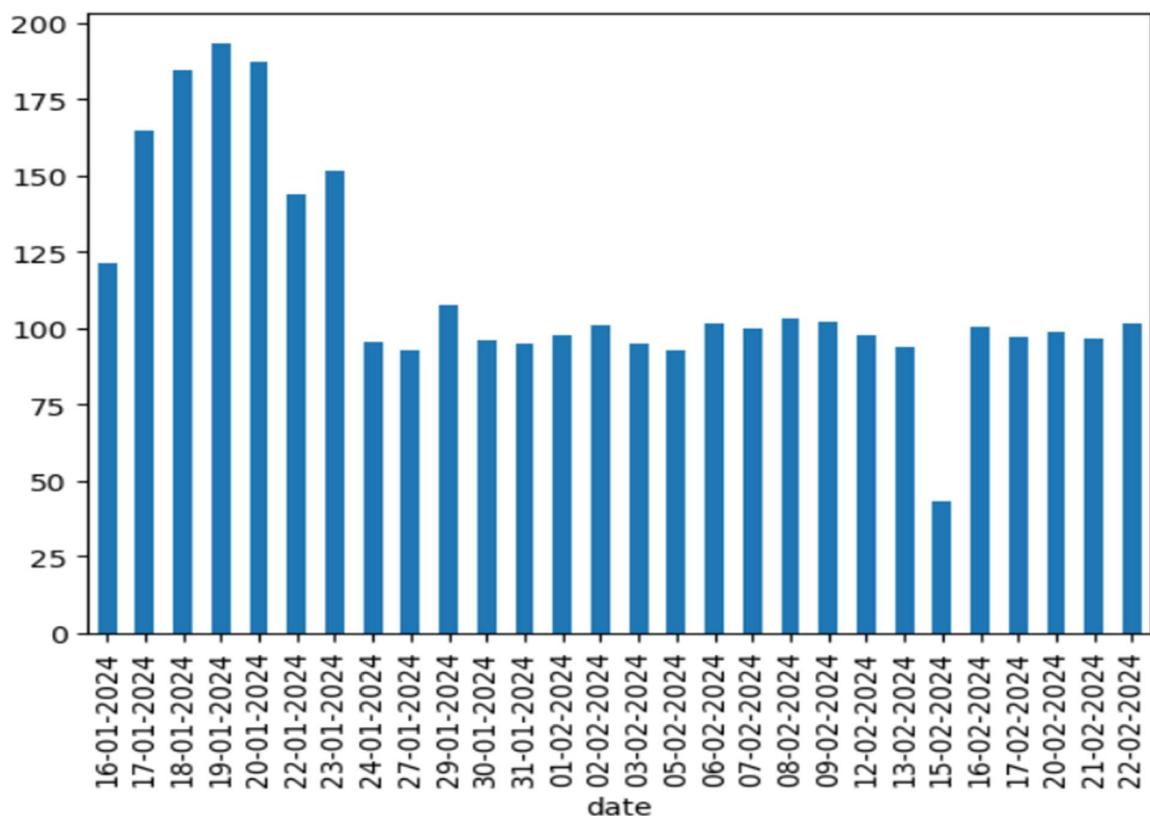


Ulubari to Bhangagarh:

Total Average: 111.6190476190476

**Rajgarh to Bhangagarh:**

Total Average: 112.79761904761904

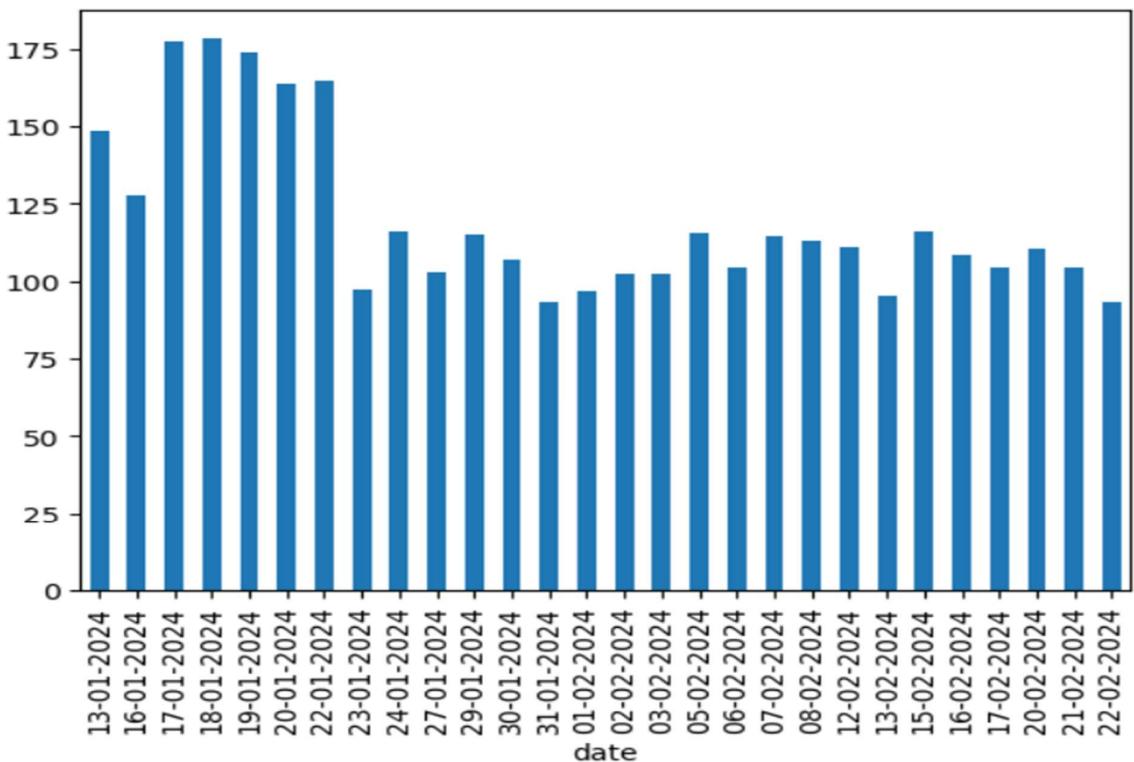


The traffic from 5 PM to 6PM:

In the following graphs, x-axis indicates the date and the y-axis indicates the average number of vehicles arrivals in 10-minute intervals between 5PM to 6PM.

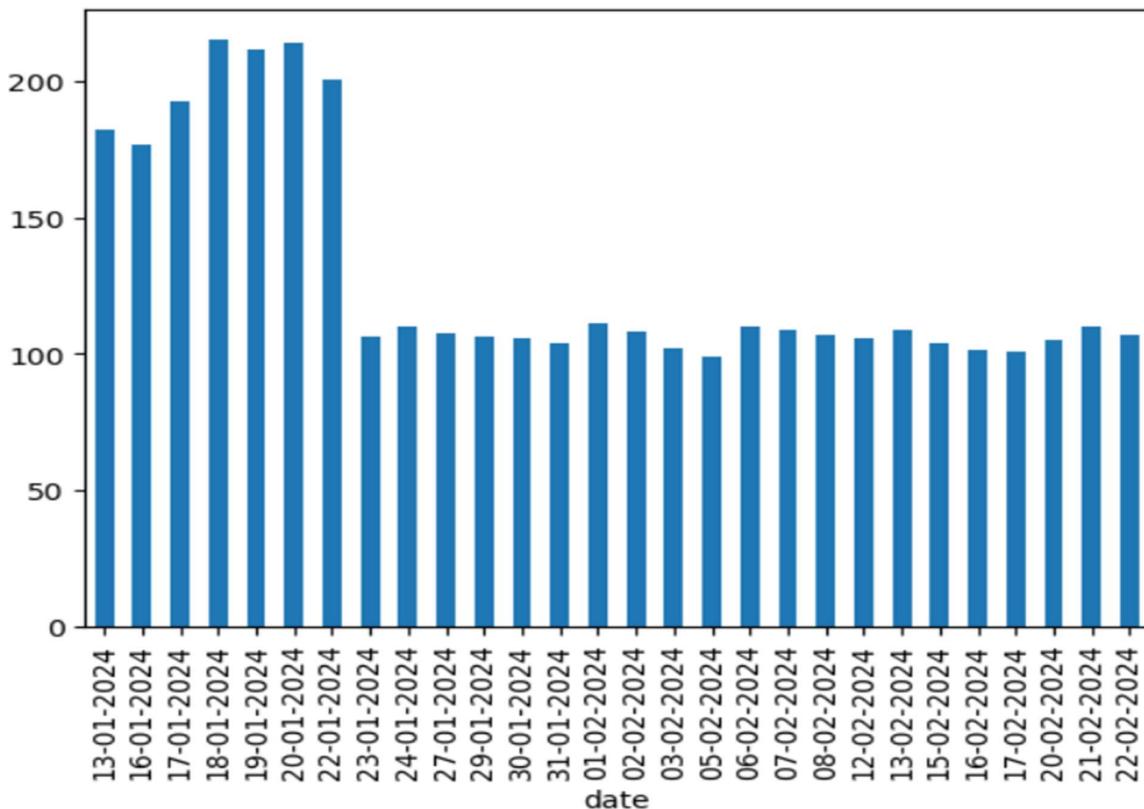
ABC to Bhangagarh:

Total Average: 120.0297619047619



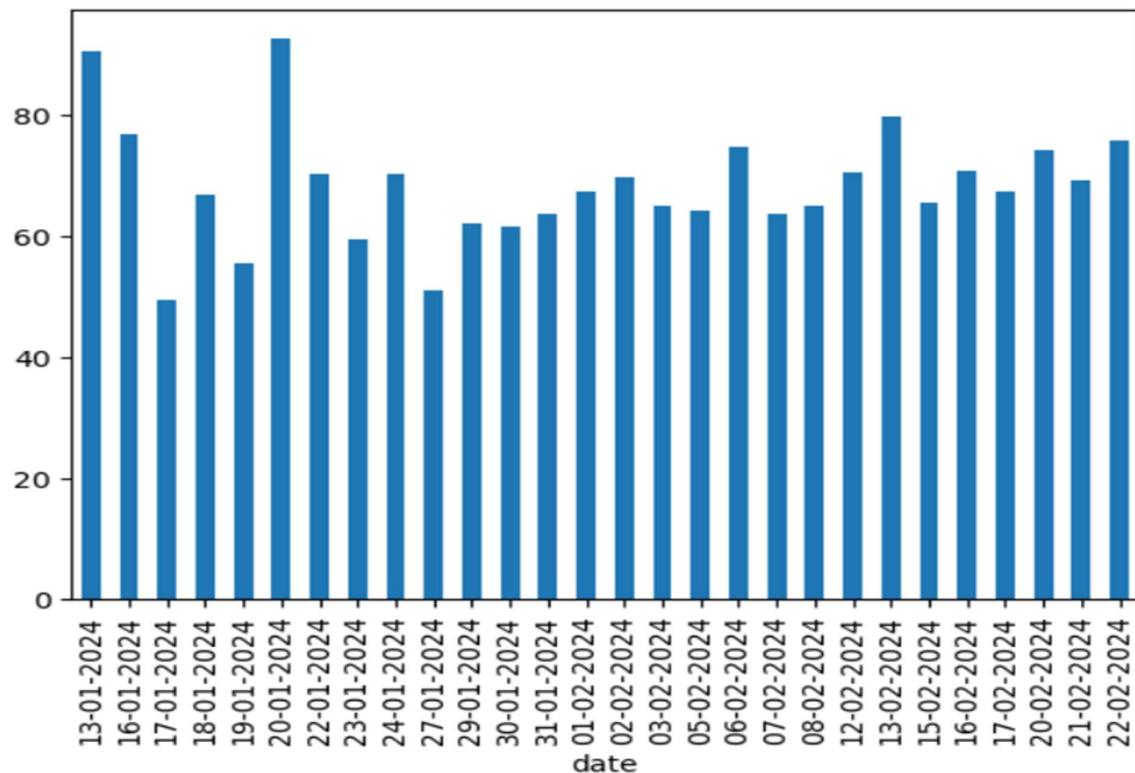
Ulubari to Bhangagarh:

Total Average: 129.29761904761904



Rajgarh to Bhangagarh:

Total Average: 68.20238095238096

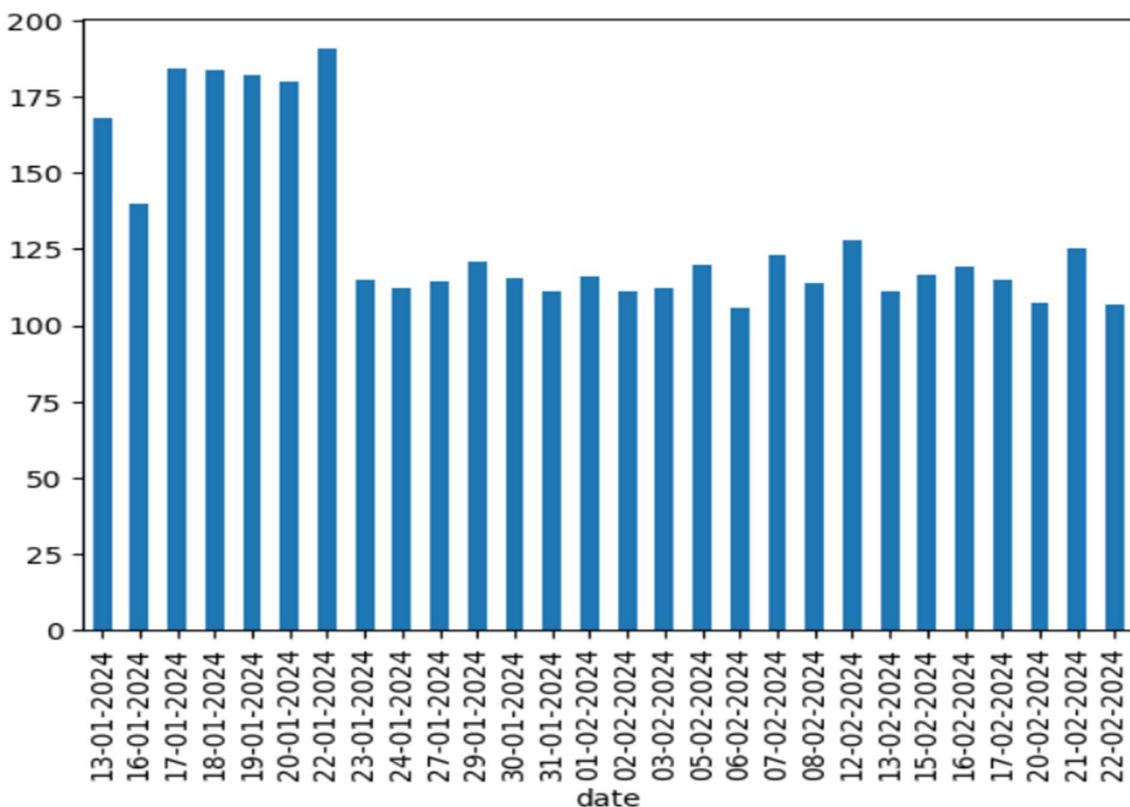


The traffic from 6 PM to 7PM:

In the following graphs, x-axis indicates the date, and the y-axis indicates the average number of vehicles arrivals in 10-minute intervals between 6PM to 7PM.

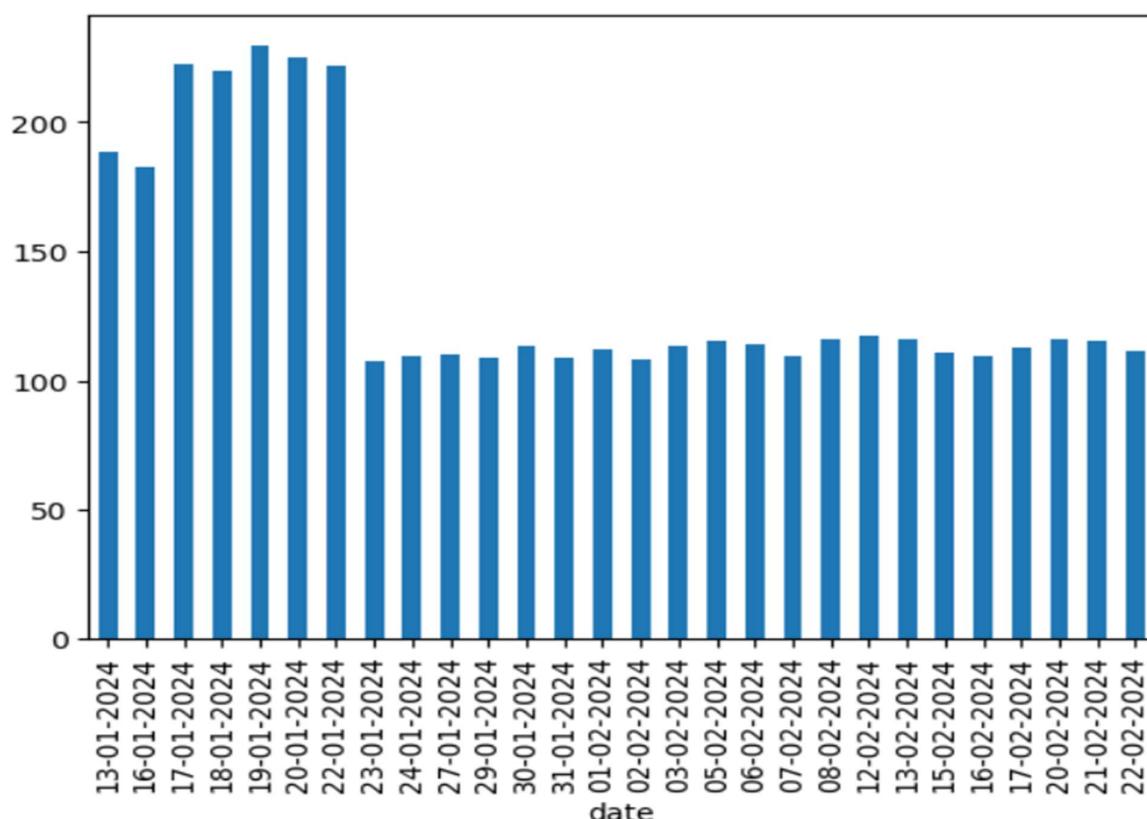
ABC to Bhangagarh:

Total Average: 130.2797619047619

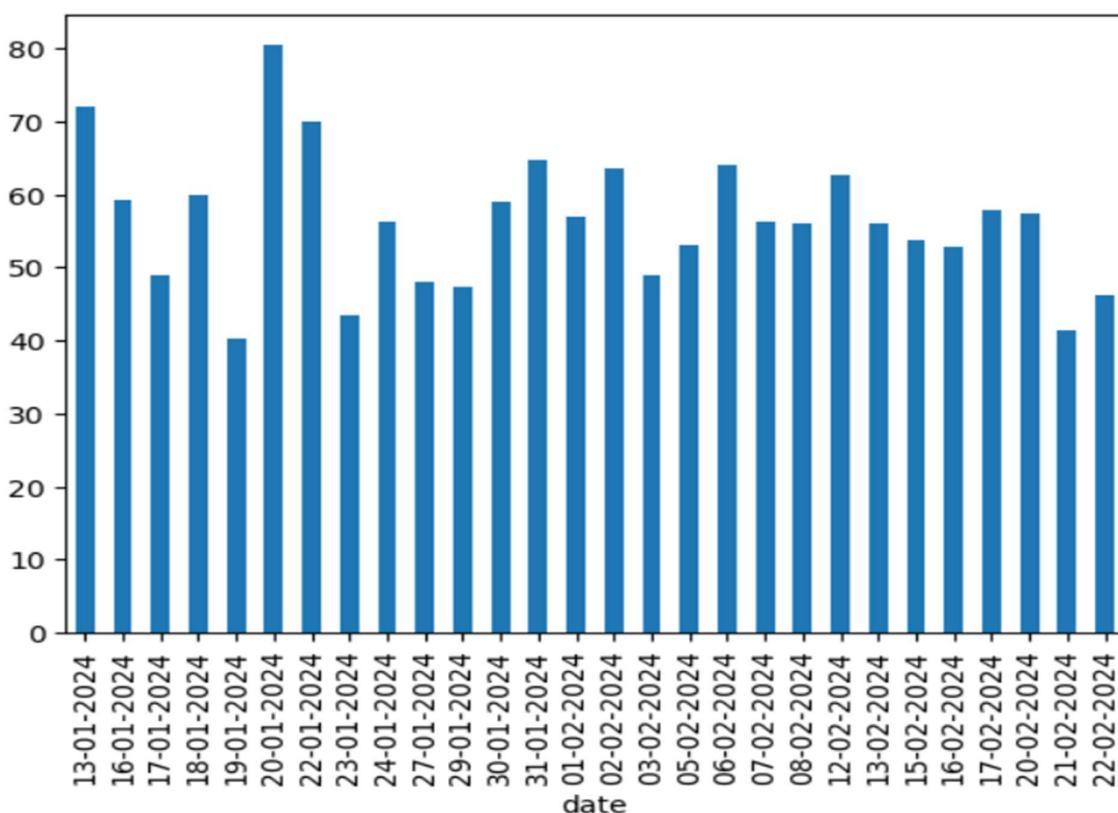


Ulubari to Bhangagarh:

Total Average: 137.4404761904762

**Rajgarh to Bhangagarh:**

Total Average: 56.30357142857143

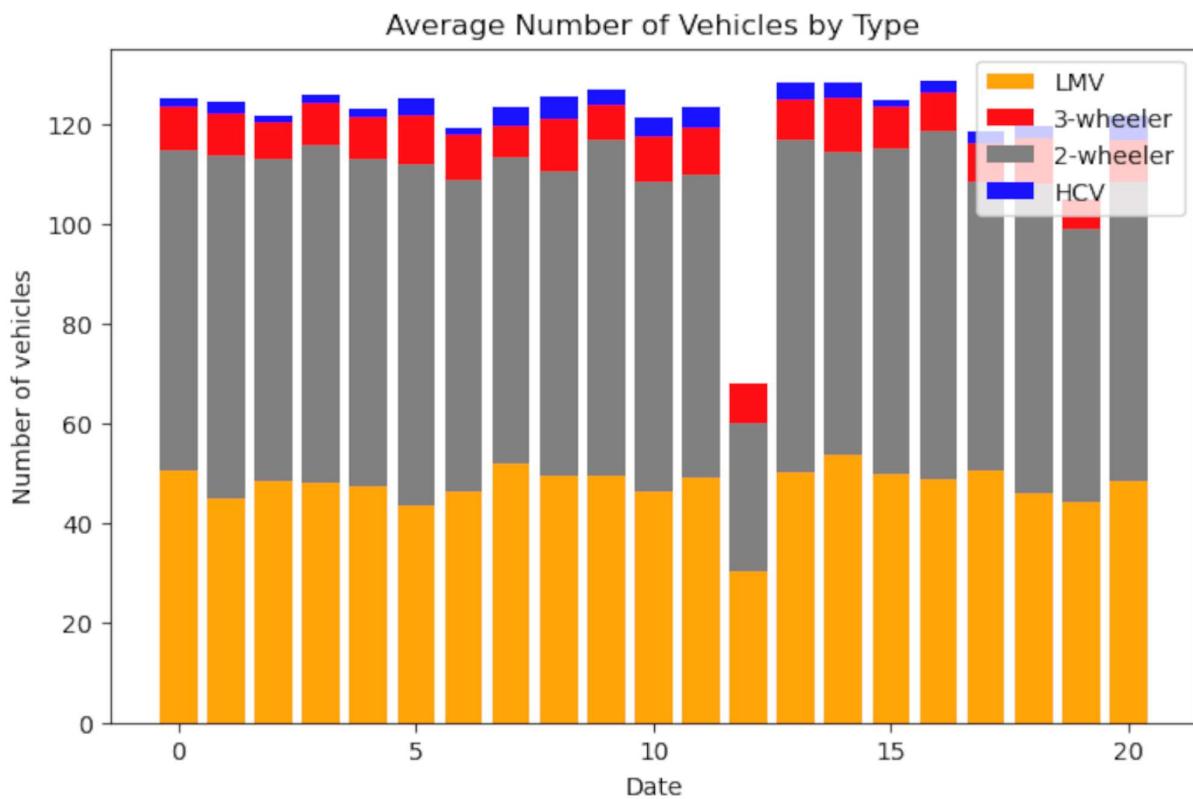


Appendix-B

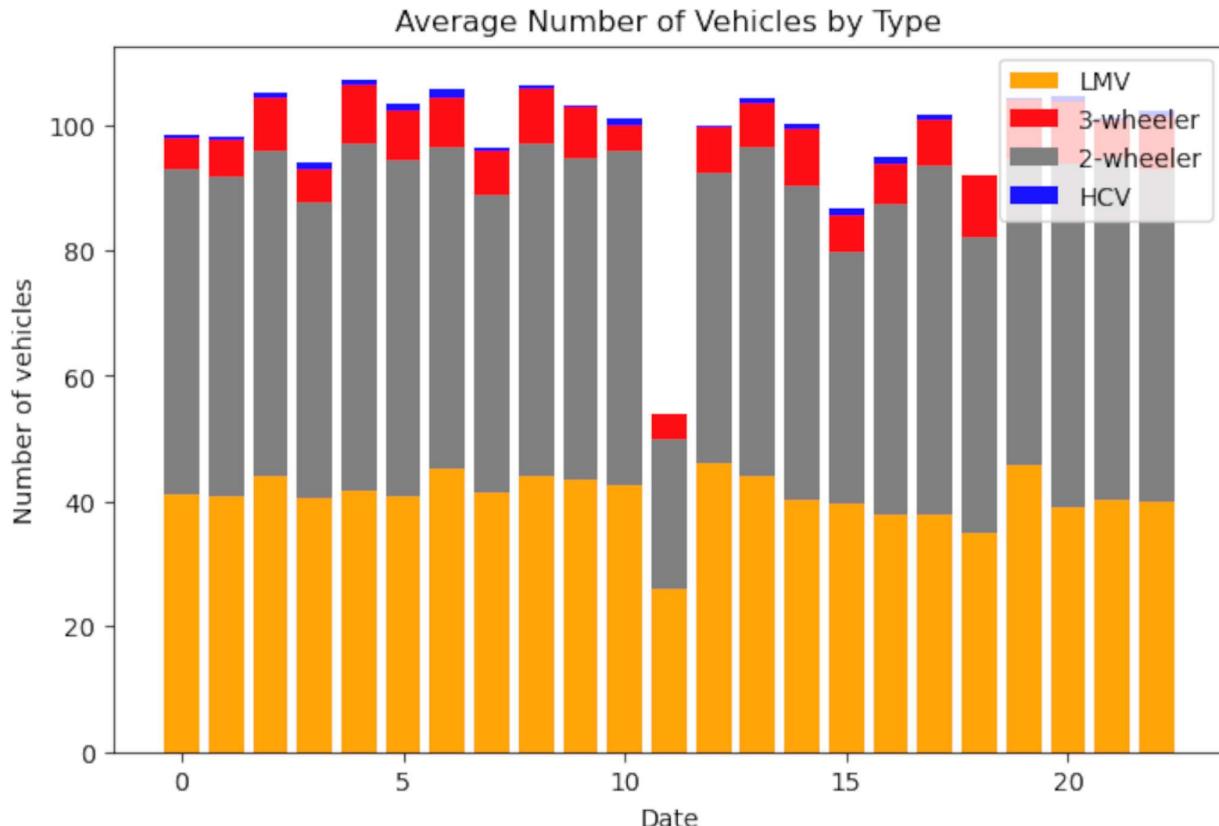
The traffic from 1 PM to 2 PM:

In the following graphs, x-axis indicates the day, and the y-axis indicates the number of vehicles with their types arrived in between 1 PM to 2 PM.

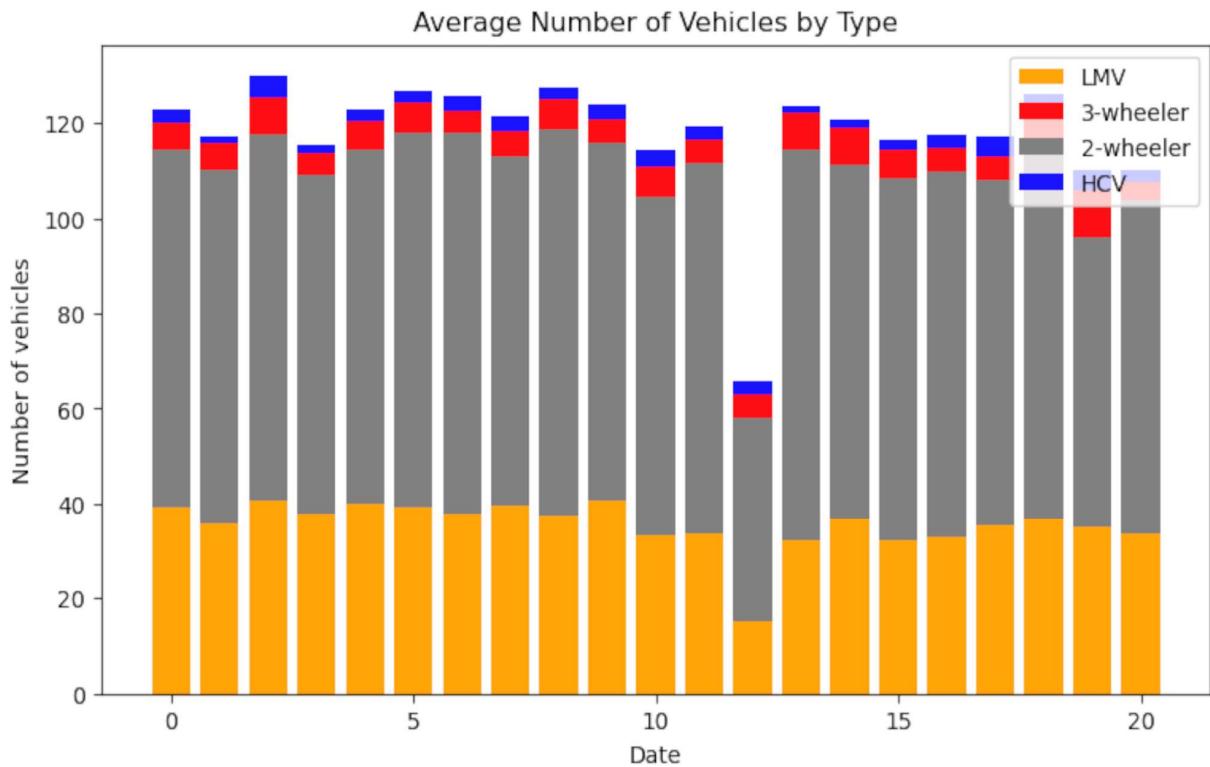
From Ulubari to Bhangagarh:



From Rajgarh to Bhangagarh:



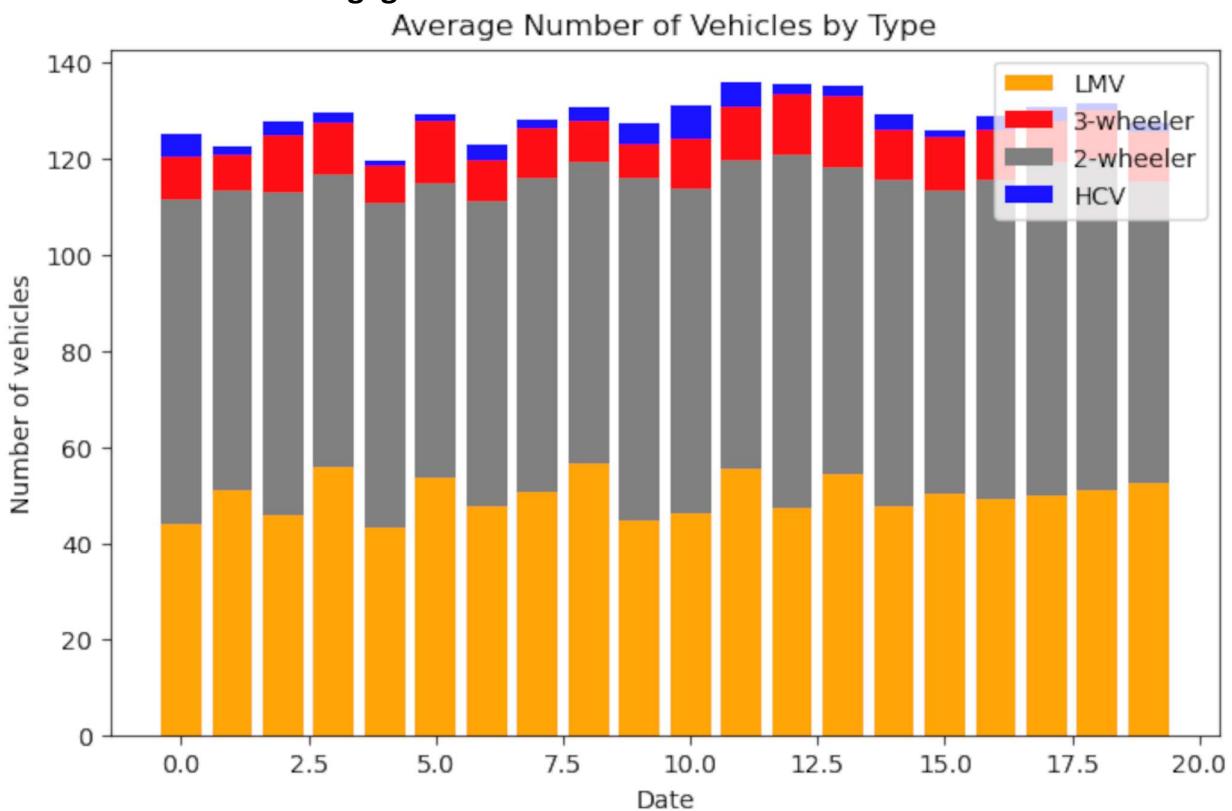
From ABC to Bhangagarh:



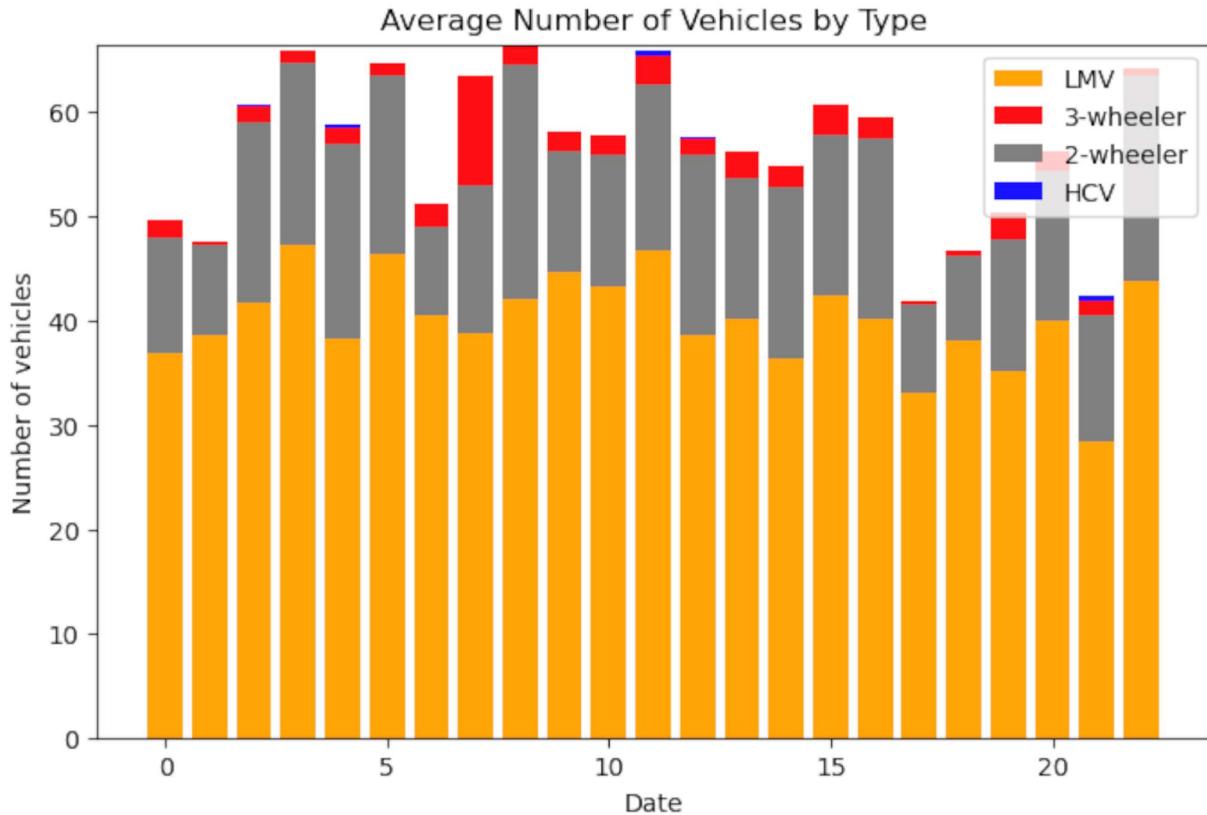
The traffic from 6 PM to 7 PM:

In the following graphs, x-axis indicates the day and the y-axis indicates the number of vehicles with their types arrived in between 6 PM to 7 PM.

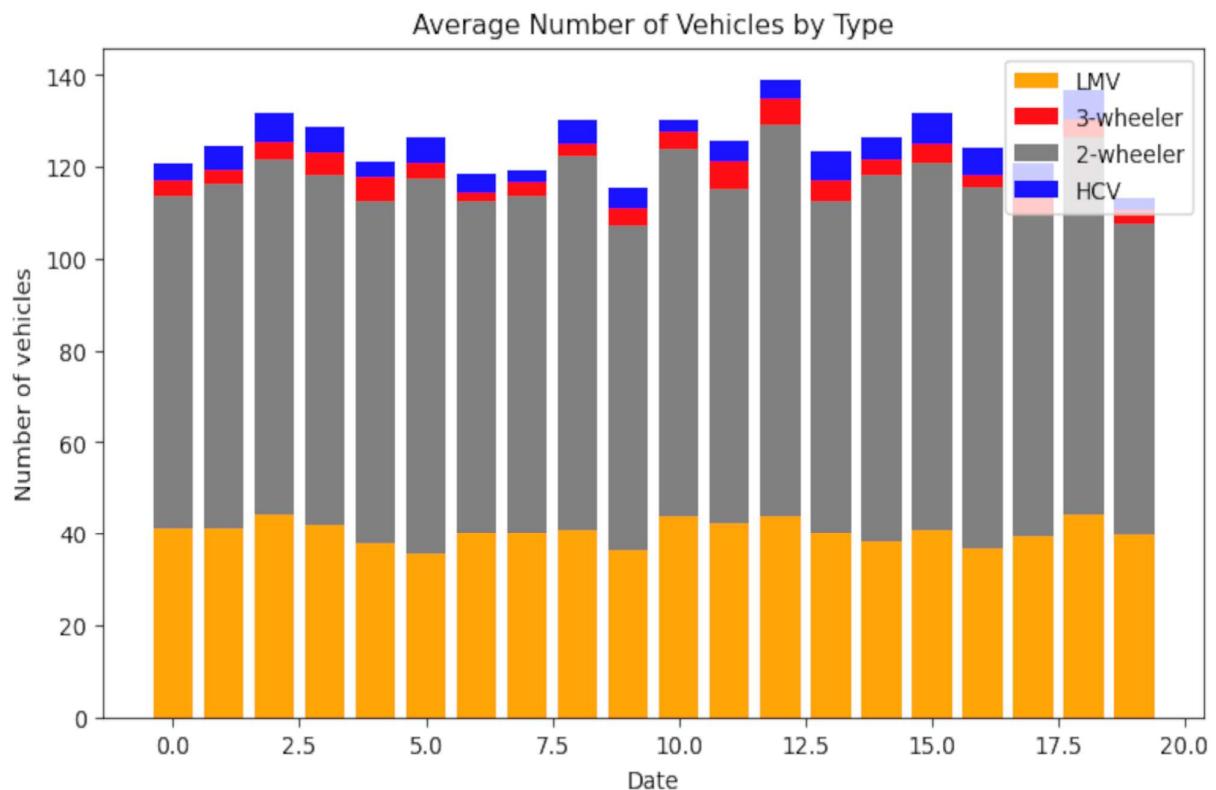
From Ulubari to Bhangagarh:



From Rajgarh to Bhangagarh:



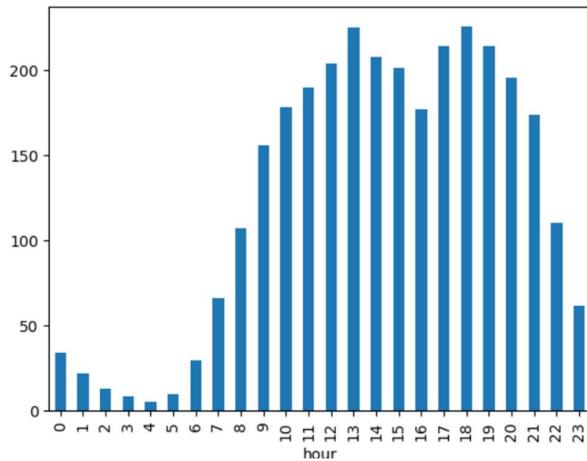
From ABC to Bhangagarh:



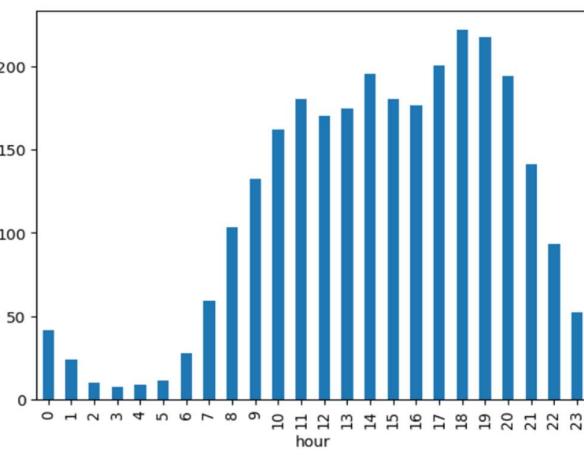
Appendix-C

In the following graphs, Y-axes denote the average number of vehicles in 10 minutes. On X-axes 'n' means the time interval n to n+1 interval in 24 hour clock.

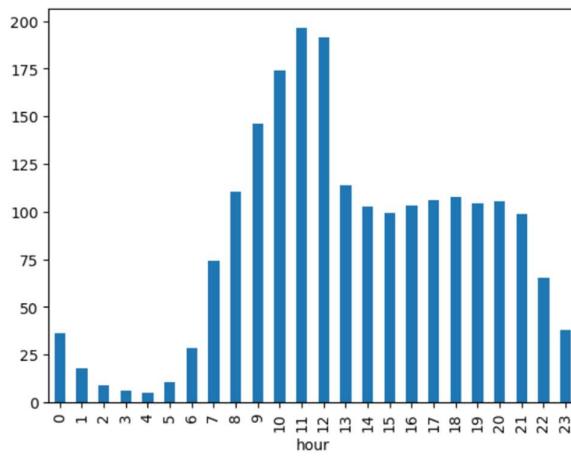
20-01-2024:



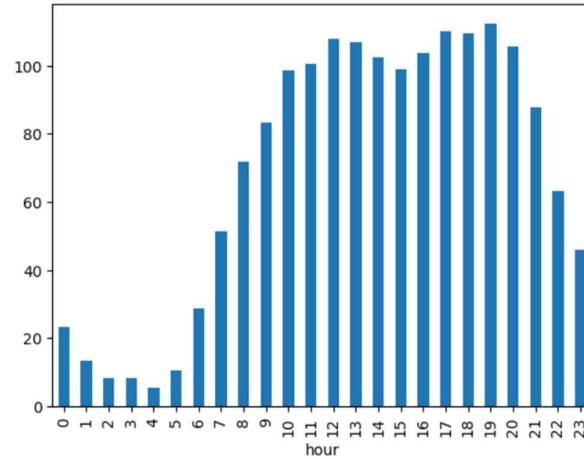
21-01-2024:



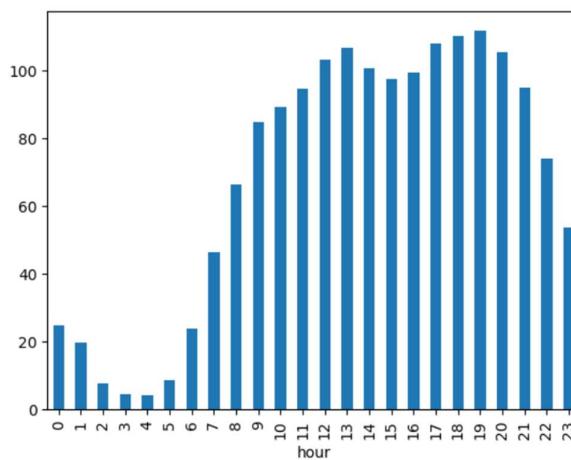
23-01-2024:



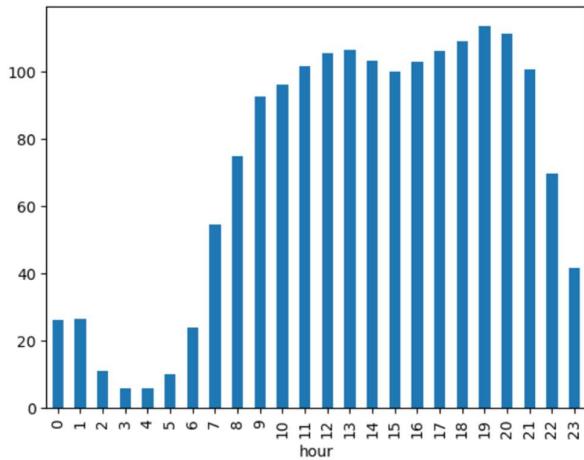
24-01-2024:



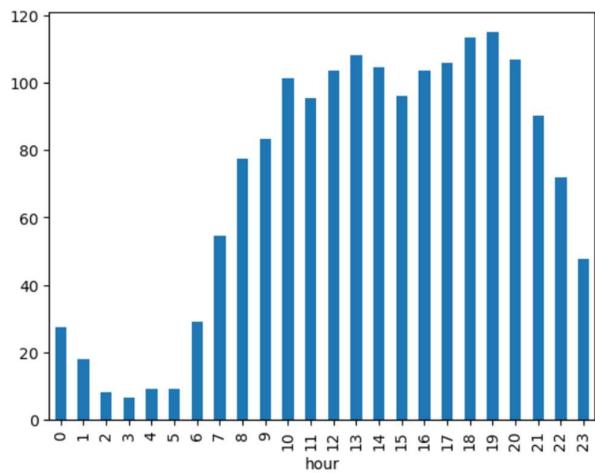
27-01-2024:



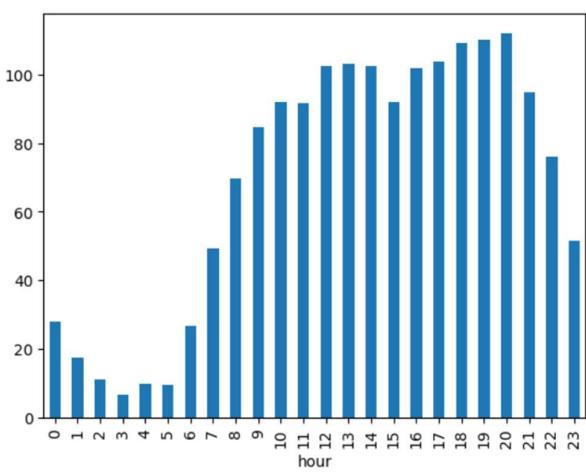
28-01-2024:



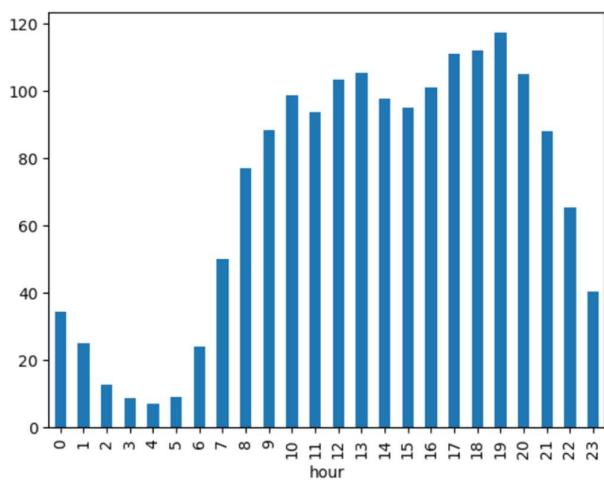
30-01-2024:



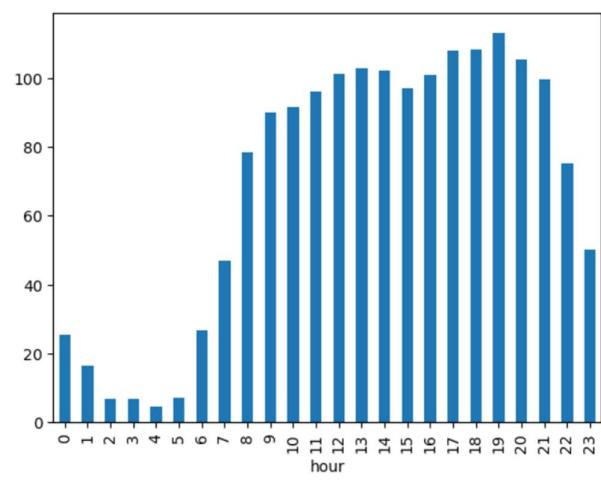
31-01-2024:



01-02-2024:



02-02-2024:

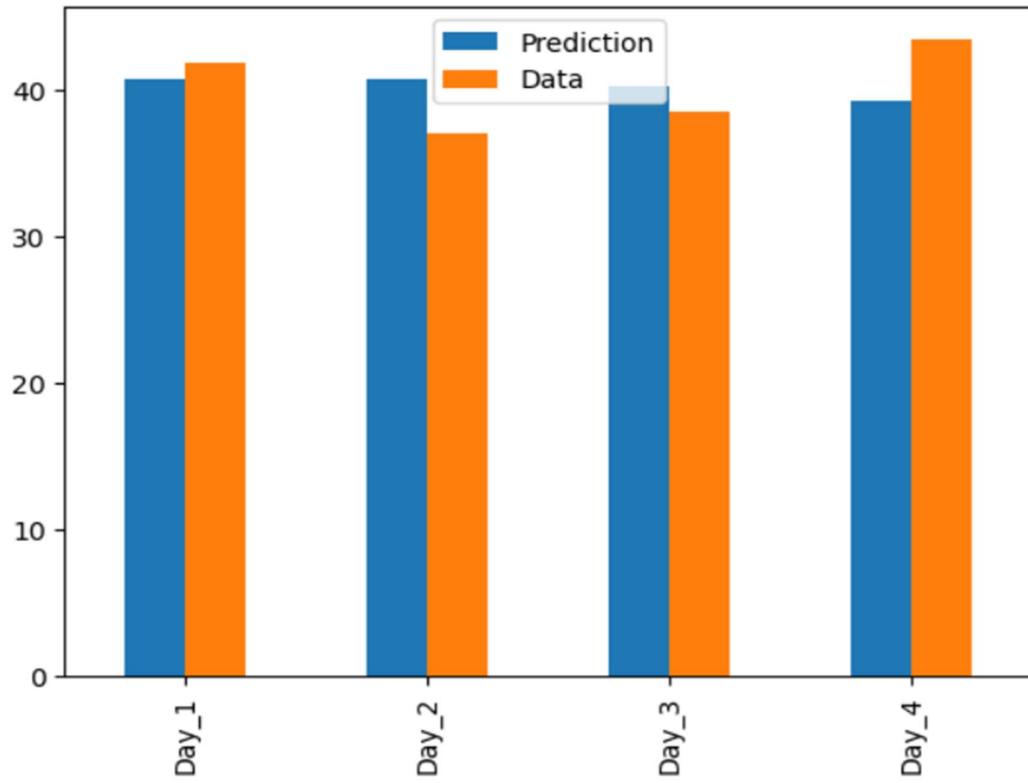


Appendix-D

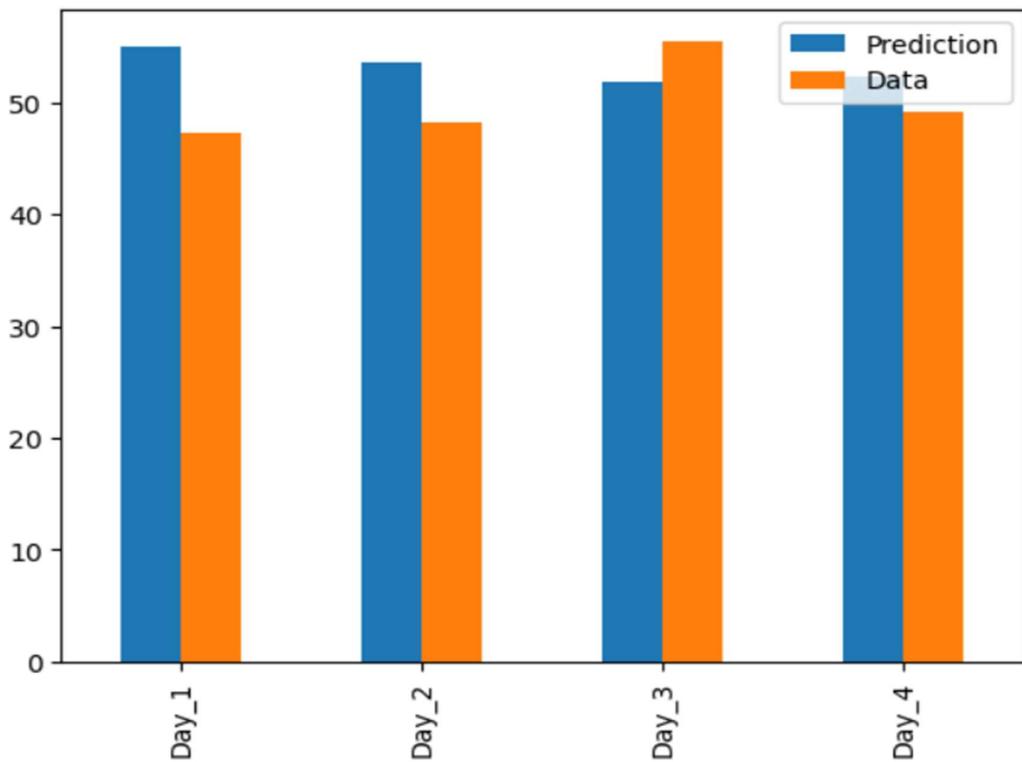
The following graphs show data for different times (9-10 AM, 10-11 AM, 1-2 PM, 2-3 PM, 5-6 PM, 6-7 PM) and three types of vehicles (Cars, Two Wheelers, Three Wheelers). The graphs illustrate the number of vehicles per day and highlight the difference between the actual data and the predicted values.

From 9AM to 10 AM

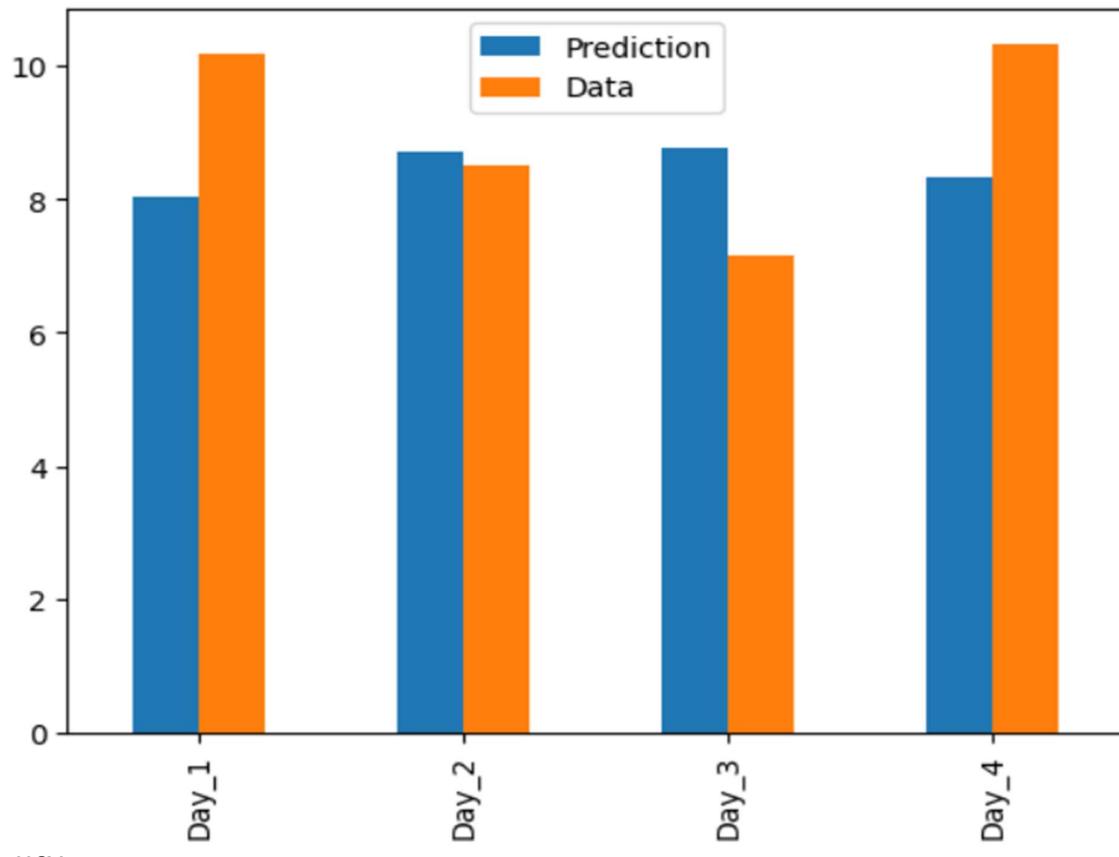
Cars:



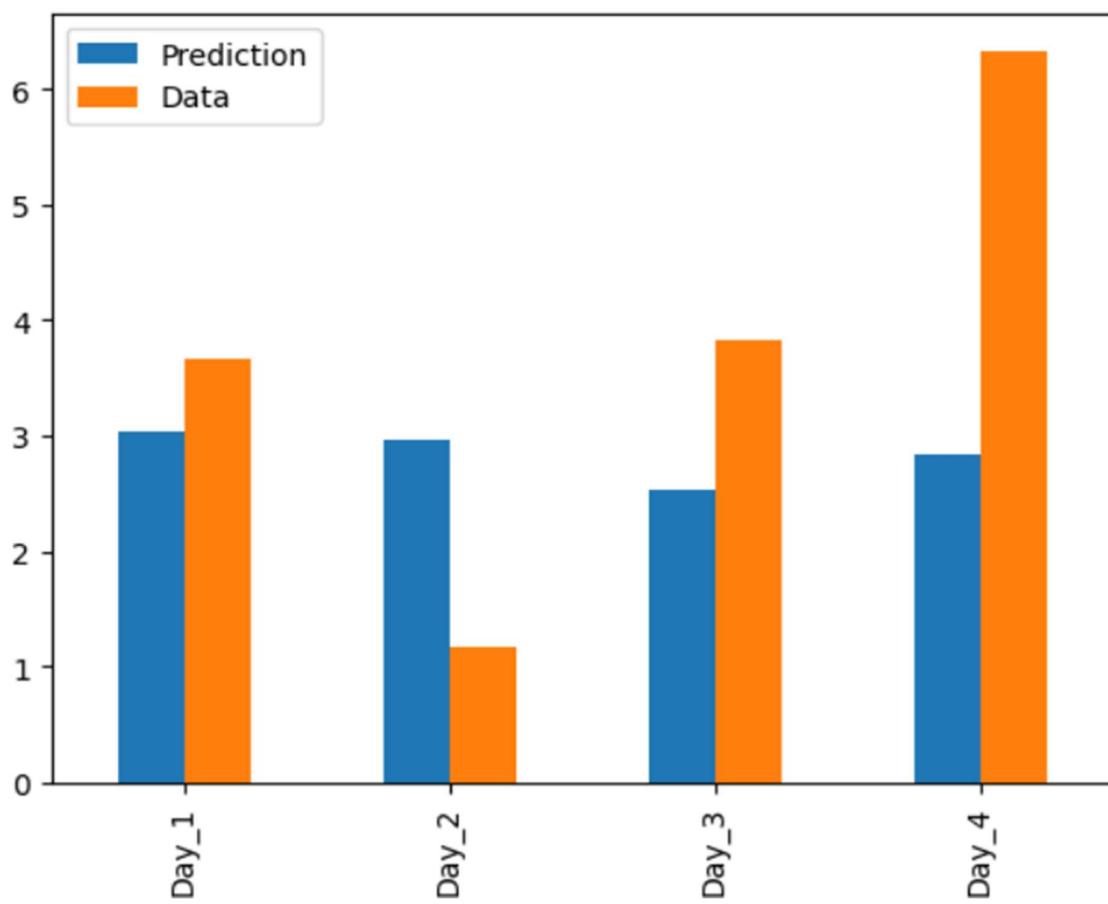
Two Wheelers:



Three Wheelers:

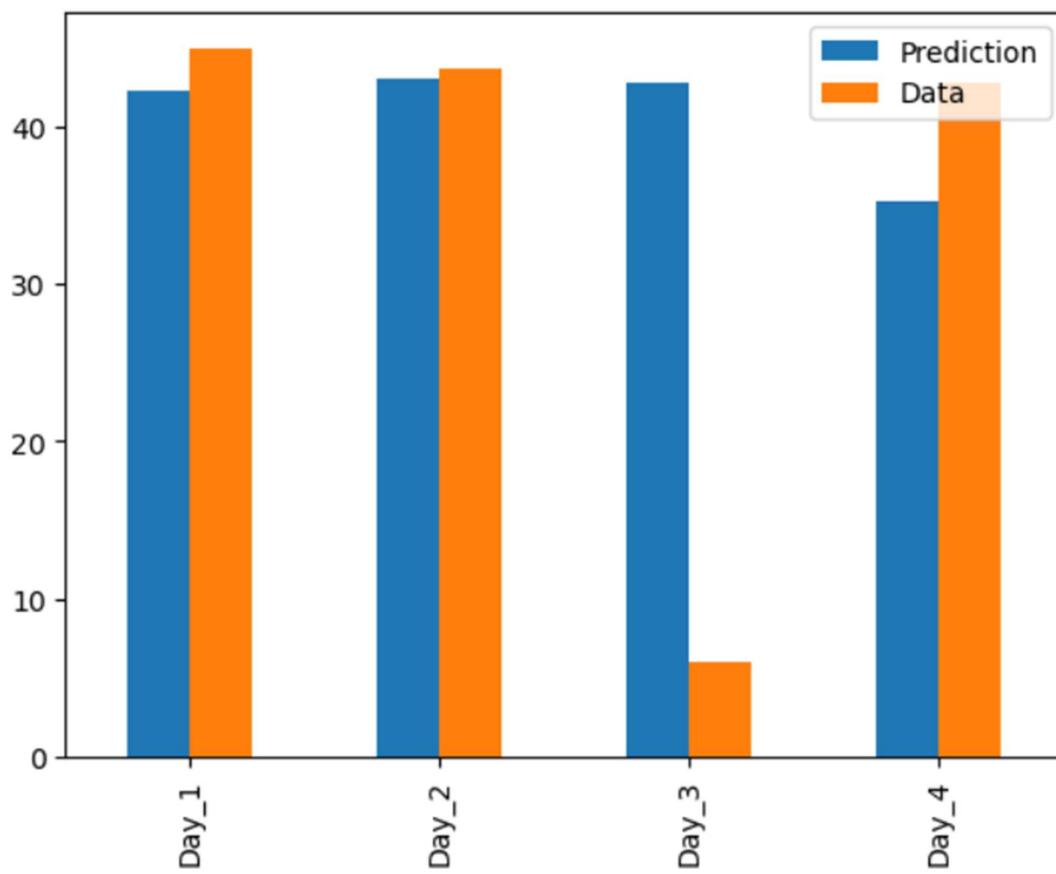


HCV:

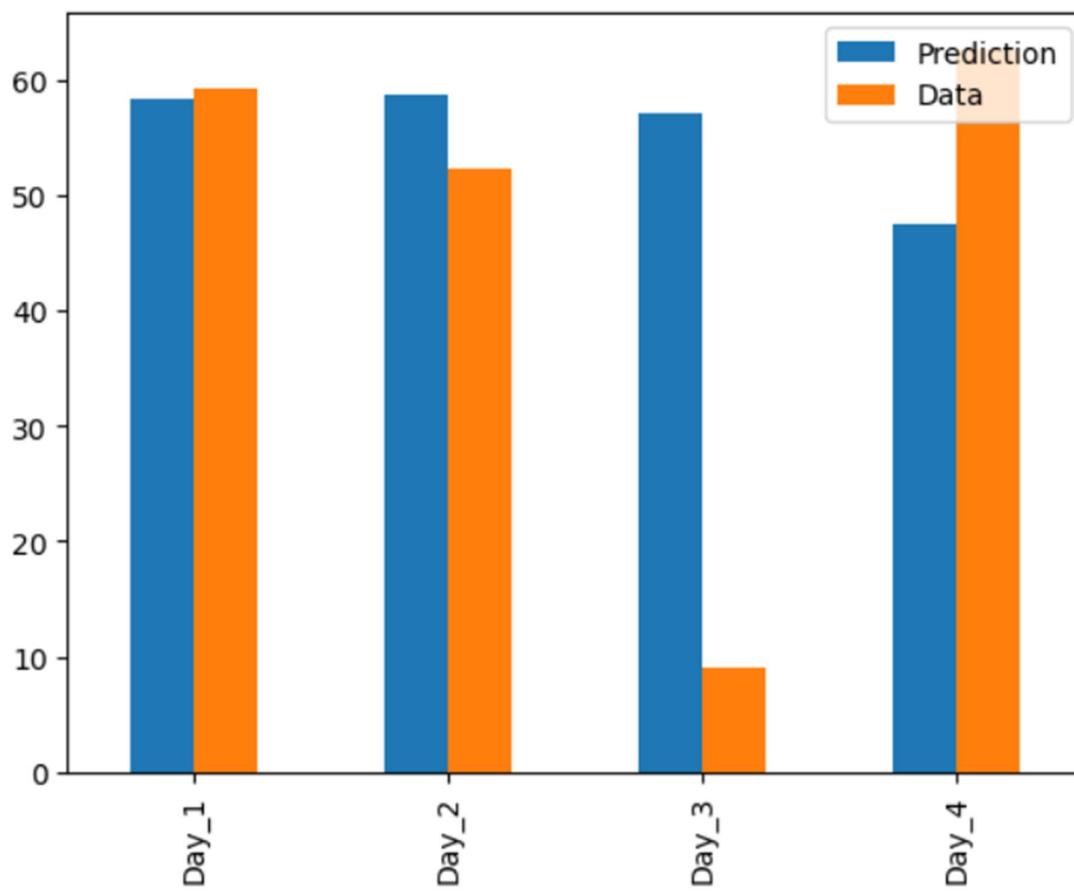


From 10AM to 11 AM

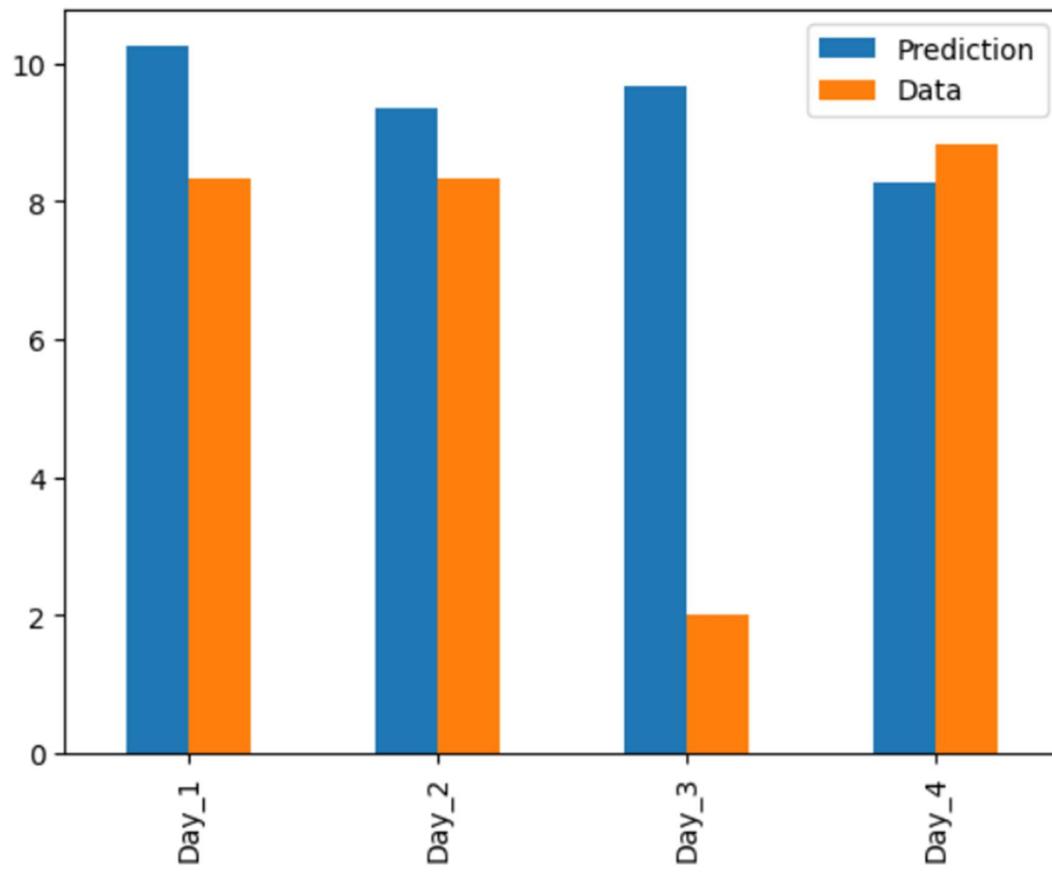
Cars:



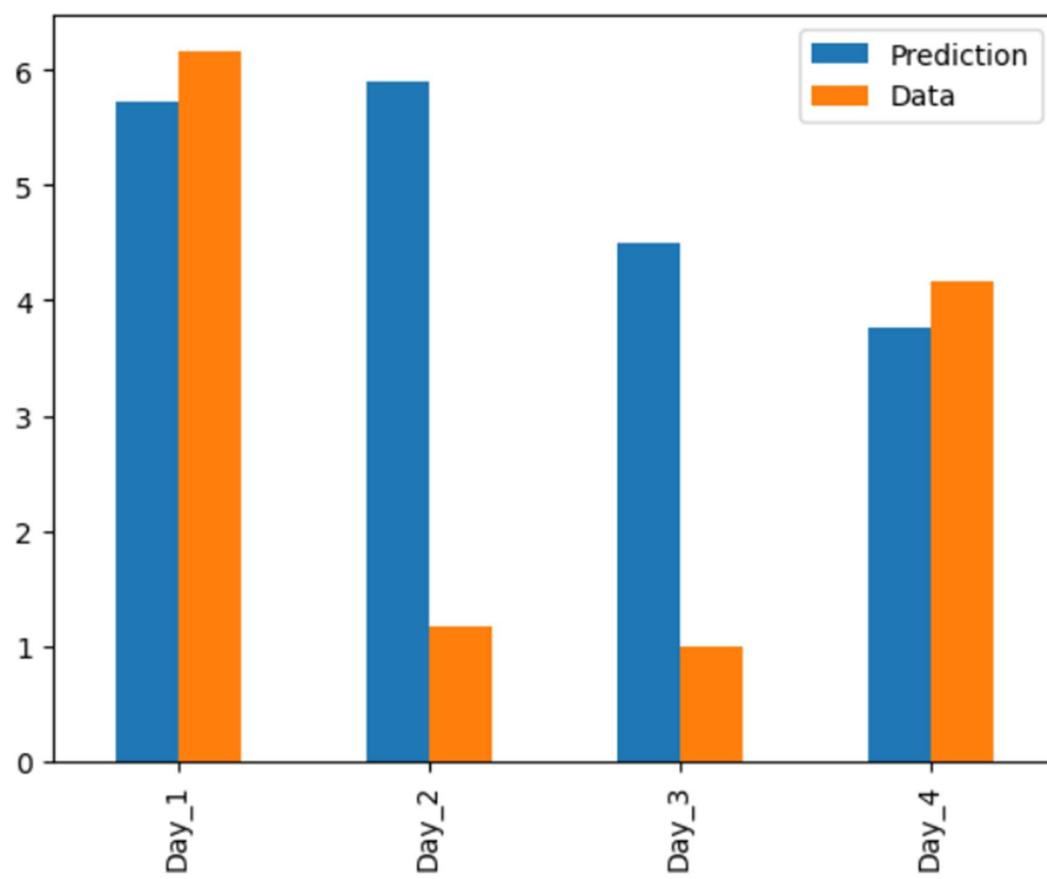
Two Wheelers:



Three Wheelers:

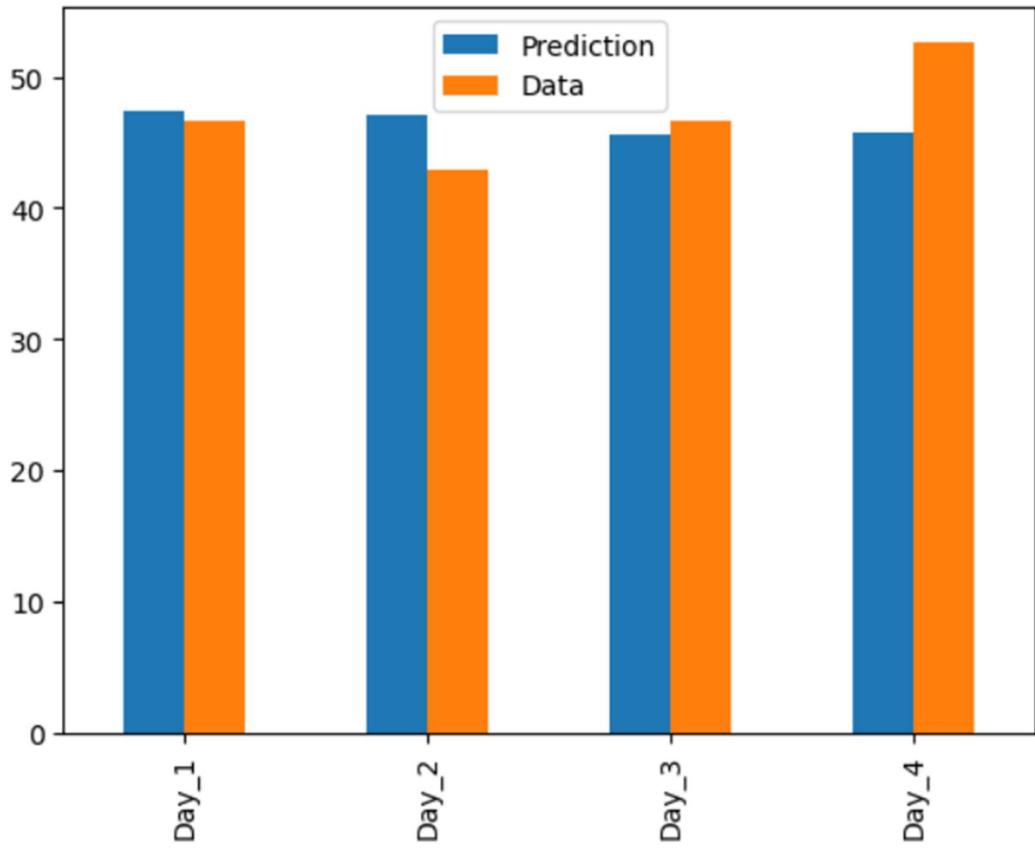


HCV:

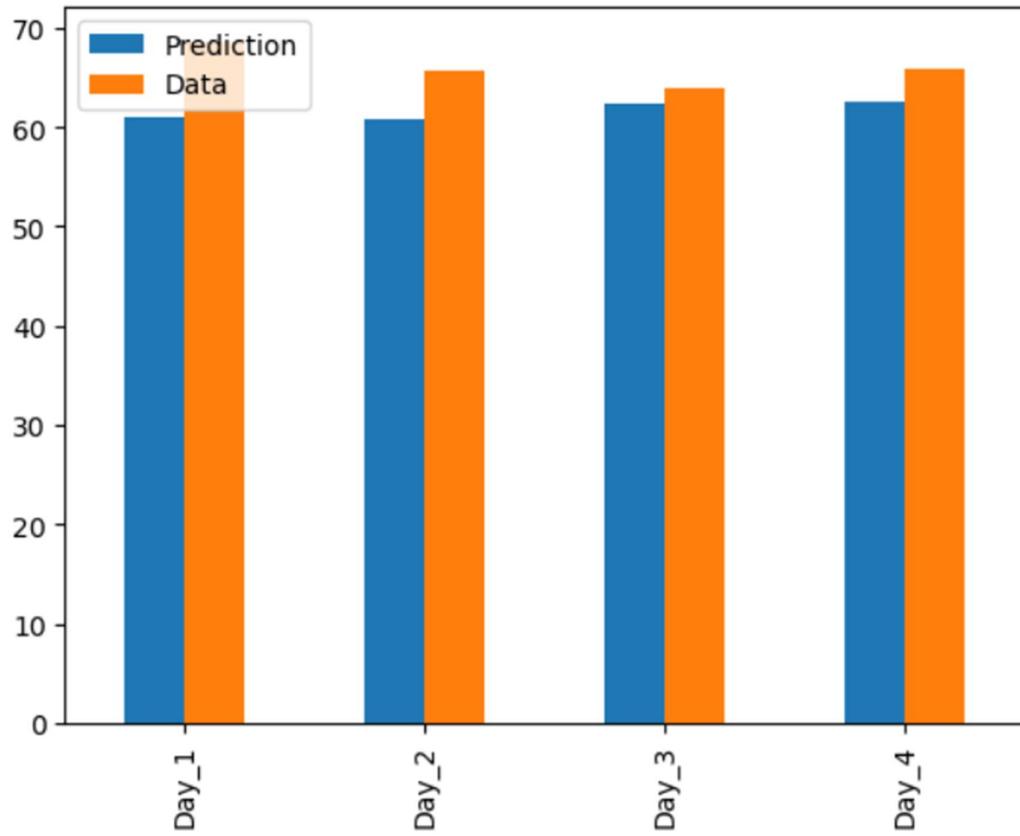


From 1PM to 2PM:

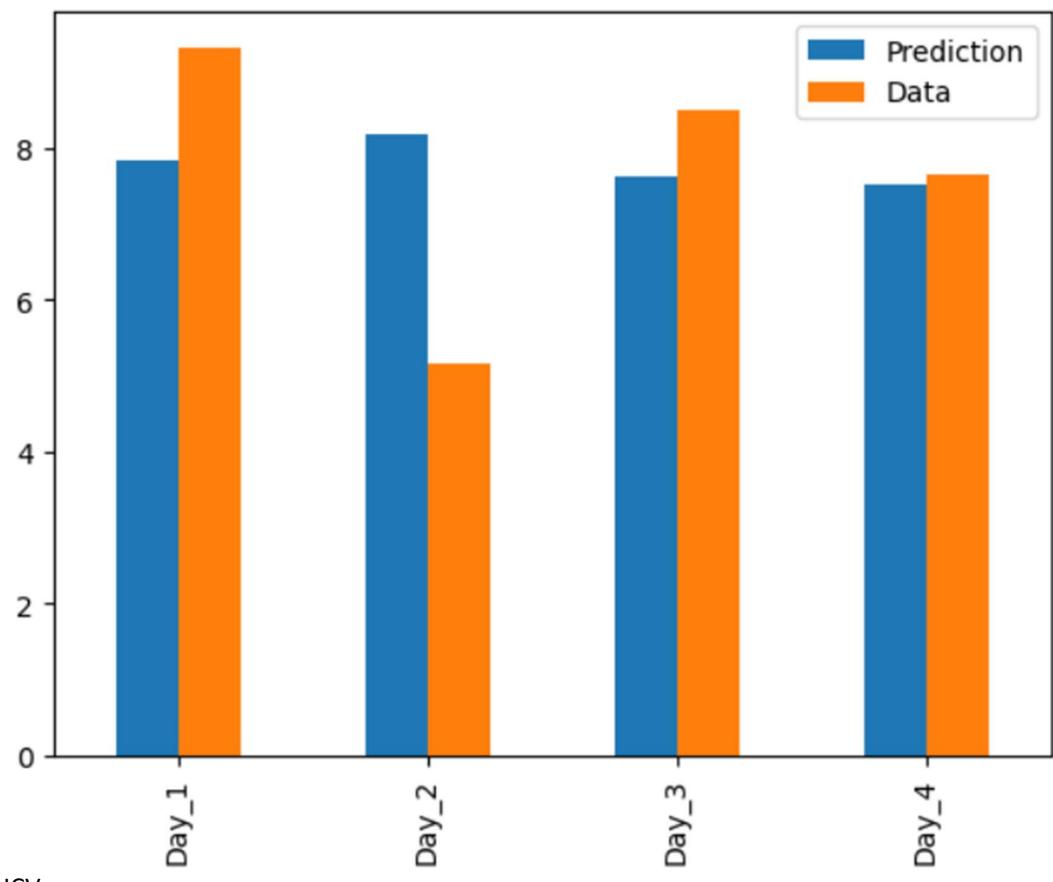
Cars:



Two Wheelers:



Three Wheelers:



HCV:

