REPORT ON PASSENGER TRAIN TIME TABLES AND FREIGHT PATHS IN GHAZIABAD MUGHALSARAI SECTION

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This report contains some analysis and initial conclusions based on simulation and other analytical techniques regarding the traffic performance on the Ghaziabad-Mughalsarai section of Allahabad (ALD) division. We note that this division has an active plan of upgrading facilities and improving operations through several detailed measures even as this report is being finalized.

The infrastructure can be visualized using the following figure.

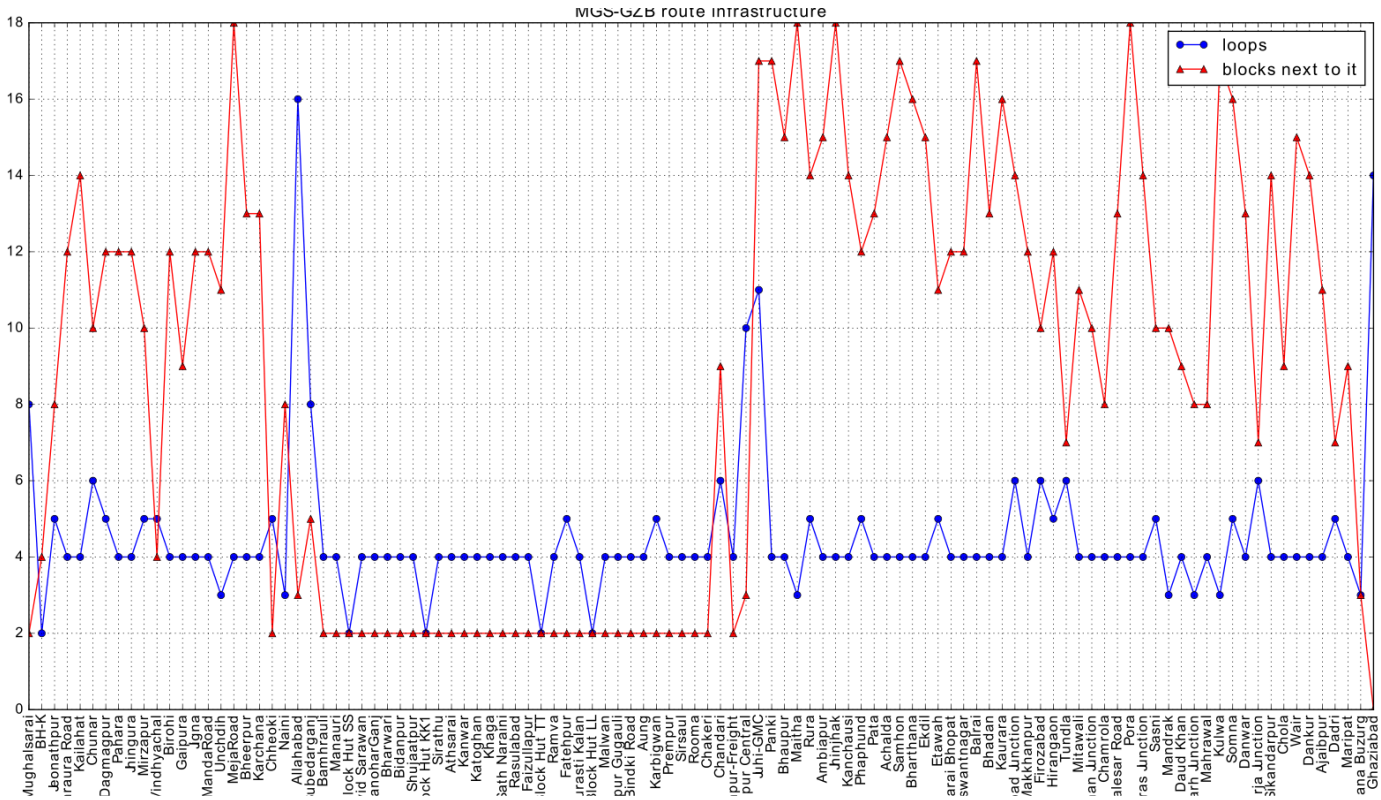

Figure 1: Infrastructure for the stations: number of loops at a station, and number of blocks between stations.

- Information about stations- Start and end km of each the 106 stations, number of loop lines and their configuration. Station working rules of each of the major stations such as Kanpur, Allahabad, Tundla, Ghaziabad and Mughalsarai. Total number of loops considered across all stations are 464.

- Information about signal locations- Inter-station block sections are defined using the location of Home and Advanced Starter signals, and the location of inter-station automatic or intermediate block signals. The total number of blocks considered are 898 (both up and down).
- Information about passenger train traffic- A time-table of the 245 trains (both up and down) - only Day 6 trains have been considered for the purposes of simulation.

With this data, we present an analysis of the Saturday (Day 6) time-table, where the maximum number of trains operate.

1. Statistics of average performance of passenger trains in the section

From the passenger timetable, the following parameters of passenger trains have been evaluated:

A. Stations with a significant amount of halt time
B. Average halting time at stations
C. Number of through & halting passenger trains at each station
D. Number of planned overtakes
E. Average speed of all passenger trains in part-sections: MGS-ALD, ALD-CNB, CNB-TDL and TDL-GZB in both up and down directions.
F. Congestion ratio and a few preliminary suggestions to reduce congestion.

These give us an idea of the major congestion areas in this section. The following charts and tables will represent the above parameters in a graphical way. Note that some of the tables and charts do not include the major junctions namely, Mughalsarai, Allahabad, Kanpur, Tundla and Ghaziabad. These junctions and terminal areas need detailed analysis and the suggestions for improvement in their jurisdiction are to be taken up separately. The analysis regarding the congestion in the stations (other than such major junctions/terminals) points to some areas of improvement where small investments may be needed to supplement the bigger investments that are needed at the major junctions in due course.

1A. Top 15 Stations (other than GZB, TDL, CNB, ALD and MGS) in the order of planned halting time:

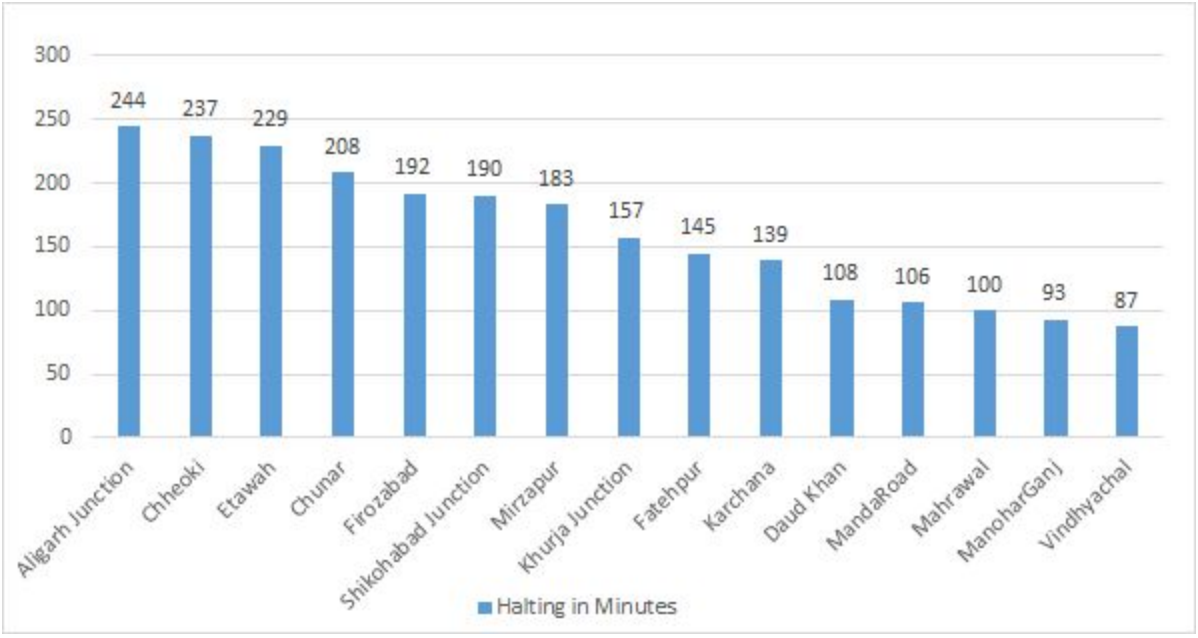

Figure 1: Top 15 Stations in the order of planned halting time (other than GZB, TDL, CNB, ALD and MGS)

Figure 1 depicts the 15 stations (other than GZB, TDL, CNB, ALD and MGS) where the maximum amount (in minutes) of planned halts in 24 hours take place. The number of platforms for these stations are: Aligarh (3), Chheoki (5), Etawah (5), Chunar (6), Firozabad (6), Shikohabad (6), Mirzapur (3), Khurja (6), Fatehpur (5), Karchana (4), Daud Khan (4), Manda Road (4), Mahrawal (4), ManoharGanj (4) and Vindhyachal (5). The planned halting time should be commensurate with the loop resources at these stations. A large halting time with insufficient number of loops is a potential cause of operational delays.

1B. <u>Top 15 stations in the order of average halting time:</u>

Average halting time is total minutes for trains that halt at a station divided by the number of trains halting in that station. The major reason for large average halting time is planned overtakes by other passenger trains.

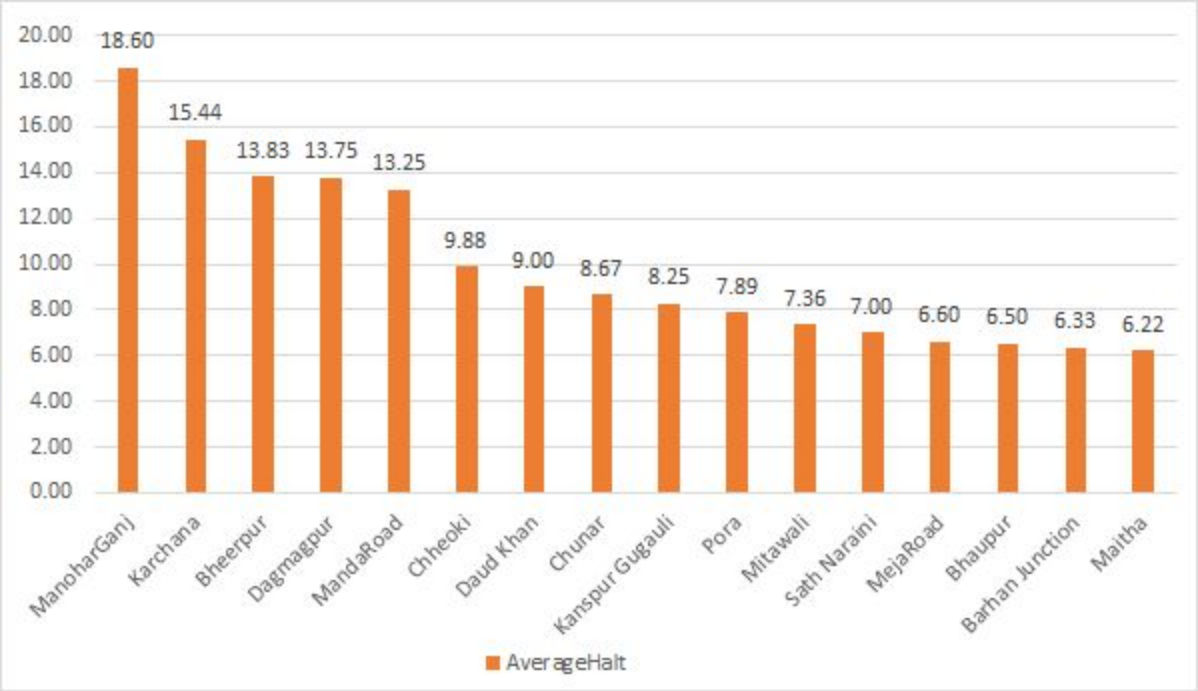

Figure 2: Top 15 stations in the order of average train halting in minutes (other than GZB, TDL, CNB, ALD and MGS)

Figure 2 depicts the top 15 stations (other than junctions/terminals) in the order of decreasing average halting time in minutes.

1C. <u>Top 15 stations with high halting proportion:</u>

We consider the parameter 'halting proportion': this fraction is the number of halting trains divided by total number of trains passing through the station. This can potentially help in planning for station infrastructure.

Figure 3: Top 15 stations with high halting proportion (other than GZB, TDL, CNB, ALD and MGS)

Figure 3 represents the top 15 stations (other than GZB, TDL, CNB, ALD and MGS) with high halting proportion. The figure also represents the number of halting trains and total number of trains passing through the corresponding stations.

1D. <u>Planned overtakes at stations:</u>

Table 4 below contains the number of planned overtakes at major junctions (ALD, CNB, TDL) whereas Figure 4 contains data regarding overtakes in stations other than major junctions.

Junctions/Terminals	Planned UP overtakes	Planned DOWN overtakes
Allahabad	7	12
Kanpur Central	9	7
Tundla	7	7

Table 1: Number of planned overtakes at major junctions/terminals

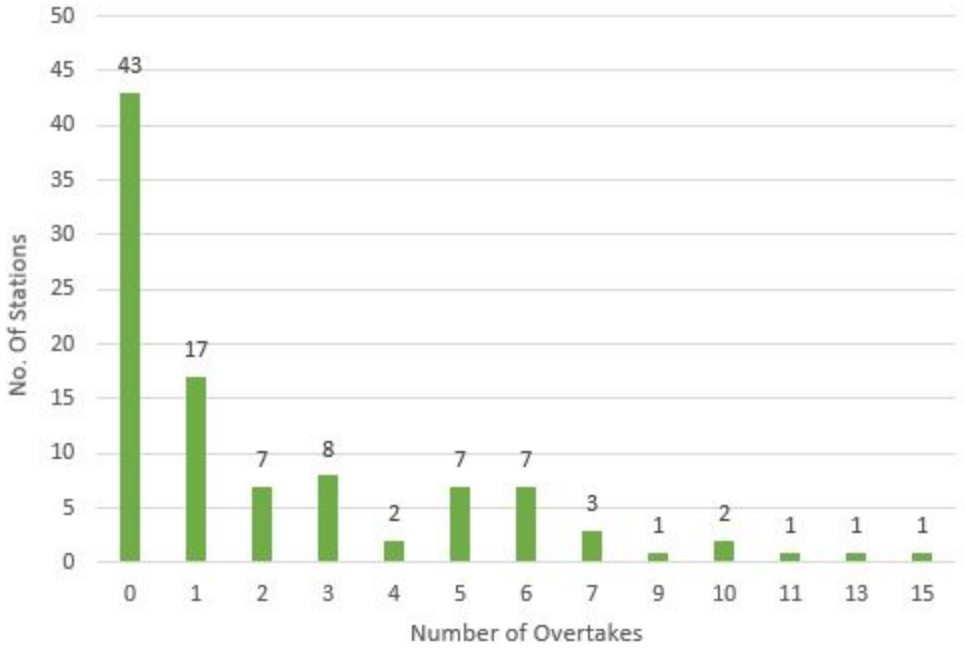

Figure 4: Intermediate stations and number of planned overtakes (other than GZB, TDL, CNB, ALD and MGS)

Figure 4 represents stations (other than GZB, TDL, CNB, ALD, MGS) and number of overtaken trains in 24 hours. For example, at 7 stations, 2 overtakes occur in 24 hours. The 3 stations where maximum number of overtakes happen are:

1. Manda Road - 15 overtakes (7 UP + 8 DOWN)
2. Chheoki - 13 overtakes (6 UP + 7 DOWN)
3. Shikohabad - 11 overtakes (6 UP + 5 DOWN)

1E. <u>Average speed in sections:</u>

Figure 6 represents the average traversal speed in part sections with the considerations of allowances and halting in the intermediate stations. The halt time at the junctions (MGS, ALD, CNB, TDL and GZB) were not considered.

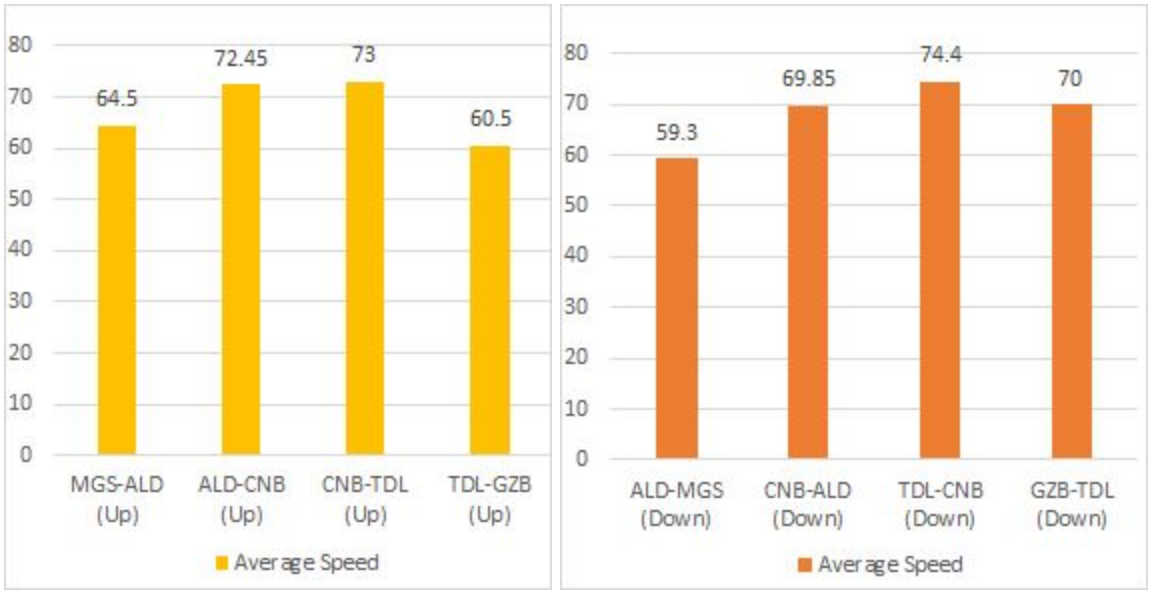

Figure 5: Average Speed (kmph) in both UP & DOWN Direction

In the up direction, we note that the lowest speeds are in the TDL-GZB section due to the allowances provided in this section (the Delhi area impact, despite the third line between Aligarh and GZB) followed by the ALD-MGS section. In the down direction, it is striking that the average speeds planned on the ALD-MGS section is lower than the more congested TDL-GZB section. Overall, even with freight trains, the ALD-MGS section is the most congested among the four listed here and the planned average speeds are a partial reflection of that.

2. Comparison of Scheduled and Simulated Running of the Passenger Trains

While simulating the passenger trains using our simulator, we compared the timetable generated by our simulator with that received from RITES. Using the values of acceleration, deceleration and maximum speed in the working timetable, most trains run approximately according to schedule in the simulation study. The major discrepancies and differences with respect to the working timetable are the times at which trains reach their terminating stations/major terminals. We checked the timetable of such trains from two other sources, namely, the Working Time Table 2015 (WTT 2015) and The Working Time Table 2016 (WTT 2016). The major difference between these two documents is the way in which allowances (slack times) are allocated. In WTT 2015, for example, the allowances in the up direction have been spread more uniformly across sections especially between Aligarh and Ghaziabad whereas in WTT 2016, they have all been loaded at the division boundary (after Maripat).

For example, for the train 18101 (TATA HTE-JAT Muri Express) an allowance of 79 minutes (E+T) is given between Maripat and Chipayana Buzurg. Earlier (according to WTT 2015), this allowance was uniformly distributed between Khurja and Chipayana Buzurg. In our simulation, the train (whose acceleration and

deceleration are assumed as in Section 2, Table 9) reaches Maripat at the nominated time according to schedule (WTT 2016), after which it reaches Ghaziabad approximately 1.2 hours earlier than schedule. This is due to the fact that simulator does not utilize the allowance which is provided between Maripat and Chipayana Buzurg as the simulator assumes ideal running.

This practice is followed at all major junctions. This is because before every major junction, allowances are provided, especially so at congested times of the day: for example, arrival at GZB in the morning hours. However, when the simulator schedules the trains, it reaches the station before the junction as per the schedule. The simulator assumes ideal running and hence does not need the allowance. The simulator preserves the train running logic viz. if a train reaches before the scheduled arrival time, then it will wait till its scheduled departure time and then it traverses the subsequent part of the section.

Remarks:

1. We have analyzed the planned timetable of passenger trains.
2. We brought out some discrepancies between the planned timetable provided in soft-form, the two Working Time Tables (WTT) 2015 and 2016.
3. A comparison with respect to various criteria was performed between the planned timetable and the simulation-timetable. Some features are analyzed in the **absence** of freight trains (e.g. average speeds, differences in running times - timetabled versus simulated, and planned overtakes).
4. In the **presence** of freight trains, the effect of freight trains (for different number of freight paths) on delays on passenger trains with respect to the planned timetable is mainly because of the occupation of loop lines. In such a situation, if passenger trains do not run as per their designated paths, their schedule could be disrupted.
5. A comparison can be made between the following timetables:
    - planned timetable (provided by RITES)
    - simulated timetable: without freight trains
    - simulated timetable: with a small number of freight trains
    - simulated timetable: with the full capacity of freight trains

3. Analysis involving Freight movement in the section

In an attempt to find "good" firing times of freight trains, we start with the firing times mentioned in WTT-2016, as they are presumably based on experience. While analyzing the freight movements from MGS-ALD we consider all the passenger trains running on the section. We note that the average Hours-on-Run of freight trains from MGS to ALD had been mentioned to be 4 hours 35 minutes in 2015, and that this figure is not presented in the 2016 timetable. The earlier figure was not such a realistic figure and has been confirmed from the data that we received from RITES.

Section/Terminal	Average running/halting time of freight trains (hrs)		
	Up		Down
MGS-ALD	9.23		5.25
ALD	0.65		0.75
ALD-GMC	9.35		8.64
GMC	1.20		1.25
GMC-TDL	8.38		8.23
TDL	0.55		0.61
TDL-GZB	5.70		8.37
Total (MGS-GZB)	35.06		33.10

Table2: Average running/halting time of freight trains

We analyse the situation of the traffic movement in the section with freight movements. To start with, we consider the effect of introducing freight trains in the section in the up direction between Mughalsarai and Allahabad. The freight trains that we have taken are assumed to have the following characteristics:

- Acceleration-0.04m/s^2
- Deceleration-0.08m/s^2
- Length-680m
- Maximum Speed-60km/hr

3.1 Up Direction analysis

In this section we introduce freight trains into the system at the firing times mentioned in WTT 2016 from Mughalsarai. Thus we have 32 freight paths. All the freight trains are assumed to have the same characteristics. They are mentioned below:-
Length = 680m
Maximum Speed = 60 km/hr
Acceleration = 0.02 m/s^2
Deceleration = 0.06 m/s^2

For this analysis we have considered the following values for detentions at each important junction/terminal station:-

Allahabad = 25 minutes
Juhi-GMC = 55 minutes
Tundla = 30 minutes

In a separate analysis, detentions at these major junctions are analyzed in more detail, but for getting a picture of end to end capacity, we take these values as representative.

3.1.1 Most Congested sections for freight movement

The first analysis that we provide are the most congested parts of the entire section. Waiting time for freight trains are indication of congested or bottleneck sections. The table below has the top ten stations where freight trains are detained (apart from the major junctions, where they wait for a number of reasons, including waiting for path on sections). We see that all ten in this list are in the MGS-ALD section, which as a whole can be considered to be a bottleneck in the movement of freight trains.

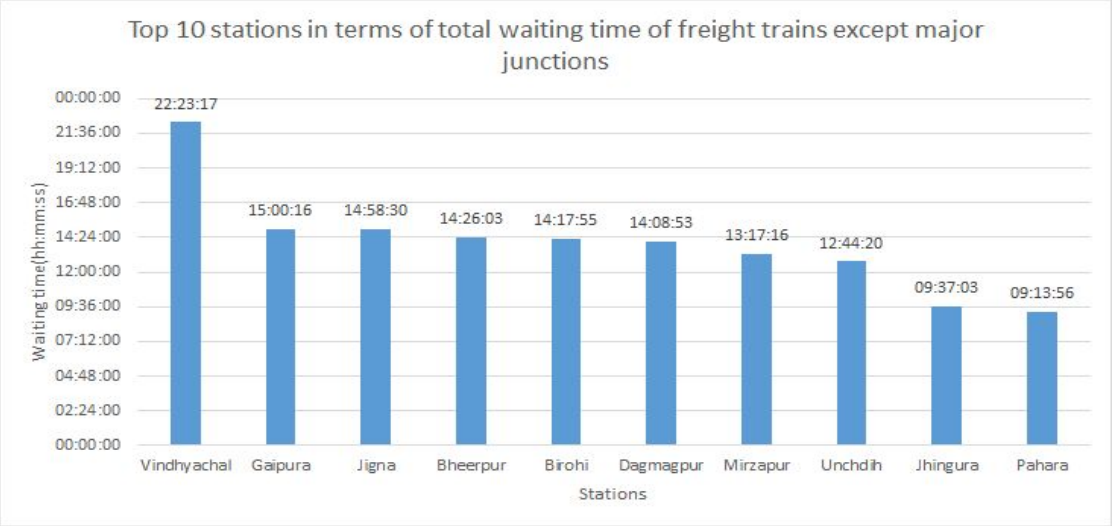

Fig 6: Waiting times at different stations other than major junctions

3.1.2 Analysis of Average Speeds according to Firing time

Congestion of the section differs during different times of the day. Thus the average speed will differ according to the firing time. This gives us a measure of the "goodness" of the freight path.

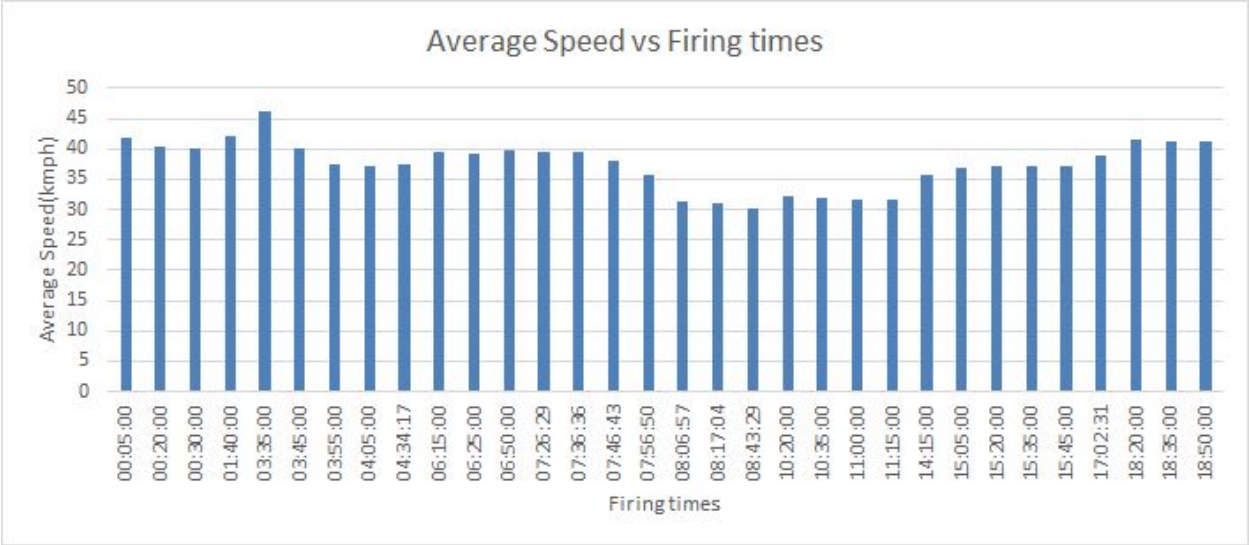

Fig 7 : Average speed in kmph vs firing time

3.1.3 Analysis of the Freight movements in Mughalsarai-Allahabad Section

We evaluate the freight paths listed in the WTT 2016. We have taken the following the characteristics for the freight trains:-
Length = 680m
Maximum Speed = 60 km/hr
Acceleration = 0.02 m/s^2
Deceleration = 0.06 m/s^2

Analysis of the MGS-ALD section without considering detention at Allahabad

All the freight trains are started from Mughalsarai at the timings mentioned in the WTT 2016. However no compulsory halt time is provided at Allahabad. In such a scenario we calculate the total waiting time of all the freight trains and provide the top 5 stations. Of course, we expect Allahabad to be extremely congested. Thus the top 5 stations are displayed below:-

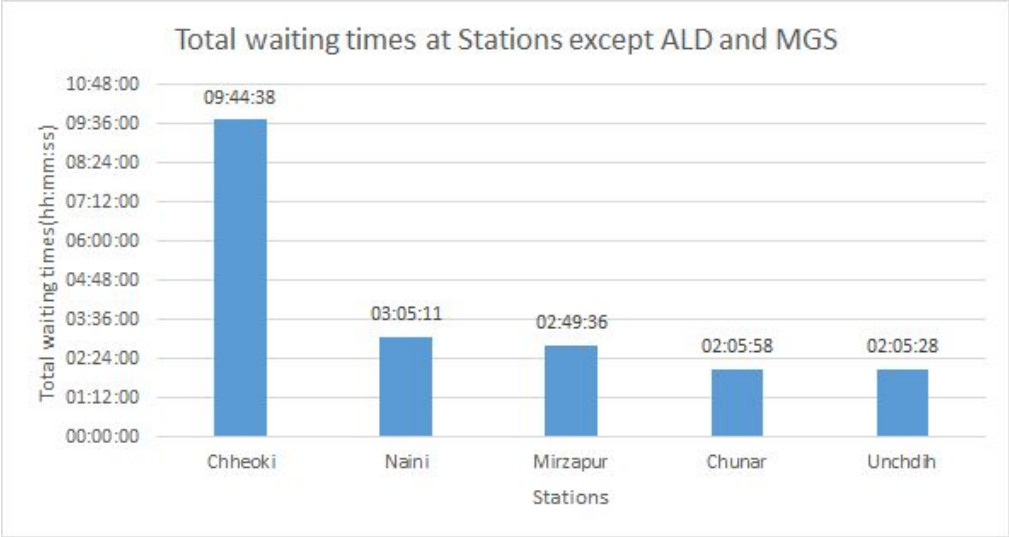

Fig 8 :Waiting times at different stations except at Allahabad

We now present an analysis of the average speed of the freight trains through his section.

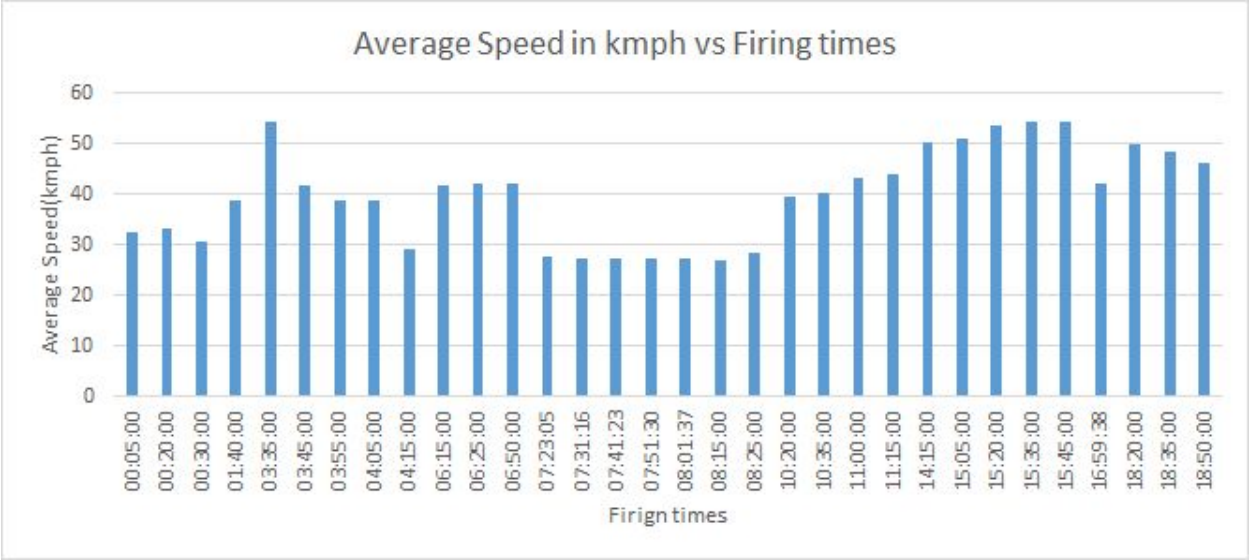

Fig 9: Average Speed vs Firing times of the freight trains in MGS-ALD section

We note that even without considering detention at Allahabad, trains starting from Mughalsarai between 7-830 a.m. in the morning have an average speed less than 30 kmph. Thus these firing times can be changed for better performance.

3.1.4 Analysis of the Freight movements in Allahabad-Juhi-GMC Section

We validate the freight paths listed in the WTT 2016. We have taken the following characteristics for the freight trains:-
Length = 680m
Maximum Speed = 60 km/hr
Acceleration = 0.02 m/s^2
Deceleration = 0.06 m/s^2

Analysis of the ALD-GMC section without considering detention at Juhi-GMC

All the freight trains are started from Allahabad at the timings mentioned in the WTT 2016. However no compulsory halt time is provided at Juhi-GMC. In such a scenario we calculate the total waiting time of all the freight trains and provide the top 5 stations.The top 5 stations are displayed below:-

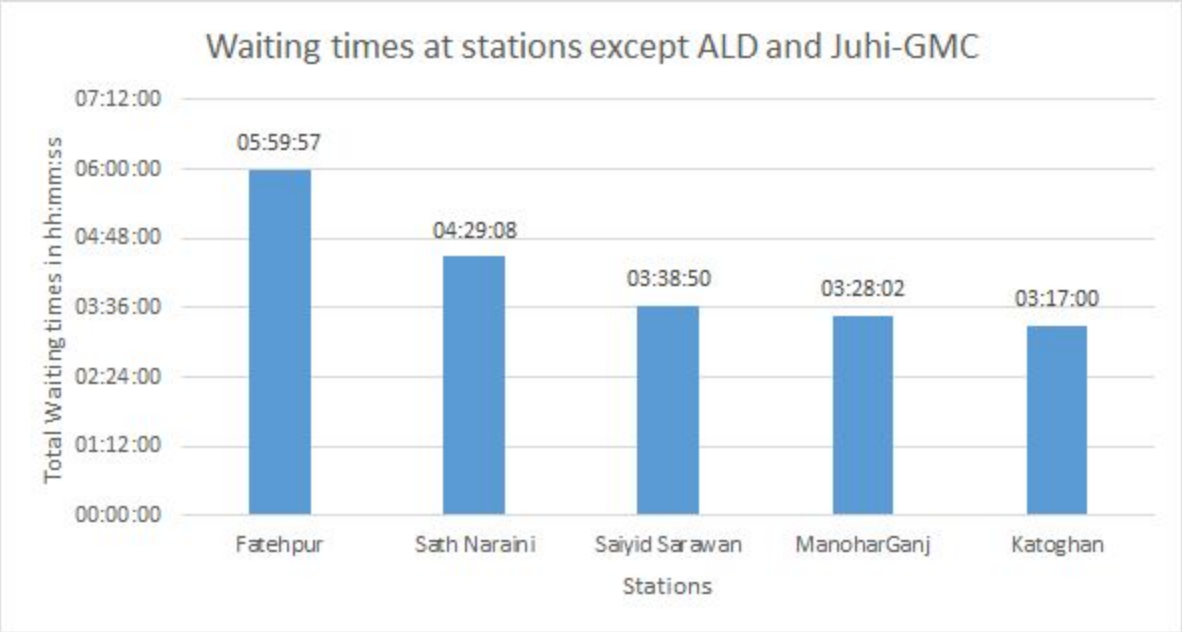

Fig 10 :Waiting times at different stations except at Juhi-GMC

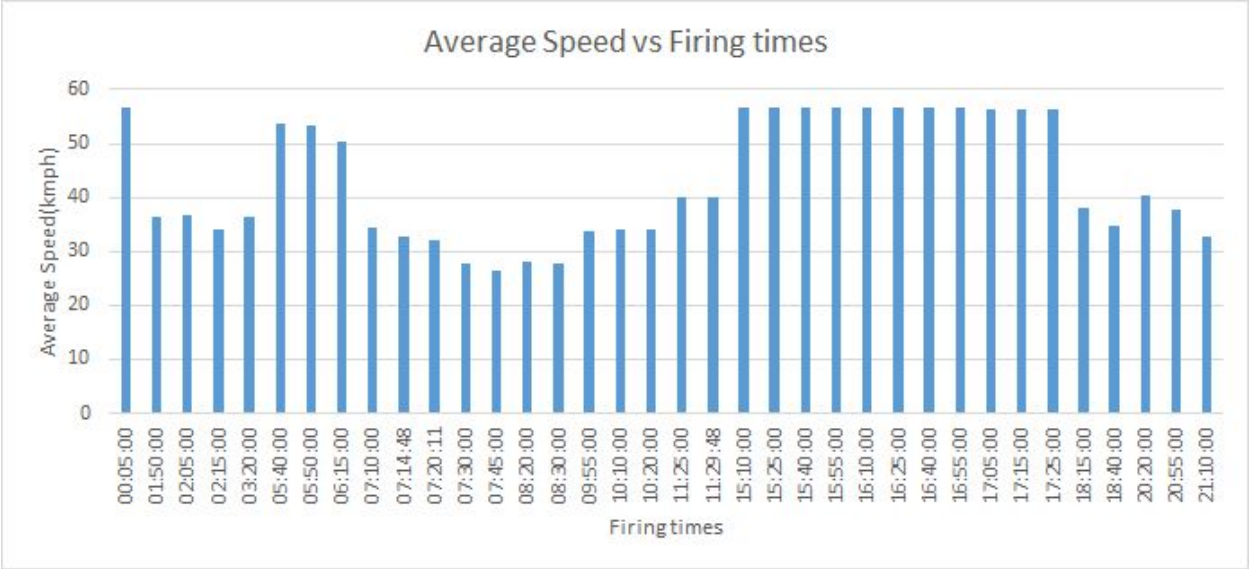

Fig 11 : Average Speed vs Firing times of the freight trains in ALD-GMC section

We note that as compared to MGS-ALD section, we do not have any major bottleneck station in this section. However, we have a number of cases in which the average speed of the trains are less than 30 kmph.

3.1.5 Analysis of the Freight movements in Juhi-GMC-Tundla Section

We evaluate the freight paths mentioned in the WTT 2016. We have taken the following the characteristics for the freight trains:-
Length = 680m
Maximum Speed = 60 km/hr
Acceleration = 0.02 m/s^2
Deceleration = 0.06 m/s^2

Analysis of the GMC-TDL section without considering halts at Tundla

All the freight trains are started from Juhi-GMC at the timings mentioned in the WTT 2016. However no compulsory halt time is provided at Tundla. In such a scenario we calculate the total waiting time of all the freight trains and provide the top 5 stations.The top 5 stations are displayed below:-

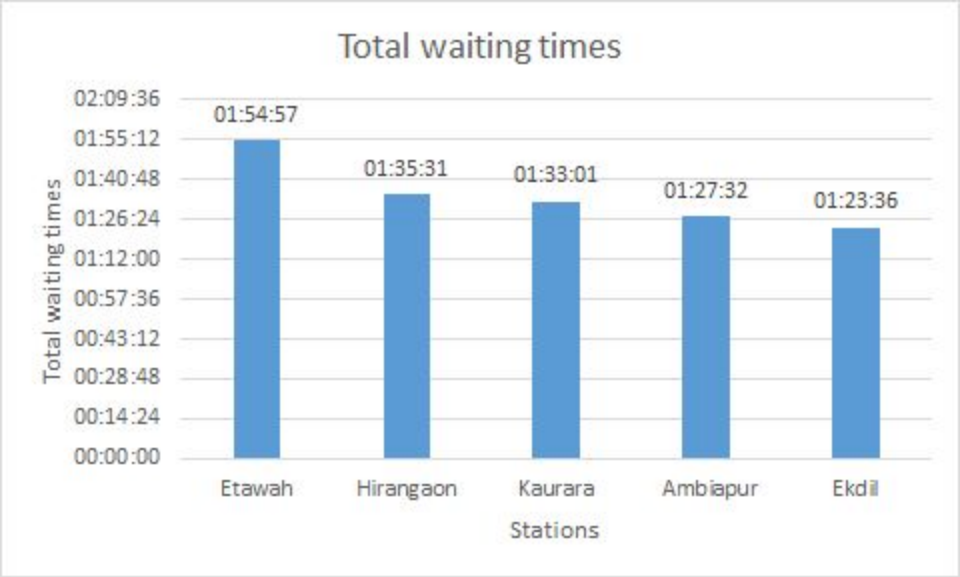

Fig 12 :Waiting times at different stations except at Tundla and GMC

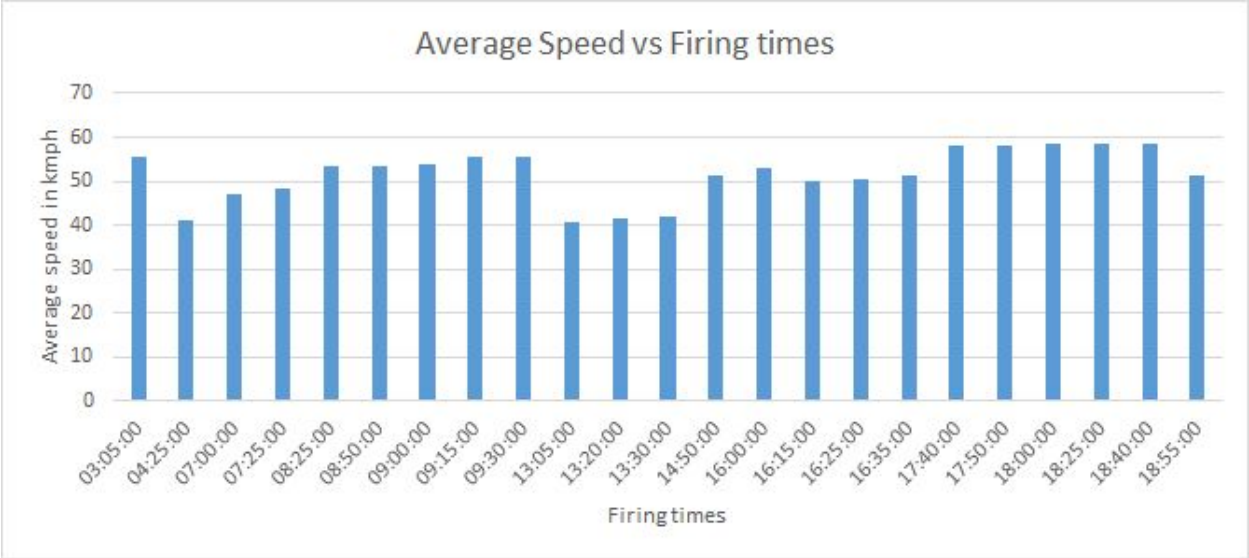

Fig 13 : Average Speed vs Firing times of the freight trains in GMC-TDL section

3.1.6 Analysis of the Freight movements in Tundla-GZB Section

We validate the good freight paths mentioned in the WTT 2016. We have taken the following the characteristics for the freight trains:-
Length = 680m
Maximum Speed = 60 km/hr
Acceleration = 0.02 m/s^2
Deceleration = 0.06 m/s^2

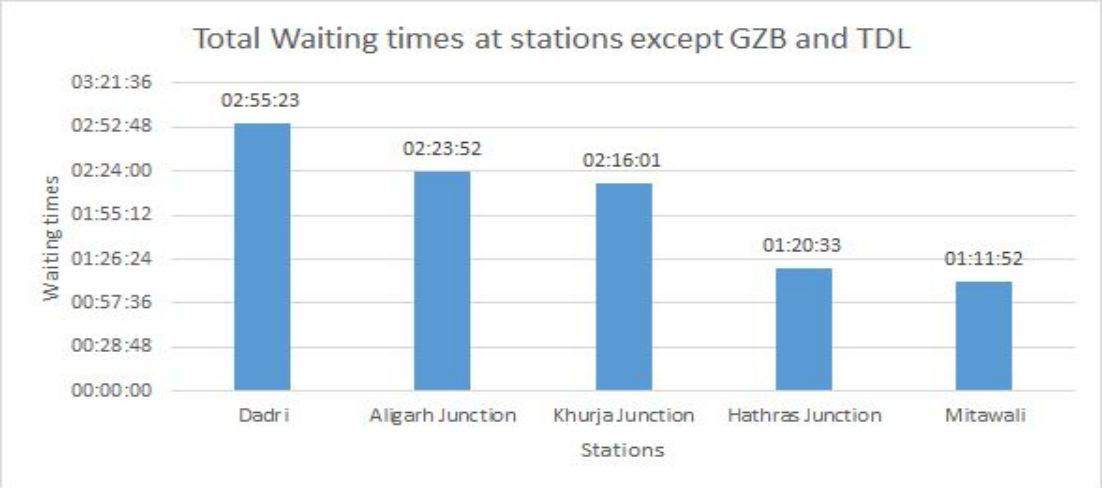

Fig 14 :Waiting times at different stations except at Tundla and Ghaziabad

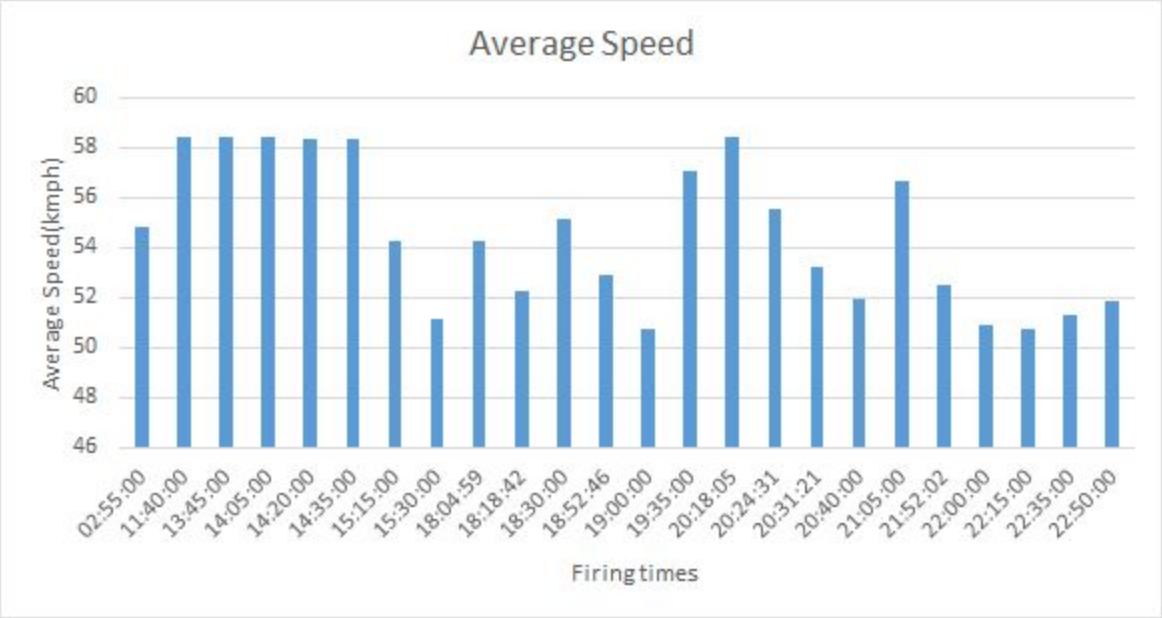

Fig 15: Average Speed vs Firing times of the freight trains in TDL-GZB section

3.2 Validation of sectional freight paths in the down direction

A similar analysis is now presented for the freight paths listed in the down direction.

3.2.1 Analysis of the freight paths in Allahabad-Mughalsarai Section

We validate the good freight paths mentioned in the WTT 2016. We have taken the following the characteristics for the freight trains:-
Length = 680m
Maximum Speed = 75 km/hr
Acceleration = 0.02 m/s^2
Deceleration = 0.06 m/s^2
We have not considered any compulsory halt at Mughalsarai for this sectional analysis. The total waiting times of all the freight trains are calculated at all the stations. The top five stations (except the terminal stations) are displayed below:-

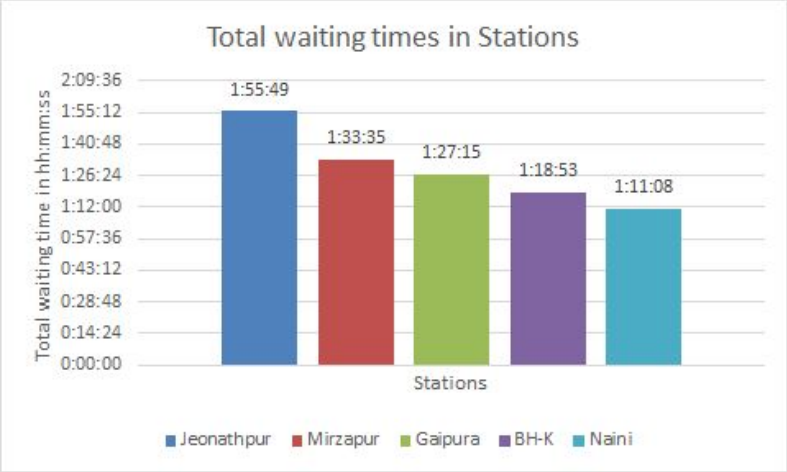

Fig 16: Waiting times in ALD-MGS(excluding ALD and MGS)

The average speed vs firing time is provided below:-

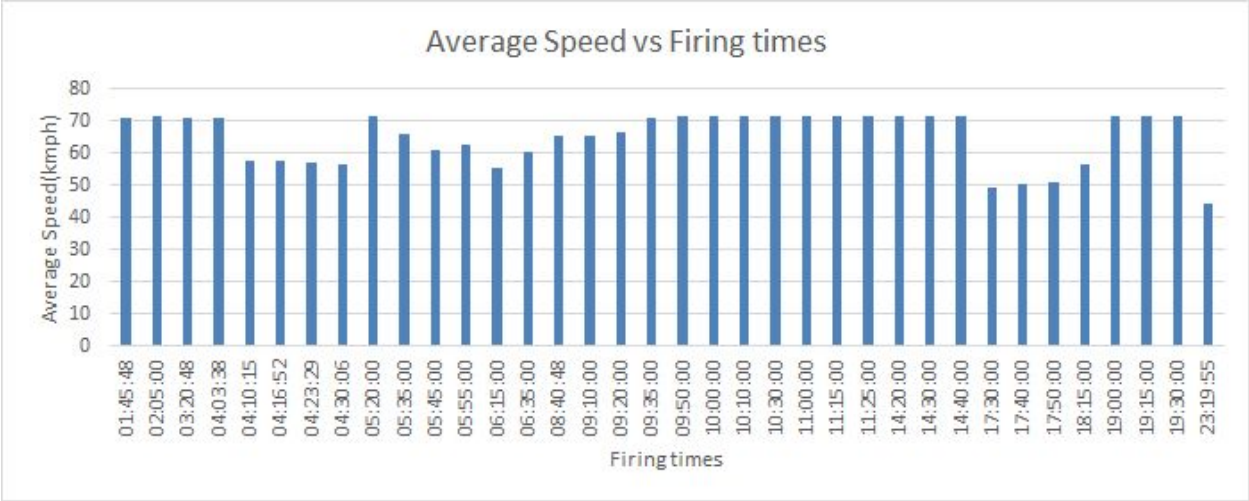

Fig 17: Average Speed vs Firing times

3.2.2 Analysis of the freight paths in Juhi-GMC- Allahabad Section

We validate the good freight paths mentioned in the WTT 2016. We have taken the following the characteristics for the freight trains:-
Length = 680m
Maximum Speed = 75 km/hr
Acceleration = 0.02 m/s^2
Deceleration = 0.06 m/s^2
We have not considered any compulsory halt at Allahabad for this sectional analysis. The total waiting times of all the freight trains are calculated at all the stations. The top five stations (except the terminal stations) are displayed below:-

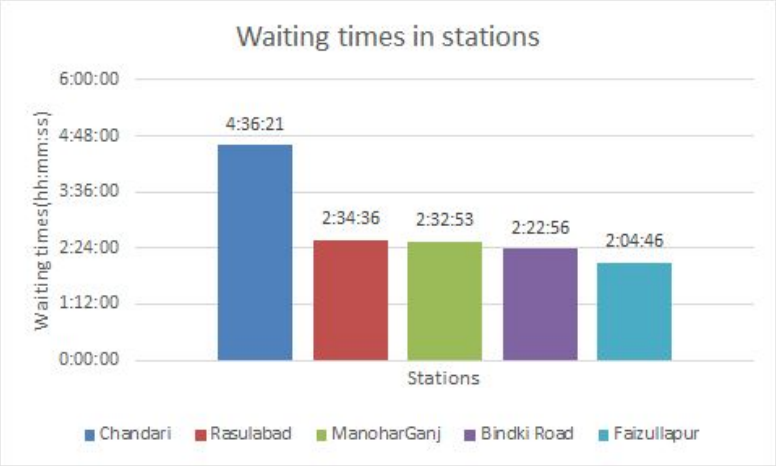

Fig 18: Waiting times in GMC-ALD(excluding ALD and GMC)

The average speed vs firing time is provided below:-

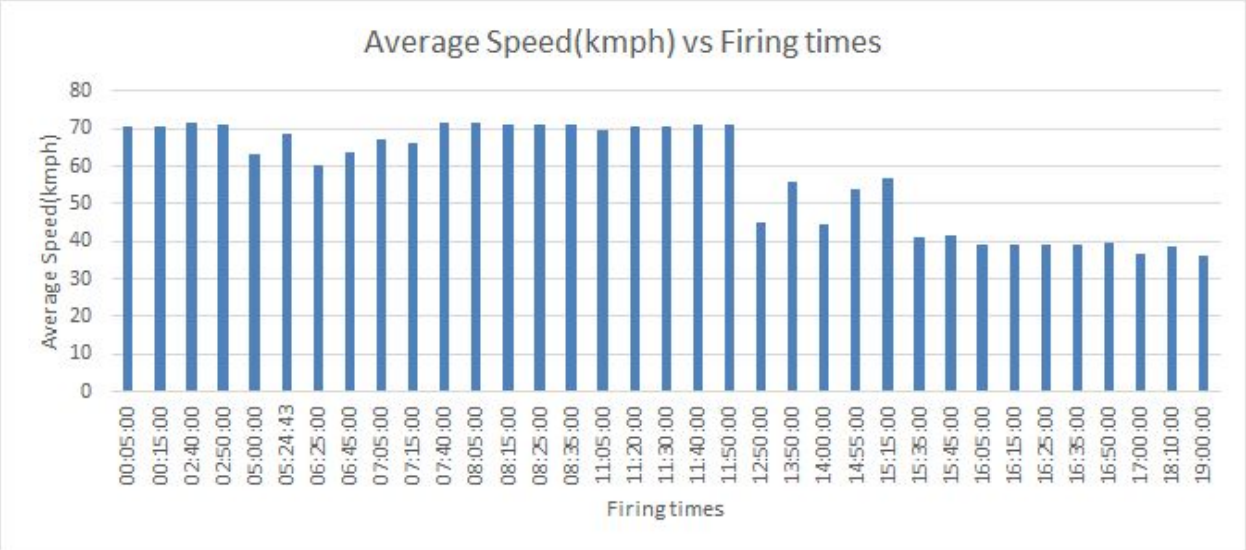

Fig 19: Average Speed vs Firing times

3.2.3 Analysis of the freight paths in Tundla-Juhi-GMC Section

We validate the good freight paths mentioned in the WTT 2016. We have taken the following the characteristics for the freight trains:-
Length = 680m
Maximum Speed = 75 km/hr
Acceleration = 0.02 m/s^2
Deceleration = 0.06 m/s^2
We have not considered any compulsory halt at Juhi-GMC for this sectional analysis. The total waiting times of all the freight trains are calculated at all the stations. The top five stations (except the terminal stations) are displayed below:-

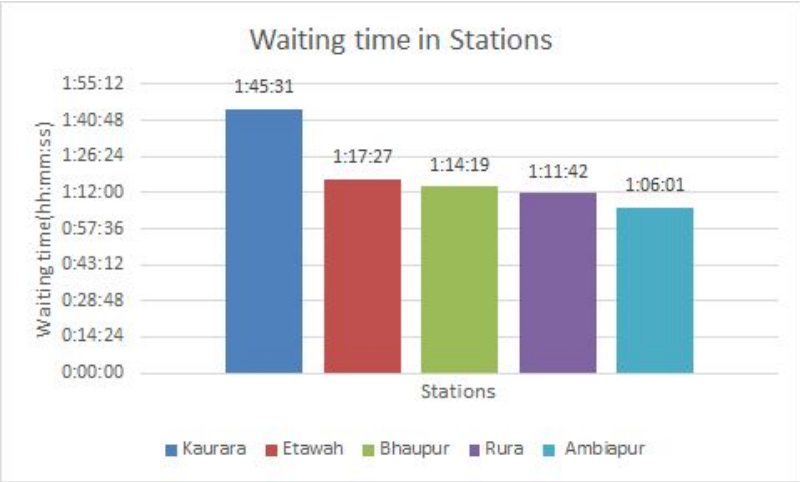

Fig 20: Waiting times in TDL-GMC(excluding TDL and GMC)

The average speed vs firing time is provided below:-

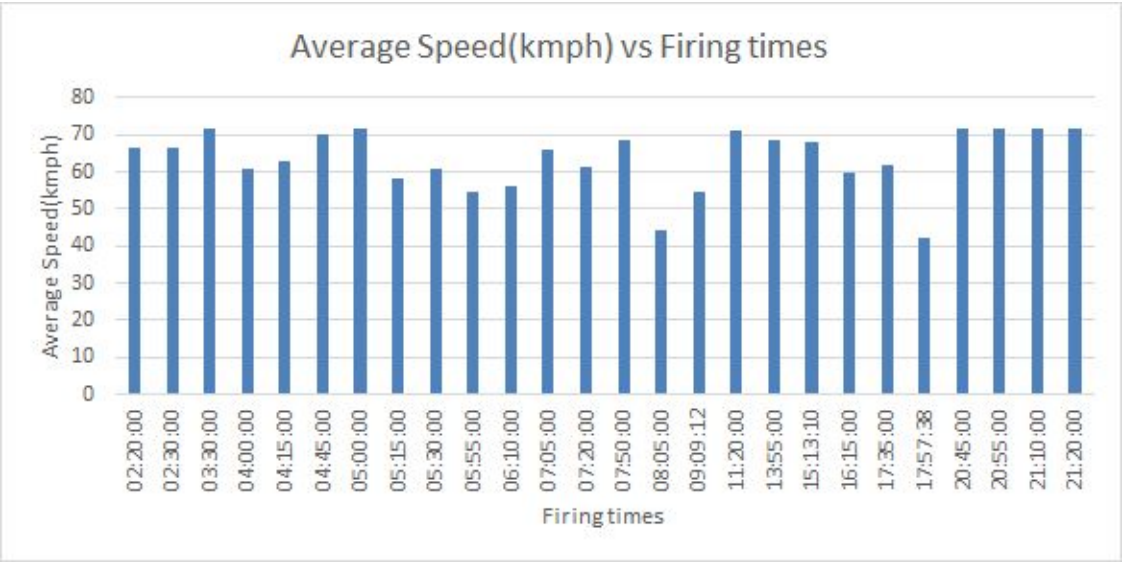

Fig 21: Average Speed vs Firing times

3.2.4 Analysis of the freight paths in Ghaziabad-Tundla Section

We validate the good freight paths mentioned in the WTT 2016. We have taken the following the characteristics for the freight trains:-
Length = 680m
Maximum Speed = 75 km/hr
Acceleration = 0.02 m/s^2
Deceleration = 0.06 m/s^2
We have not considered any compulsory halt at Tundla for this sectional analysis.
The total waiting times of all the freight trains are calculated at all the stations. The top five stations (except the terminal stations) are displayed below:-

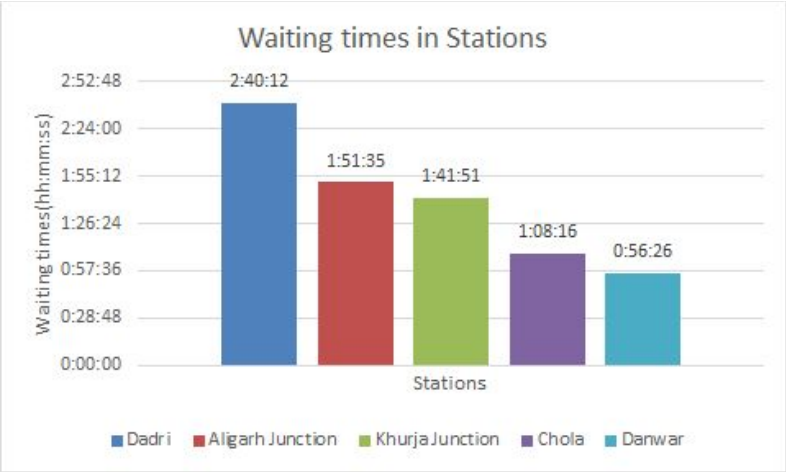

Fig 22: Waiting times in GZB-TDL(excluding TDL and GZB)

The average speed vs firing time is provided below:-

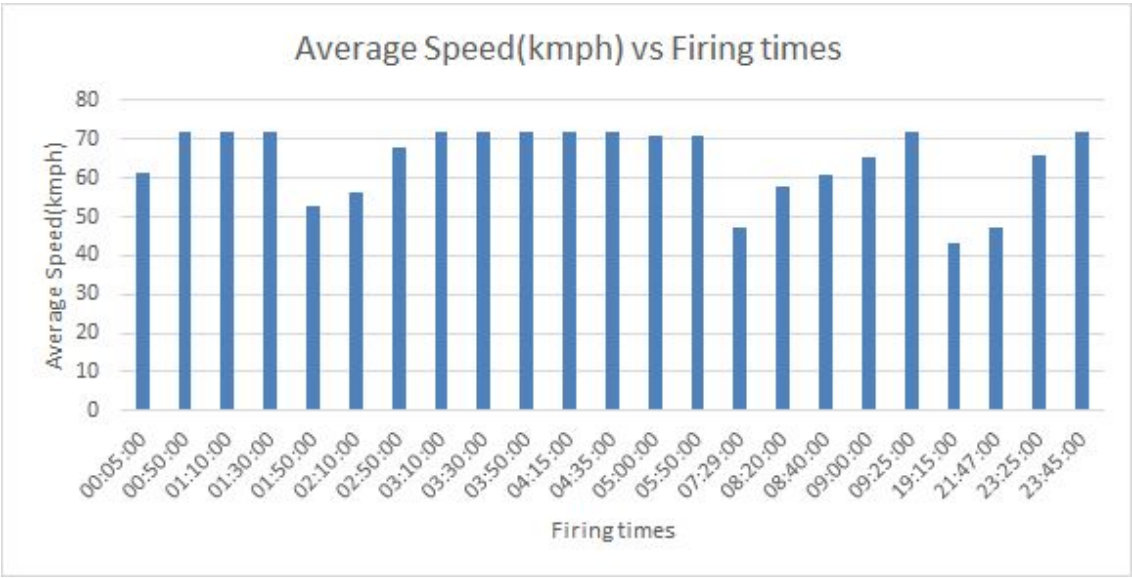

Fig 23: Average Speed vs Firing times

3.3 GOOD FIRING TIMES FOR FREIGHT TRAINS FROM MAJOR STATIONS

Modeling the major stations such as Allahabad, Tundla, Kanpur are important parts for any realistic measure of congestion. However due to to several coupled movements this modeling is quite difficult. We represent below an estimate of the halt time of the freight trains in the up direction against the firing time from Allahabad and Juhi-GMC in Figures 16 and 17 respectively.

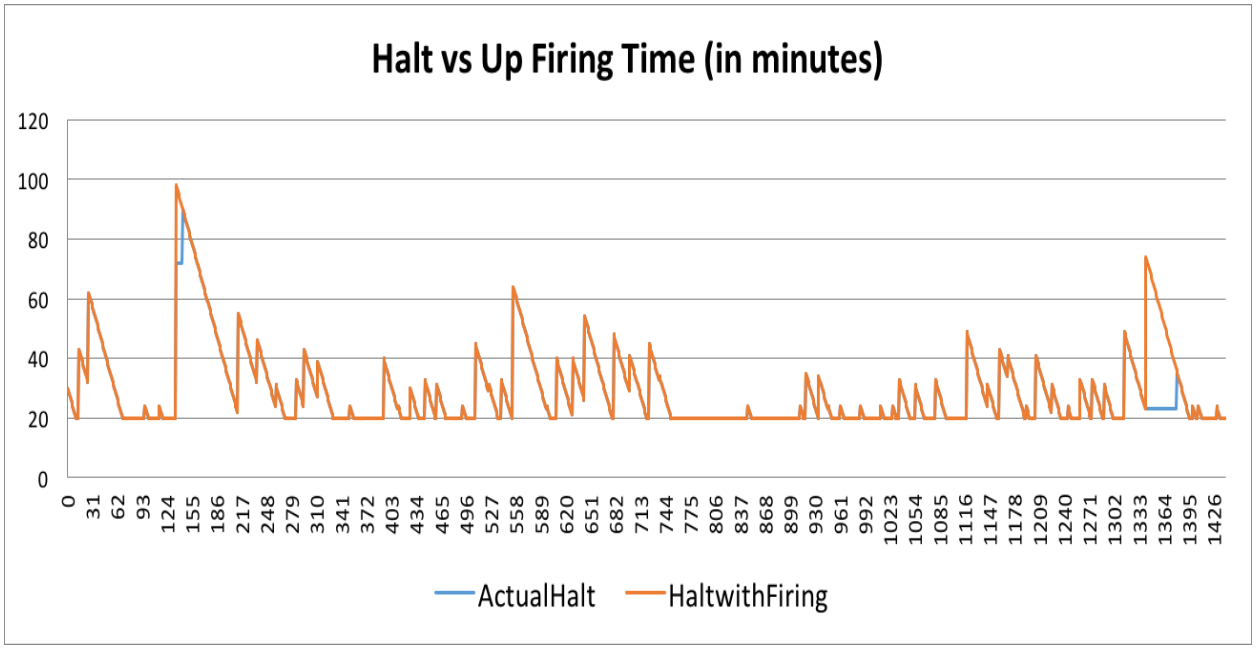

Fig 24: Halt of the trains vs Firing time in minutes at Allahabad

We conclude from the figure that the following are good time windows for firing freight trains from Allahabad in the up direction:-

1:05 am- 2:15 am; 5 30 am to 6 30 am; 12 30 pm to 3 15 pm

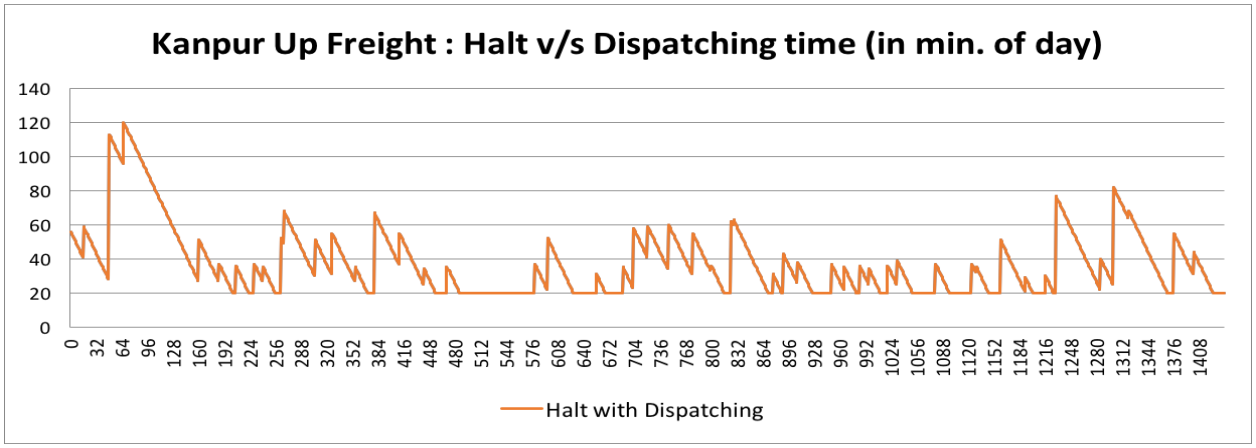

Fig 25: Halt of the trains vs Firing time in minutes at Juhi-GMC

We conclude from the figure that the following are good time windows for firing freight trains from CNB-Juhi-GMC in the up direction:-

8:00 am - 9:35 am; 10:30 am to 11:30 am

3.4 NEW FREIGHT PATHS FROM MUGHALSARAI-GHAZIABAD

In this section we suggest some additional freight paths in the section in addition to the 32 freight paths suggested in WTT 2016. While doing this analysis we have considered both up and down scheduled trains. The characteristics of the freight trains are similar as in Section 3B. The dynamic characteristics are as follows:-

- Acceleration-0.04m/s^2
- Deceleration-0.08m/s^2
- Length-680m
- Maximum Speed-60km/hr

Apart from these the freight trains are considered to have the following compulsory halts:-

Allahabad = 25 minutes
Juhi-GMC = 55 minutes
Tundla = 30 minutes

The plot of the average speed vs Firing times are provided below:-

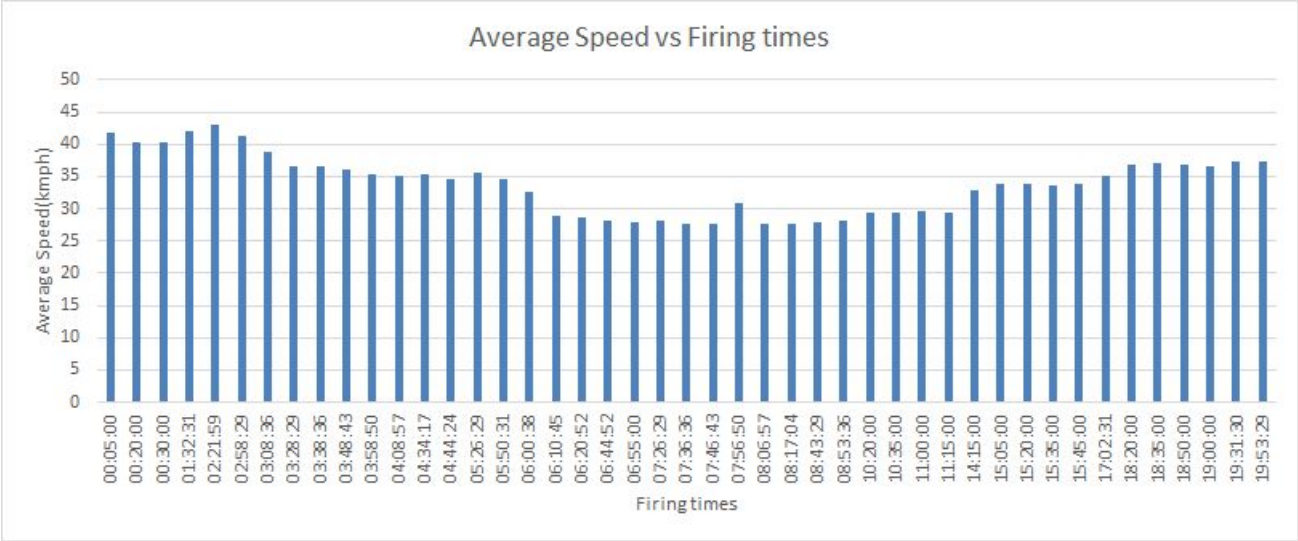

Fig 26: Average Speed vs Firing times after adding 13 freight paths

We compute a selection of new freight paths below. For assessing the quality of these new paths we also provide a tabular representation of the new paths and the average speeds that are achieved.

Firing times	**Average Speed (kmph)**
01:32	41.93
02:22	42.98
02:58	41.18
03:28	36.61
03:38	36.47
03:48	36.19
05:50	34.613
06:00	**28.98**
06:10	**28.98**
06:20	**28.74**
19:00	36.68
19:30	37.40
19:53	37.33

Table 3: New firing times and their average speeds

The 3 paths which are marked in bold have low average speeds - less than half the maximum speed. Adding additional freight paths leads to overall deterioration of performance on the section, i.e. the impact is felt on many of the other freight train paths as well, due to increased congestion and the limited resources available for train passing. From our analysis we conclude the following:-

- New freight paths can be introduced in the section between 1:00 AM and 3:00 AM. 4 paths can be added in this time window
- Although freight paths can be added in the section between 04:00 AM and 05:30 AM, they can be made to wait a long time in between as the system starts to get congested after this window. 1-2 freight paths can be added in the system. It is seen on adding more freight paths, they are made to wait in Mughalsarai itself for a long time.
- After 6:00 AM the system becomes very congested and the existing freight paths are also delayed. Thus freight paths can again be introduced after 07:00 PM. These paths are found to perform satisfactorily

We remove 4 paths and now retain 41 paths, i.e. we suggest adding 9 additional paths for satisfactory performance as far as average speeds of the entire group goes.

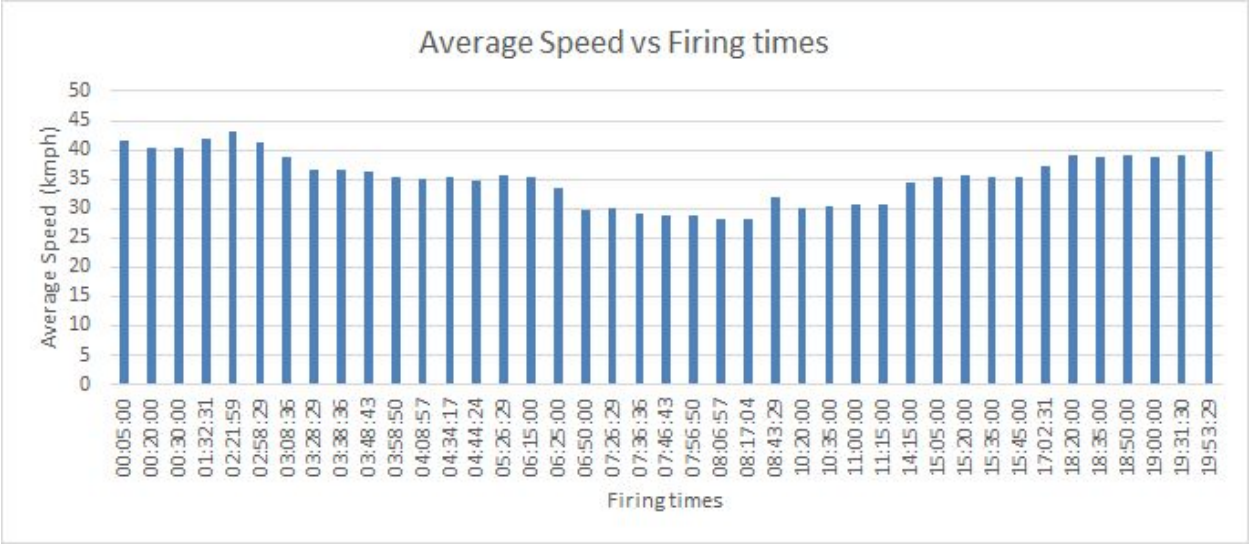

Fig 27: Average Speed vs Firing times after adding 9 freight paths

The new freight paths are tabulated below:-

Firing times	Average Speed kmph)
01:32	41.93
02:22	42.98
02:58	41.18
03:28	36.61
03:38	36.47
03:48	36.19
19:00	38.68
19:30	39.19
19:53	39.67

Table 4: New firing times and their average speed

We note that the freight paths mentioned in this section are only the end-end ones as they are the most constrained. However we have already listed the "good" firing times from intermediate major junctions such as Allahabad and CNB-Juhi-GMC. These firing times can give an idea about the sectional freight paths in the up direction.

Additional freight paths from ALD-Juhi-GMC after re-routing of trains

For this section we pick out some trains which can be re-routed to free up some time windows in the section ALD-Juhi-GMC. The names of the trains thus picked are as follows:-

Shiv Ganga and Manduadih-NDLS SF Exp- They start from Manduadih. It is possible to consider these trains routed via Varanasi - Lucknow - Kanpur, as they do not really serve any passenger traffic on the CNB-ALD section.

However, we do not expect the end-end analysis to be very different, as in Section 3.2 we have already seen that the most congested stations are all in the MGS-ALD section. However we present four new paths in the section ALD-Juhi-GMC in addition to the existing paths in WTT-2016.

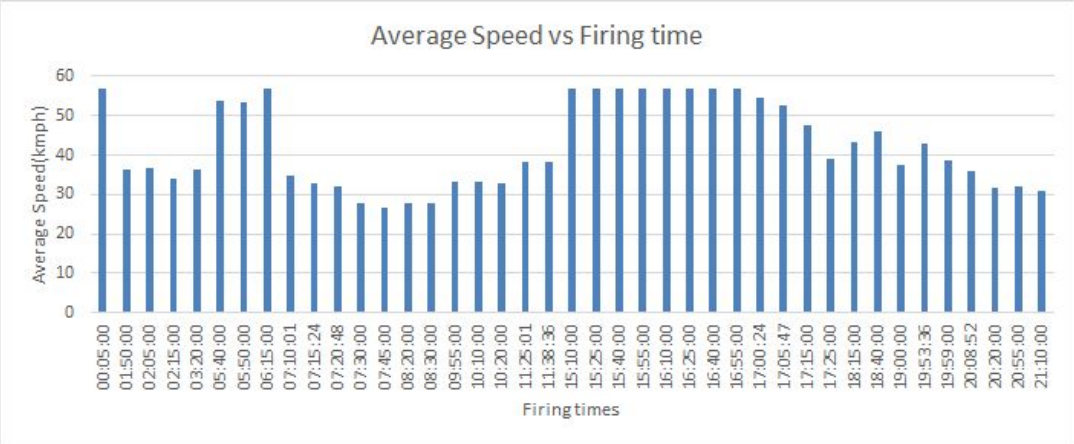

Fig 28: Average Speed vs Firing time after adding new paths

Comparing with Figure 11, we note that the existing paths are not affected after adding these new paths. The firing times and the average speed of these new paths are tabulated below:-

Firing times	Average Speed(kmph)
19:00:00	37.48
19:53:00	42.81
19:59:00	38.51
20:08:00	35.96

Table 5: The new firing times and the average speed in kmph

APPENDIX 1

Calibration of dynamic characteristics of different types of passenger trains:

All trains do not have the same dynamic characteristics. We divide the trains into groups and assume reasonable values of acceleration, deceleration and maximum speed of the individual groups. Each train can have an individual value of acceleration and deceleration if needed (and provided).

For our traffic simulator, we have a simplified model of train running that takes constant acceleration and constant deceleration in order to compute inter-station traversal times. In comparison with more exact models of train running, involving load speed curves and tractive effort, we have concluded that the maximum error in assuming a constant value of acceleration is to the tune of about 15 seconds in the acceleration part of the curve. Our model overestimates the time required for reaching maximum speed and is therefore

conservative. The error in computation is only a few seconds in most of the velocity profiles.

An indicative table of values that we are have used is given below:

Train Type	**Number of Coaches (typical)**	**Type of Loco**	**Acceleration (m/s^2)**	**Deceleration (m/s^2)**	**Max Speed**
Rajdhani/ Shatabdi/ Garib Rath/ Duronto	18	WAP-7	0.13	0.4	130 km/hr
Superfast Mail Express	20	WAP-4	0.13	0.4	130 km/hr
Mail Express	24	WAP-4	0.13	0.4	110 km/hr
EMU/DEMU	--	--	0.15	0.4	96 km/hr

Table 6: Acceleration and deceleration parameters considered in the study

Notes:

1. With reference to Working Timetable 2016 (Pg.3), the acceleration and deceleration of WAP-4 & 7 locos were estimated to be 0.13 and 0.4 m/s^2. This values agrees with our simulation trials and all the simulated trains of 130 & 110 kmph are reaching the respective stations within 5 mins of the scheduled arrival time (not considering allowances).
2. For EMU/DEMUs, the acceleration and deceleration parameters are much more important than for express trains, as they halt at all stations.
3. For different acceleration/deceleration values, the table below provides the times and distances for reaching maximum speed and braking from maximum speed. This can be used to validate the assumptions.

	Speed: 60 kmph		**Speed: 100 kmph**		**Speed: 110 kmph**		**Speed: 130 kmph**	
Acc/Dec (m/s^2)	Distance Needed (km)	Time Taken (min)	Distance Needed (km)	Time Taken (min)	Distance Needed (km)	Time Taken (min)	Distance Needed (km)	Time Taken (min)
0.13	1.07	2.14	2.97	3.56	3.59	3.92	5.02	4.63
0.15	0.93	1.85	2.57	3.09	3.11	3.40	4.35	4.01
0.4	0.35	0.69	0.96	1.16	1.17	1.27	1.63	1.5

Table 7: Distance and Time taken to reach maximum speed for different parameters

Table 7 provides the distance/time taken to reach maximum speed from halt or to halt from its maximum speed for different Acceleration and Deceleration parameters. For Example, WAP-7 Loco's Acceleration is 0.13m/s^2, so it takes 5.02 kms and 4.63 minutes to reach 130 kmph. But the same Loco decelerates from 130 kmph to halt in 1.63 kms and 1.5 mins, since its deceleration parameter is 0.4 m/s^2. These values are consistent with acceleration and deceleration time allowances listed in WTT 2016 (page 3).

APPENDIX 2

Congestion Ratio:

This section attempts to define sections/stations where additional resources would be most useful to add. The concept of congestion ratio at stations is used. This is defined as follows:

Congestion Ratio = (Time blocked at a station/Total time available in a station)*100

Time Blocked at a Station = Time blocked because of scheduled halts +
Time blocked because of through trains +
Time blocked because of halting trains +
Time blocked because of taking non-main lines

Time available at a station = Number of (up/down) effective PFs up/down)*24*60

A thumb-rule to define the number of "effective" UP loops =
= 1*(# main UP loop) + 0.8*(# non-main UP loops)
+ 0.6*(# number of common loops)/2

Non-main loops and common loops need slowing of the train and 0.8 and 0.6 values have been chosen to describe this situation. These values will be fine-tuned with inputs from RITES.

Assumptions:

1 Each through train creates a hindrance of 5 minutes
2 Each halting train creates an extra hindrance of 15 minutes considering acceleration and deceleration
3 Train going to a non-main line creates hindrance to all up/down PFs of 10 minutes

This evaluation can be performed for Up direction, Down direction separately or for both directions combined. From the combined analysis, the following stations (other than GZB, TDL, CNB, ALD and MGS) have higher congestion ratios.

Stations	Congestion Ratios
Aligarh	36.20
Mirzapur	27.82
Etawah	23.56
Maitha	19.63
Panki	18.83

Table 8: Stations (other than GZB, TDL, CNB, ALD, MGS) with high congestion ratios

Congestion ratio can be interpreted as the ratio of amount of time a station is occupied in a day and total time available in the station for a day (24 hours). Hence a higher congestion ratio means the station is congested more. Therefore, infrastructural development or reduction of train halts will be needed at the stations which have higher congestion ratio. From Table 8, it can be inferred that the Aligarh station is more congested than Mirzapur station.
Similar congestion ratios can be evaluated for up and down directions separately. Using this, it is observed that Mirzapur, Aligarh and Naini have high congestion ratios of 36.4, 26 and 22 respectively in the Up direction and Aligarh, Etawah, Kulwa and Panki have high congestion ratio of 46.4, 28, 22.7 and 22.6 in the down direction.

1. Mirzapur, Aligarh and Naini station require infrastructure improvements in Up direction
2. Aligarh, Etawah, Kulwa and Panki require the infrastructure improvements in Down Direction