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Finding the Reasons for the Delay Time in a Highway by Analyzing the Travel Time, Delay Time and Traffic Flow Data

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ABSTRACT

The objectives of this study are to show a comparison among travel time, running time, delay in peak and off-peak hours on different days of a week, and reasons behind the delay time. Moving car observer method has been carried out to count the traffic flow, journey time, running time, and delay time. Total vehicle flow, and comparative vehicle flow during the peak hour and off-peak hour for workdays and weekend days were surveyed to show a relationship between delay time and traffic flow. As the traffic flow increases the delay time also will increase. To measure the reasons behind the delay time of Fulbarigate-Daulatpur road, spot speed study was done in two intersections of the road. The 15^{th} percentile speed for Religate intersection road is 10 K.P.H. That means 85% of vehicles tends to go faster than 10 K.P.H. in this section. And hence vehicles with less than or equal 10 K.P.H. are responsible for increasing the delay time in this area. This speed limit should be prohibited in this section to reduce delay time and congestion. For the Mohosin More road intersection, the prohibited speed is also 10 K.P.H. Easy bike and Mahindra account for the congestion of these intersections and tend to stop in these intersections to collect passengers which creates unwanted queue in this study area. Controlling traffic flow at intersections can be a possible way to reduce the congestion rate of Fulbarigate-Daulatpur road.

Keywords: Spot Speed; Journey Time; Travel Time; Percentile; Congestion; Delay Time.

1. Introduction

The provision of adequate and equitable service for all groups is the main target of urban planning. Transportation is one of the most important elements of such a service [1]. Transportation is a process that involves the movement of commuters, goods, and services from a given point of origin to a specific destination [2]. It determines the regional patterns of development, economic viability, environmental impacts, and maintenance of socially acceptable levels of quality of life. It is a means to access business activities, education, employment, and recreational opportunities [3]. Various transportation modes are available like road-based, railway based, air-based, and water-based [4]. In our country, road-based transportation is dominant among them. In a road-based transportation system, the public transport system is most popular [5].

"Since the end of the Second World War, high demand for mobility increases due to rapid urbanization and economic growth in third world cities" [6]. Like other developing countries in Bangladesh, problems related to the lack of traffic mobility are getting extremely high [7]. Bangladesh cannot bear the cost of the financial and ecological misfortune that came about because of this serious traffic obstacle [8]. Main urban areas like Dhaka (eats up to 3.2 million working hours/day), Chittagong, and Khulna are under the disturbing worry of this issue [9]. Khulna, the third biggest city of Bangladesh, in such a case is close to repeating a similar incidence [10].

In respect of Khulna division's transportation system, Khulna-Jessore Highway is the most important road network for both intra and intercity connectivity. "Besides after the completion of Padma Bridge transportation between the Khulna region and the Dhaka region will become even easier which will increase the economic activities of Khulna. To support this economic growth and future public demand a well-planned transportation system is a prerequisite" [11]. The common modes of public transportation in Khulna are pedal rickshaw, baby taxi, battery bike and auto-rickshaws etc. [12].

However, a comparison among travel time, running time, delay in peak, and off-peak hours on different days of a week is shown in this study, and the reasons behind the delay time are found out. Several traffic studies e.g. volume study, speed study, etc. have been carried out for this study. By conducting travel time, speed, and delay studies congestion can be measured [13]. Moving car observer method is used in measuring travel time, delay time, vehicle flow. Delay can be measured by doing field measurement, simulation, analytical derivation, or by using a combination of these methods [14]. The reasons behind the delay time at two intersections of Fulbarigate-Daulatpur road is carried out by using spot speed. This type of evaluation of the public transport system is very suitable for a highly populated country like Bangladesh [15]. As the western part of Khulna is facing acute traffic congestion due to the haphazard movement of traffic, the amount of delay time has increased. Particularly the delay time at major intersections and road sections in Khulna Metropolitan City is increasing faster [16]. A huge number of slow-moving vehicles create a huge delay time due to the lack of proper management [7].

There are 66 National highway routes in Bangladesh and 9 of them are from Khulna division. The route chosen for this research is called Khulna-Jessore road and our study area Fulbarigate to Daulatpur is within Khulna City Corporation. The road covers 3.2 kilometers distance [17]. Thus, this research will assist to develop a proper transportation system. In the end, the output of this research can be useful in further tasks associated with the Khulna-Jessore highway.

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2. Methodology

To conduct the study, traffic flow, travel time, running time, and spot speed are studied. The study has been conducted based on primary data. Primary data sources are - Reconnaissance survey, Spot Speed Survey, Running Speed, Journey Speed Study, and Delay Studies. Moving car observer method has been used for the measurements of running speed and journey speed. Congestion and delay time in two intersections of Fulbarigate-Daulatpur road is carried out by using spot speed. Spot speed has been surveyed through a direct-timing procedure.

2.1 The moving car observer method

The field survey was carried out to collect the data on Fulbarigate to Daulatpur which has a 3.9 km length. To count the traffic flow, average journey Speed, average running speed, and delay time, moving car observer method has been used. Several test runs are made along the road section and a group of observers records various parameters. Four observers were fixed for recording four types of data. The four types of data were –

- Total journey time, delay points and delay time
- Number of overtaking vehicles
- Number of overtaken vehicles
- Number of modes coming from the opposite direction

The average journey time (min.) for all vehicles in a traffic stream in the direction of flow (q) is given by following equation.

$$q = (M_a+M_w)/(T_a+T_w)$$

$$T_{avg}=T_a-(M_w/q)$$

Where, T_{avg} = Average journey time, Tw = Average journey time when vehicle is travelling in the stream,

M_w = Overtaking vehicle minus Overtaken vehicle, M_a = Average number of vehicle in opposite direction,

Ta = Average journey time when vehicle is travelling in opposite stream [18].

2.2 Spot speed study

For our study area, the stopwatch method is preferred. For calculating spot speed 60/100 m length at each link of a highway will be taken which has free flow. When the vehicles passed at the first reference point, the first observer signaled the second observer and then the second observer started the stopwatch, and finally when the vehicles crossed the other reference points, then stop the watch and recorded the time. The speed of a particular vehicle will be calculated from how much time it takes to cross a certain distance. Thus, from known distance and time, found out the vehicle's spot speed. The spot speed of the vehicles was measured four times in two days.

The cumulative speed distribution curve was prepared to analyze the spot speed condition for different speed percentile groups. The 15th, 50th, 85^{th,} and 98th percentile speeds are four parameters that are commonly used in traffic safety and traffic engineering. For example, the 15th percentile speed reflects the minimum or critical speed limits, 50th percentile speed reflects median speed limit, 85th percentile speed reflects the optimum speed limit and 98th percentile speed reflects the maximum or design speed limit [19], [20].

Table 1 Moving car observer data collection sample.

Morning Weekend Peak Hour						
Location	Direction	Journey Time (minutes)	Stop Time (minutes)	Number of Vehicles		
				Over Taking	Over Taken	In Opposite Direction
Fulbarigate to Daulatpur	N-S	6.7	0.6	51	47	159
		5.8	0.3	63	37	127
		6.8	0.5	55	51	161
		6	0.4	57	42	147
		5.6	0.2	68	39	138
		6.9	0.35	52	49	162
Total		37.8	2.35	336	265	894
Mean		6.3	0.4	56	44.2	149

Source: Field Survey

3. Data collection & calculation

As shown in Table 1 data collection sample and sample calculation of moving car observer Survey. Same procedure carried out both workdays and weekends during Peak Hours (8.00-9.00 AM, 12.00-1.00 PM, 5.00-6.00 PM) and Off-Peak Hours (10.00-11.00 AM, 3.00-4.00 PM) in both directions.

4. Data Analysis

For finding out the possible causes of delay time and the level of service of the Fulbari to Daulatpur highway- this study focused on several factors. First of all, through the vehicle flow survey the amount of total vehicle flow during the peak hour and off-peak hour for workdays and weekend days were determined to find out if there was any anomaly in total vehicle flow number in this road. Secondly using the spot speed survey in different intersections in the road the minimum and maximum speed for different types of vehicles available was found out. After analyzing the data the ideal speed for every vehicle has been determined. It also shows those vehicles which travel below the 15th percentile speed that causes unwanted congestion in that road. Here, to visualize the data of spot- the related speed map for the two different intersections is also prepared. Through this analysis, the connection between vehicle flow and vehicle speed is figured out which eventually leads to those factors which impact the delay time in this road.

Table 2 Sample calculation of moving observer survey.

Calculation	
M_w = Overtaking vehicle minus overtaken vehicle	11.8
M_a = Average number of vehicle in opposite direction	149
Tw = Avg. journey time when vehicle is travelling in the stream	6.3 min
Ta = Avg. journey time when vehicle is travelling in opposite stream	6.4 min
(Flow) Q veh./hr =	759 veh./hr
Avg. Journey time	5.37 min
Avg. journey speed = (3.9*60) / 5.7	43.57 Kmph
Avg. Running time = Avg. journey time – Avg. Stopped Delay	4.98 min.
Avg. Running Speed = (3.9 * 60)/4.98	47 Kmph

4.1 Journey time and delay time study

This study considers more than one intersection to gather data and both of the intersections don't have any traffic signal. That means the delay time found in this study is caused by other factors than by the traffic signals. Here the average journey time, running time, and delay time is calculated for workday and weekend during the pick and off-pick hours. This study considers both sides of the vehicle flow (North to South and South to North) to analyze the travel time and delay time conditions for these intersections.

As Journey time = Running time + Delay time, the journey time is always significantly more than the running time. The more the difference between the journey time and running time the more the delay time is. Now delay time can be caused by many factors including traffic signal, road condition (Ex: Potholes, speed breaker, road width), vehicle type (Ex: Car, Bus, Auto rickshaw, Rickshaw), total number of vehicles, etc. Now this study area doesn't have any traffic signals that means, other factors that cause traffic jams or traffic delays are the reason behind the delay time.

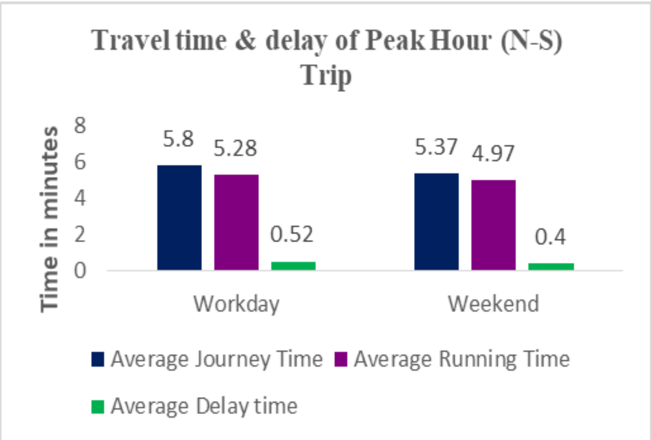


Fig. 1 Travel time & delay of peak hour (N-S) trip.

As shown in Fig. 1 travel time & delay of peak hour (N-S) trip workday has the highest travel time & delay between workday and weekend, same for the return trip (S-N) Peak Hour workday has the highest travel time & delay as shown in Fig. 2, for Travel time & delay of off-peak period (N-S) trip workday has the highest Travel time & delay is shown in Fig. 3, Fig. 4 shows the return of off-peak period trip (S-N).

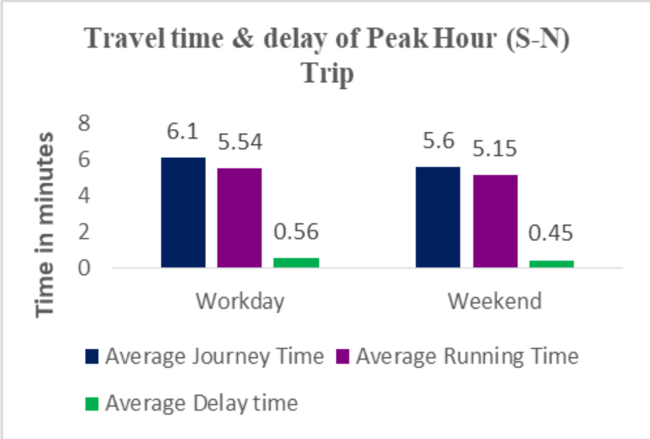


Fig. 2 Travel time & delay of peak hour (S-N) trip.

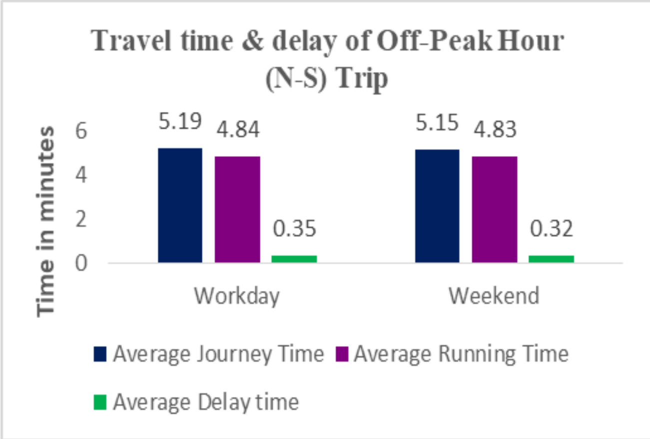


Fig. 3 Travel time & delay of off-peak hour (N-S) trip.

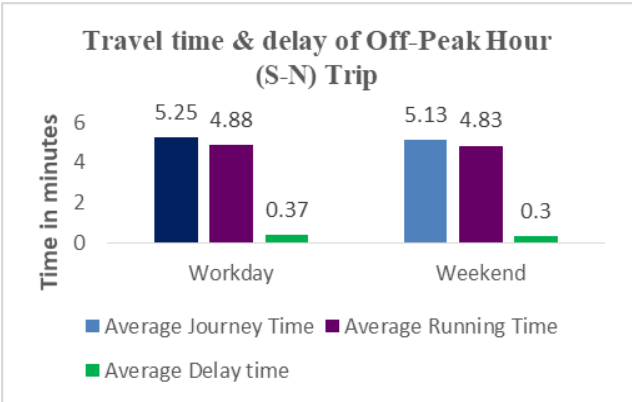


Fig. 4 Travel time & delay of off-peak hour (S-N) trip.

In workdays for the South to North (S-N) trip the average delay time was the maximum (0.56 minutes) during peak hours. And during the off-peak hours of weekend days, the delay time was the minimum (0.30 minutes) for the same South to North (S-N) trip. Even the average delay time (0.40 minutes) during the peak hours in the weekend days (Fig. 1) is greater than the average delay time during the off-peak hours of working days (Fig. 3).

Normally in peak hours, the number of vehicles remains higher than the off-peak hours. So that means the number of vehicles can be the prominent factor for the increased amount of delay time during the peak hours in the workdays. If the delay time of the study area becomes perfectly equivalent to vehicle flow, then it will mean that the total number of vehicles is the number one factor for delay time in this road. And it will also mean that if the number of vehicles increases every time the delay time also increases in this road too if the other factors remain the same.

4.2 Vehicle flow analysis and related travel time-delay time comparison

To analyze the traffic flow behavior of the study area the vehicle flow chart was prepared. It also explains the possible cause of journey time and delay time differences during peak and off-peak hours for both workdays and weekend days. The comparative vehicle flow for both directions of the road during the peak and off-peak hours in workday and weekend is shown in Fig. 5 and Fig. 6.

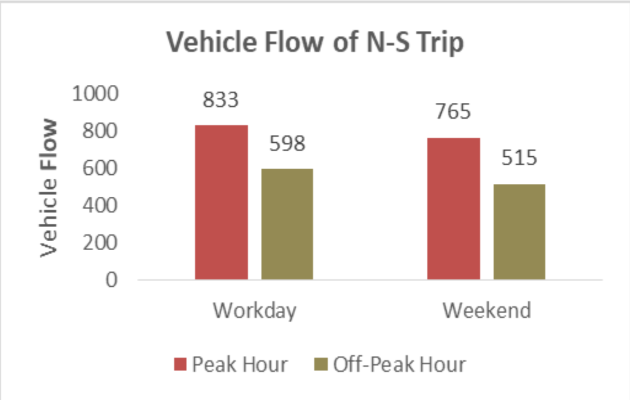


Fig. 5 Vehicle flow of N-S trip.

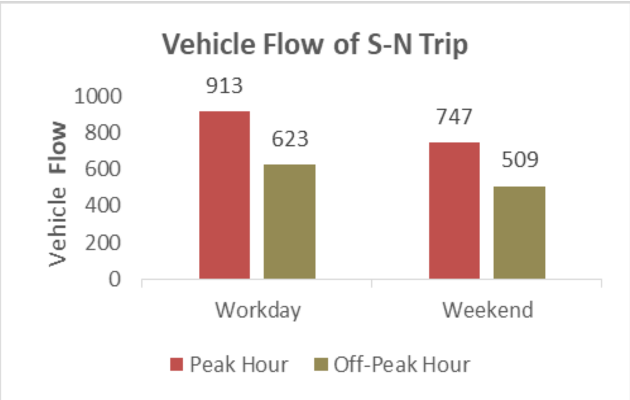


Fig. 6 Vehicle flow of S-N trip.

Workday had the highest Vehicle flow in peak hour for both directions of a vehicle trip. Here, the S-N trip shows a bigger number of vehicle flow in this study area. Most importantly, the total number of vehicles during peak hours of workdays was 833, and 913 which are greater than the off-peak hour's vehicle flow in workdays. These relations remain the same for both North to South (N-S) and South to North (S-N) trips. That means in this study area the total number of vehicles is always higher during the peak hours and hence the traffic pressure also remains higher during the peak hours of both workdays and weekend days and for both side of the trip.

The journey time and delay time data also show the exact fact of increased traffic pressure during the peak hour of both workdays and weekends in both directions of the roads (Fig. 1-4). So in the study area, there is a direct relation of vehicle flow number and the average delay time. According to the data shown in Fig. 1-6, as the total number of vehicles increases in peak hours, the delay time also increases as result.

4.3 Spot speed analysis

Spot speed analysis was performed to determine the speed distribution of different vehicles (Easy bike, Mahindra, Motorcycle, Bus, Truck) available in the traffic stream of this study area. Spot speed frequency distribution curve and cumulative distribution curve have been analyzed for both intersections (Religate and Mohosin More) to find the vehicle types which are directly responsible for the increased delay time in this study area.

4.3.1 For Relegate intersection

The collected speed datasets were grouped into several speed-class interval sections. Within these sections, the number of vehicles was counted to prepare the speed frequency distribution table. From this table, the arithmetical mean speed and a histogram of speed-class intervals against the percentage frequency of vehicle numbers were developed (Fig. 7). Here the speed represents the average speed of all the collected vehicle's speed.

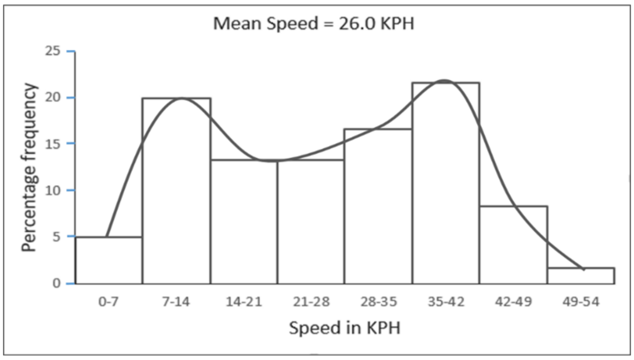


Fig. 7 Spot speed frequency distribution curve for Religate intersection area. (Source: Field Survey)

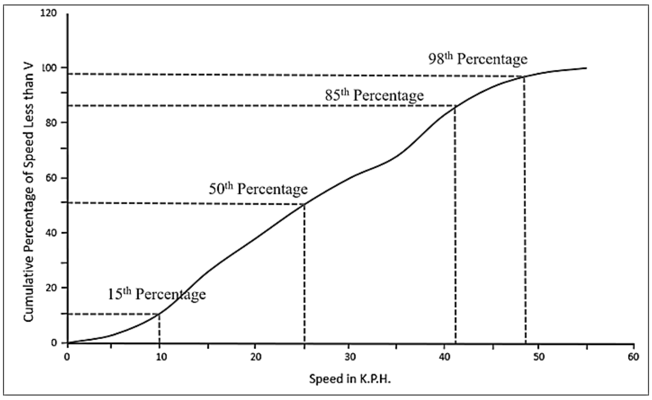


Fig. 8 Cumulative speed distribution curve for Religate intersection road area. (Source: Field Survey)

The average speed of vehicles in the Religate intersection area was 26.0 K.P.H. with a standard deviation of 12.66 which means speed fluctuates a lot during traffic congestion. From Fig. 7 it is clear that the speed of vehicles does not tend to cluster to the mean speed. But the frequency increases if the speed deviates slightly from the mean speed value. This indicates that there are a significant amount of vehicles travel both at high speed and low speed in this section.

4.3.1.1 Cumulative distribution curve

The cumulative speed distribution curve for the relegate intersection area has been prepared from the speed-class interval and frequency table. To prepare the curve the speed-class intervals are plotted in the X-axis the cumulative percentage of speeds for each class intervals are plotted on the Y-axis. Then from the curve, the related percentile speed is identified (Fig. 8).

The related percentile speed for Fig. 8 are as follows:

i. The 15th percentile speed for Religate intersection road is 10 K.P.H. That means 85% of vehicles tends to go faster than 10 K.P.H. in this section. And hence vehicles with less than or equal 10 K.P.H. are responsible for increasing the delay time and congestion significantly in this area. So the 10 K.P.H speed limit should be prohibited in this section. This will reduce congestion and the unnecessary overtaking tendency of the other drivers in this section.

ii. The 50th percentile speed for this section is 23.6 K.P.H. which the median speed for the observed data set. It represents the average speed of the total traffic stream. It means half of the vehicles travel faster than this 50th percentile speed and half of the vehicles travel slower than this.

iii. The 85th percentile for the Religate intersection is 41.20 K.P.H. which represents that under a free-flowing condition 85% vehicles go in this speed or slower than this. And only 15% of vehicles travel faster than this speed. The 85th percentile speed is commonly used in traffic engineering and traffic safety guidelines as it is considered as the quickest safe speed for any traffic in a road under a free-flowing condition [19].

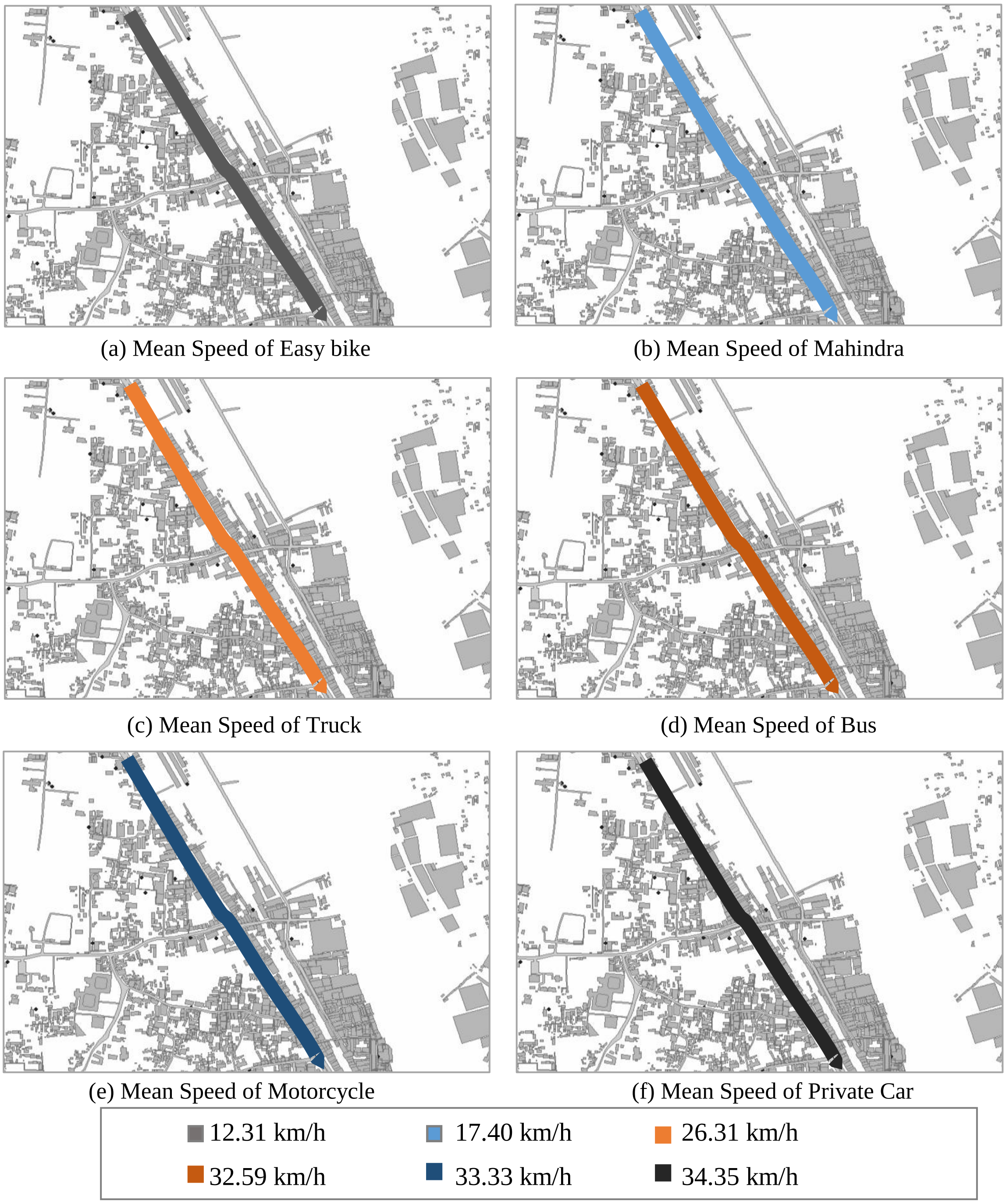
iv. The 98th percentile speed for the Religate intersection area is 47.50 K.P.H. That means 98% of the vehicles travel equal or less than this speed. This speed is normally considered as the design speed of any road [21].

Table 3 reveals that Mahindra and Easy bike have the highest coefficient of variation with a maximum speed of 30 K.P.H and 23 K.P.H. respectively. It means that they could move faster if they don't face any congestion. Mahindra and Easy bike account for a very large portion of traffic composition on the road. The minimum speed of Mahindra and Easy bike go lower than the 15th percentile speed for this section.

Table 3 Spot Speed statistics of different types of vehicles on Religate intersection.

Vehicle type	Speed of Vehicles				
	Mean	Maximum	Minimum	Standard Deviation	Coefficient of variations
Easy bike	12.31	23.00	4.00	5.95	.48
Mahindra	17.40	30.00	5.75	8.90	.51
Motorcycle	33.33	53.20	12.41	12.41	.37
Private Car	34.35	47.50	15.20	10.21	.30
Bus	32.59	45.60	13.50	9.63	.30
Truck	26.31	43.29	12.50	10.36	.39

It means that if queuing is formed during congestion, this traffic mode makes the congestion more acute as other vehicles need to overtake opportunities while approaching to move. The direct field survey data (Fig. 9) also upholds the results of Table 3. The minimum spot speed of Easy and Mahindra found lower than the 15th percentile speed in this intersection with a speed of only 4 K.P.H and 5.75 K.P.H respectively. According to the field survey data, Easy bike and Mahindra often stops in this intersection to collect passenger which creates an unwanted queue. This consequently results in traffic congestion and travel time delay.



(a) Mean Speed of Easy bike

(b) Mean Speed of Mahindra

(c) Mean Speed of Truck

(d) Mean Speed of Bus

(e) Mean Speed of Motorcycle

(f) Mean Speed of Private Car

Fig. 9 Mean speed map for different vehicles in the Religate More intersection.

4.3.2 For Mohosin More intersection

The mean speed of Mohosin More intersection was 25.7 K.P.H. with a standard deviation of 12.3. That means most of the speed varies from 13.4 K.P.H to 38 K.P.H. The spot speed frequency distribution curve shows that the speed of vehicles was not also showing cluster tendency to the mean speed in the Mohosin More intersection. But the maximum vehicle speed was very close to the mean value. However, the frequency decreases if the speed deviates from the mean speed value.

The curve indicates that there were a significant amount of vehicles that traveled near the mean speed value though the overall number of vehicles with high speed and low speed were also significant in this intersection.

4.3.2.1 Cumulative distribution curve

Using the Spot speed frequency distribution curve's data the cumulative speed distribution curve has been prepared. From this curve, the 15th, 50th, 85^{th,} and 98th percentile speed has been determined that helps to determine those which travel speed is lower than the desired speed and hence they can create extra traffic pressure and delay time as a consequence.

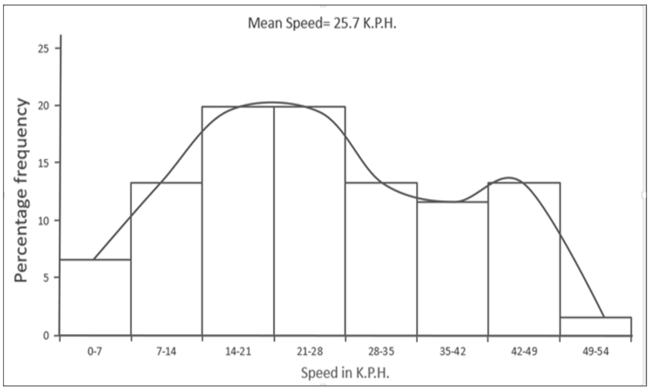


Fig. 10 Spot speed frequency distribution curve for Mohosin More road area.

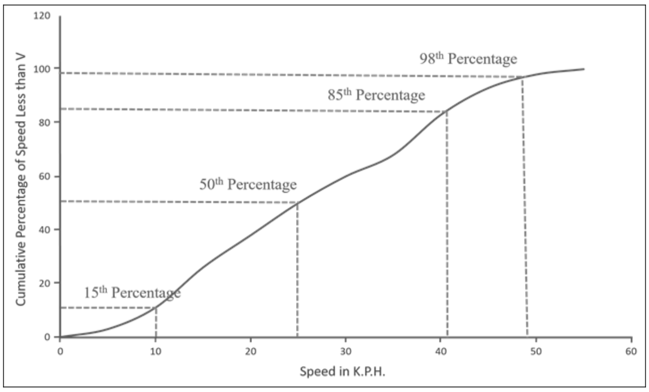


Fig. 11 Cumulative speed distribution curve for Religate intersection road area.

The related percentile speeds for Mohosin More intersection area are as follows:

i. The 15th percentile speed for the Mohosin More road intersection is also 10 K.P.H. which is just similar to the Relegate intersection area. That means 15% of the total vehicles travel equal to or lower than this speed. This speed limit should be prohibited in this section too as this speed limit increases delay time, congestion time, and overtaking tendency to the other drivers.

ii. The 50th percentile speed for this section is 24.5 K.P.H. That means 50% of vehicles travel faster than this speed and the rest of the 50% travels slower than this speed limit.

iii. The 85th percentile speed for this road section is 41.38 K.P.H. That means in a free-flowing condition 85% of all vehicle travel within this speed limit. Normally this speed limit is considered as the maximum allowable safe speed for any road.

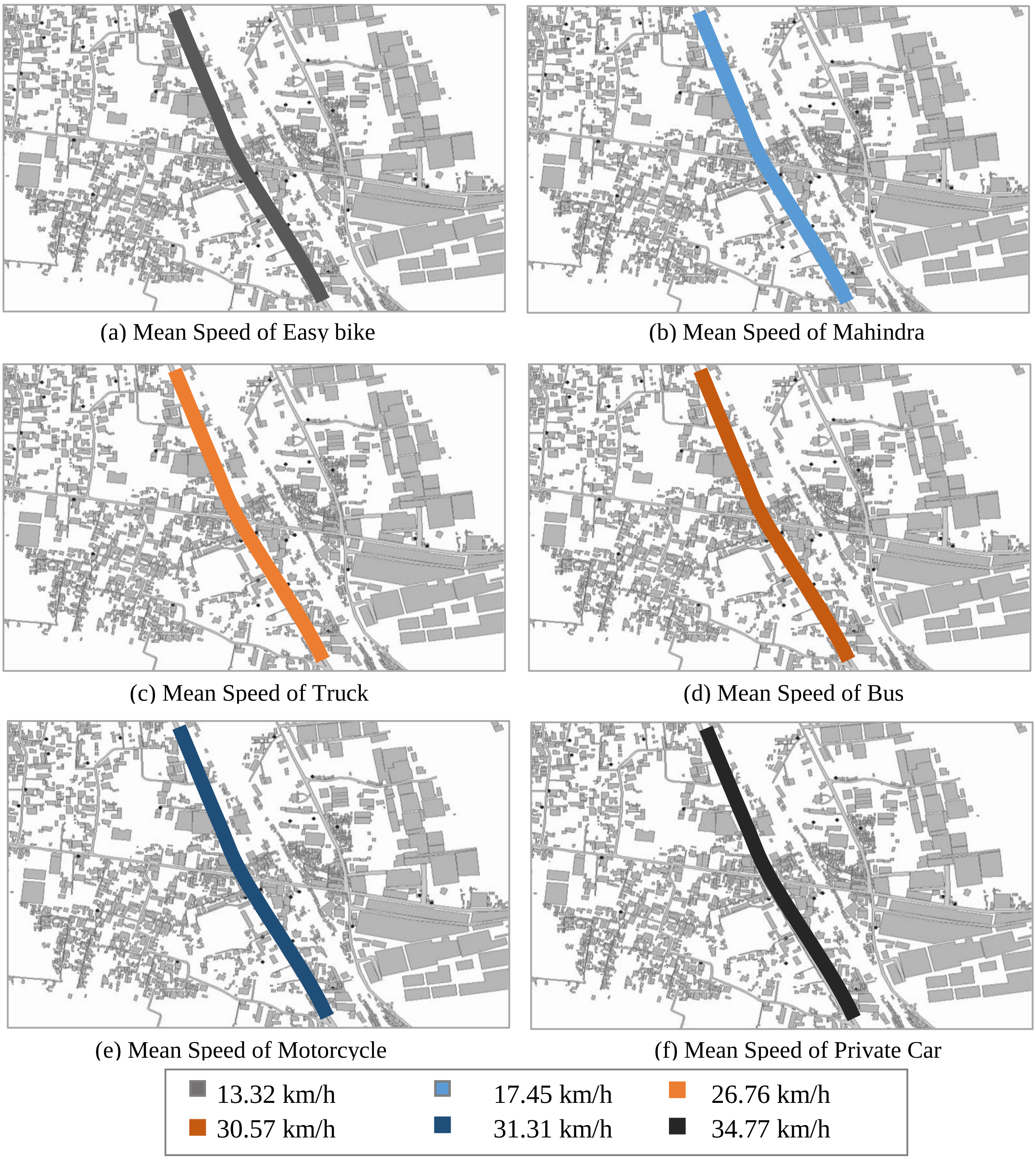
iv. The 98th percentile speed for Mohosin More Road area is 48.75 K.P.H. This speed can be considered as the design speed for this road.

Table 4 reveals that Mahindra and Easy bike have the highest coefficient of variation with a maximum speed of 29.50 K.P.H and 24.29 K.P.H. respectively. It means that they could move faster if they don't face any congestion. Mahindra and Easy bike account for a very large portion of traffic composition on the road. The minimum speed of Mahindra and Easy bike go much lower than the 15th percentile speed for this section. It means that if queuing is formed during congestion, this traffic mode makes the congestion more acute as other vehicles need to overtake opportunities while approaching to move.

The direct field survey data (Fig. 12) also approves the results of Table 4. Just like the Religate intersection, in the Mohosin More intersection, the minimum spot speed of Easy bike and Mahindra found lower than the 15th percentile with a speed of only 5 K.P.H and 4 K.P.H respectively. According to the field survey data, Easy bike and Mahindra tends to stop in these intersections to collect passenger which creates unwanted queue in this study area. This consequently adds extra traffic pressure and travel time delay as result.

Table 4 Spot speed statistics of different types of vehicles on Mohosin More intersection.

Vehicle type	Speed of Vehicles				
	Mean	Maximum	Minimum	Standard Deviation	Coefficient of variations
Easy bike	13.32	24.20	5.00	6.09	0.46
Mahindra	17.45	29.50	4.00	9.13	0.52
Motorcycle	31.31	53.25	15.50	12.81	0.41
Private Car	34.77	48.75	16.20	10.63	0.31
Bus	30.57	43.20	12.25	9.24	0.30
Truck	26.76	42.75	12.50	10.16	0.38



(a) Mean Speed of Easy bike

(b) Mean Speed of Mahindra

(c) Mean Speed of Truck

(d) Mean Speed of Bus

(e) Mean Speed of Motorcycle

(f) Mean Speed of Private Car

Fig. 12 Mean speed map for different vehicles in the Mohosin More intersection.

5. Conclusion

A comparison among travel time, running time, delay in peak, and off-peak hours on different days of a week is out in this study. From the result and analysis conclusion has been made that workdays have high travel time & delay compared to the weekends. The study shows the relation between traffic flow and delay time, as the traffic flow increases the delay time also increases. On the other hand, the reasons behind the delay time are also found out in Religate and Mohosin More intersections. Vehicles with less than or equal 10 K.P.H. are responsible for increasing the delay time and congestion significantly in these intersections, as it is the 15th percentile speed for these intersections. Easy bike and Mahindra have a minimum speed of 5 K.P.H and 4 K.P.H respectively at Mohosin More intersection and for Religate intersection the minimum spot speed of Easy and Mahindra are 4 K.P.H and 5.75 K.P.H respectively. As the minimum speed of Mahindra and Easy bike are much lower than the 15th percentile speed for these sections, they are responsible for increasing the delay time and congestion significantly on this road.

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