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A Videogrammetric Analysis of On Peak/Off Peak Traffic Density: A Case of Board Bazaar Peshawar

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Abstract: **The increasing population is a growing issue in densely populated cities, which leads to an increase in transportation services. In this paper travel time delay due to stationary bottleneck was observed throughout the week in one of the densely populated cities of Pakistan i.e. Peshawar. Videogrammetry was implemented to obtain the recorded frames through the various days of the week. The recorded frames were then statistically analyzed to identify the travel delays in Board Bazaar Peshawar at a stationary bottleneck using SPSS and Statgraphics Software. The statistical analysis revealed a direct proportionality between traffic density and travel time, whereas an inverse proportionality was identified between traffic speed and traffic density. A high traffic density was observed on working days, whereas on the non-working days a reduced traffic density was observed. This study recommends a predictive target lane vehicular guidance system for a smooth traffic flow.**

***Index Terms*-** **Statistic Analysis, Time Delay and Bottleneck, Traffic Density, Videogrammetric Analysis.**

I. NTRODUCTION

The distance covered by the vehicle in a unit of time is called speed [1]. During traffic congestion, traffic speed is slow due to the presence of larger density than the road capacity [2]. The travel time is reduced during congestion than the free flow. The difference between the expected and free flow travel time is called delay [3]. Traffic bottlenecks mostly occur due to lane reductions and are a cause of large delays and slow velocities [4]. Bottlenecks are of two types, that is, moving and stationary [5]. In a moving bottleneck, vehicle clusters are formed as no space is available to overtake slow moving vehicles [6]. In a stationary bottleneck, traffic clusters occur due to a reduction in road width [5]. Travel time delay has an economic and environmental impact on a city [7]. Fuel consumption and hazardous gases emitted from vehicles are increased due to congestion. Level of Service (LOS) classifies roads according to the quality of service been provided to the driver. Travel time delay is an important factor in network evaluation and level of service (LOS) [8, 9] . Travel time and speed data in traffic engineering are imperative for highway design and operation [10]. Best fit distributions of travel time and speed are required to predict traffic flow. The distributions are determined with the help of the Kolmogorov Smirnov (KS) test and P value [11]. The KS test evaluates the difference between two data set (observed and predicted). P value is the indication of whether the observed data follow a distribution. On a highway, speed distribution varies because of heavy trucks and small vehicle [12]. Normal and Lognormal distribution is often used for the analysis of speed and travel time [13]. Low density traffic of two lanes follows poison distribution [14]. Free flow traffic speed follows, Normal distribution [14] as mostly vehicle adopt similar speed. The best fit distribution for speed in congested traffic is Beta while in low density Lognormal seems best fit at a highway (NH-31) in Guwahati [11].
The KS statistics shows that speed data obtained from two lane follows normal distribution [15]. In uninterrupted traffic flow Normal distribution is used for the estimation of travel time [11]. Lognormal, Gamma and Weibull are considered the best fit distribution for travel time delay [16, 17, 18]. Distribution parameters changes due to infrastructure variation and data site selection [18].

In this paper, real time delay (actual time observed on site) is observed at stationary bottleneck generated due to Bus Rapid Transition (BRT) station (Board Bazar, BS 25) Peshawar, Pakistan. Distributions of speed and travel time at different week days identify value having maximum possibility of occurrence which can used in traffic modelling. Off peak travel time is observed early in the morning. Time delay is then compared with off peak travel time and the effect of larger density on speed and travel time observed.

The remainder of this paper is structured as follows. Section II represents the Methodology. The Travel Time Delay is explained in Section III and Section IV shows the Statistical data which followed by the Best Fit Distribution of speed and travel time are explained in Section V.

II. METHODOLOGY

Bus Rapid Transit (BRT) Peshawar, Pakistan generated stationary bottleneck at various position as the route is not centrally aligned. At Board office Peshawar, having coordinates (33.9955 N, 71.4700 E), a stationary bottleneck is formed due to a BRT station and the presence of old under pass. The number of road lane reduces to half which is one of the leading time delay factors. Traffic flow is observed between three consecutive poles installed on the BRT track. The distance between the entrance and exit point is 105 mas shown in Figure 1. A video camera of 30.00 FPS was installed at a pedestrian bridge of 4.5 m height. Traffic flow was observed on Monday, Tuesday, Wednesday, Thursday, Friday, Saturday, and Sunday.

FIGURE 1: The location of data collection point on google maps

The travel time delay is calculated through recorded. Speed is determined to be 105 m. A 300 opinions has been recorded which are employed to predict the best distribution. Traffic flow is observed for three hours recording on each day at different time that is 9:00 to 10:00 A.M, 12:00 to 1:00 P.M and 3:00 to 4:00 P.M. Statgraphic software is used to evaluate the optimum distributions and it shows an evaluation table and the distribution is graded rendering to the beliefs of statistic test. Kolmogorov Smirnov (KS) statistics and their P-values are employed for ranking the optimum one. There is two hypothesis, null and alternative are employed. In the null, the assumption is that the pragmatic data trail the distribution that derives best giving to KS statistics and P value, while the alternative is opposite to that. A P-value is a probability that the null hypothesis is true [19]. KS is goodness fit test of a distribution. The maximum difference between the expected cumulative distribution function (ECDF) and CDF is observed in KS [20]. The CDF is determined from the observed data by measuring the actual probability with the help of their corresponding frequencies while ECDF is representing the expected probability such that;

$$S_N\,(x) = n(i)/N \qquad (1)$$

where $n(i)$ shows the ith number of values which start from 1to N where N is the total number of count. Mathematically KS test is expressed as;

$$D = max\ |\ F_o\,(x) - S_N| \quad (2)$$

where the $F_o\,(x)$ shows the actual cumulative distribution function. The null hypothesis is passed when the KS statistic cost is lesser than the critical value [21]. These test are performed on 5 % level of significance [22] , the critical value of KS at 5% level of significance is calculated by $1.36/\sqrt{n}$ [23].

FIGURE 2: A videogrammetric analysis of traffic density

Figure 2, shows the observed recorded frame data traffic at board bazar stationary bottleneck. This road connects Peshawar university and Karkhano market which is considered main business center so we experienced high density on working days. Most people come to the urban center of Peshawar at the start of the week for education and business activities. Consequently, maximum delay due to larger density is experienced. Similarly, at the end of week such as on Thursday and Friday people complete their activities and leaving for their home stations before weekends. This results in congested traffic. However, on non-working days we observed minimum time delay.

III. TIME TRAVEL DELAY AT STATIONAR BOTTLENECK

At stationary bottleneck locations, when traffic density is small, then vehicles move with the maximum limit speeds. In off peak flow, distance headway between consecutive vehicles at bottlenecks is larger than the congested flow. In this research, off peak flow was observed and the average travel time in off-peak flow is 11.41 s so the speed of vehicle to cover the 105 m section is 9.20 m/s shown in Fig. 3.

FIGURE 3: Off peak flow

Large delays were observed on working days (Monday to Friday) such that 52.90, 52.53, 42.31, 54.35, and 54.15 s respectively. Traffic density on Saturday and Sunday is less so the observed travel time noticed was minimum i-e 32.25 and 30.13 s respectively shown in Fig. 4. The maximum difference noticed between working days and off peak traffic travel is 43.15 s which shows the delay generated due to stationary bottleneck. Reduction of road width increases the demand on the existing road as result congestion generated which is the leading factor of travel time delay.

Traffic density is calculated by counting the number of vehicles present in the 105 m section from the recorded data. The average densities noticed on Monday, Tuesday, Wednesday, Thursday and Friday were 18, 17, 15, 18, and 19 veh/m, respectively. On Saturday and Sunday, the average densities decreased to 10, and 11 veh/m, respectively as shown in the Fig. 5.

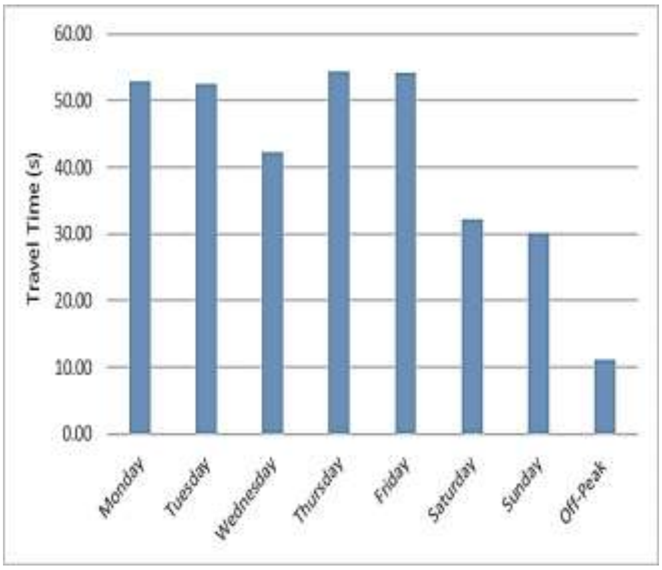

FIGURE 4: Average travel time

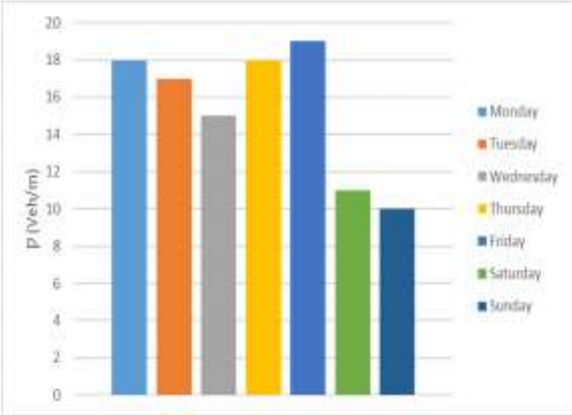

FIGURE 5: Average traffic density

IV. STAISTICAL DATA OF SPEED AND REAL TIME AT STATIONARY BOTTLENECK

The descriptive statistics of speed and travel time at a stationary bottleneck on working days (Monday to Friday) and on non-working days (Saturday and Sunday) are given in Table I and Table II respectively. Mean value represents the average which is obtained by dividing the summation of all observed data on the total number of observation i-e 300. The median shows the middle value of data organized in ascending order. Mode represents value having a high frequency. The standard deviation shows the spread of data across the mean. A large standard deviation shows that the observed data is dispersed over a wider range of values. Conversely, a small deviation shows that observed data is closely clustered around the mean.

TABLE I: Descriptive Statistics of Speed (m/s)

Speed (m/s)	**Sample Size**	**Mean**	**Median**	**Mode**	**Std. deviation**
Monday	300	2	1.981	1.91	0.188
Tuesday	300	2.02	1.981	1.94	0.185
Wednesday	300	2.53	2.5	2.5	0.34
Thursday	300	1.95	1.944	1.88	0.164
Friday	300	1.96	1.944	1.91	0.175
Saturday	300	3.36	3.281	3.28	0.617
Sunday	300	3.64	3.5	3.39	0.766

Table I shows traffic densities on working days (Monday, Tuesday, Wednesday, Thursday, and Friday) are large which generate greater disturbance at the stationary bottleneck. Speed value decrease due to congestion generated in high density traffic. The average speeds on Monday, Tuesday, Wednesday, Thursday and Friday are 2.002, 2.015, 2.525, 1.945, and 1.955 m/s, respectively. However, on Saturday and Sunday the average speed noticed are 3.358 and 3.638 m/s respectively. The maximum standard deviation which shows spread across the mean is observed on Wednesday i-e 0.340 while on Friday it is minimum i-e 0.175. The mode represents the value that is mostly repeated in data analysis and this value seems closer to the average value of speed.

Table II: Desecriptive Statistics of Travel Time (s)

Travel Time(s)	Sample Size	Mean	Median	Mode	Std. deviation
Monday	300	52.9	53	55	4.854
Tuesday	300	52.53	53	54	4.725
Wednesday	300	42.31	42	42	5.482
Thursday	300	54.35	54	56	4.505
Friday	300	54.15	54	55	4.885
Saturday	300	32.25	32	32	5.463
Sunday	300	30.13	30	31	6.162

Table II shows that the average time required to cover 105m distance on working days (Monday, Tuesday, Wednesday, Thursday, and Friday) are 52.897, 52.530, 42.307, 54.353, and 54.147s, respectively. However, on Saturday and Sunday, traffic density is low which result in small travel time as compared to high density i-e 32.253 and 30.130 respectively. Data is symmetric when change between mean (average value) and median is small. The standard deviation is maximized for travel time on Wednesday and Saturday is 5 units. However, on Thursday the spread across the mean is minimum that is 4.505. The mode of real time noticed on Monday to Sunday is 53, 53, 42, 54, 54, 32, and 30s.

V. BEST FIT DISTRIBUTION FOR SPEED AND TRAVEL TIME

The superlative appropriate distributions pragmatic for speed and real time are (Largest Extreme Value, Log-logistic, Normal, and Inverse Gaussian) and (Weibull, Gamma, Normal and Lognormal) respectively. The distributions are ranked on the basis of KS statistics and P-value. The serious cost of KS is determined by $1.36/\sqrt{n}$ [23], where n is 300 to get the serious cost to be 0.0785 . The $1.36/\sqrt{n}$ is effective when we executed KS test at 5% level of importance. The KS statistics which gives the supreme change between the ECDF and CDF for less than 0.0785. The p value should be greater than 0.05 under such condition, then the null hypothesis is accepted and concluded that the data observed follow best-fit distribution [22].

A. Distribution of Speed

Table III describes the probability density function (pdf) and KS statistics for speed. According to KS test, Largest Extreme Value, Log-logistic, Lognormal, and Normal are finest fit for speed data detected on Monday to Friday having high density traffic. P-value and KS statistics of best fit distribution observed from Monday to Friday are 0.211, 0.085, 0.199, 0.075 and 0.133, and 0.061, 0.072, 0.062, 0.074 and 0.067, respectively. The P-value is greater than 0.05 to reject the null hypothesis [12] which shows that the practical data tracked these distributions.

TABLE III: Best-fit distribution for speed as per KS test statistics and P-value

Speed (m/s)	Distribution	KS value	Critical KS Value	P-value
Monday	Largest Extreme Value	0.061	0.0785	0.211
	Log-logistic	0.091		0.013
	Lognormal	0.098		0.005
	Inverse Gaussian	0.099		0.0058
	Birnbaum-Saunders	0.099		0.0058
Tuesday	Largest Extreme Value	0.072	0.0785	0.085
	Lognormal	0.092		0.012
	Log-logistic	0.092		0.012
	Inverse Gaussian	0.092		0.012
	Birnbaum-Saunders	0.092		0.012
Wednesday	Log-logistic	0.062	0.0785	0.199
	Lognormal	0.067		0.138
	Inverse Gaussian	0.067		0.135
	Birnbaum-Saunders	0.067		0.134
	Logistic	0.069		0.119
Thursday	Lognormal	0.074	0.0785	0.075
	Inverse Gaussian	0.074		0.073
	Birnbaum-Saunders	0.074		0.073
	Largest Extreme Value	0.074		0.072
	Log-logistic	0.075		0.07
Friday	Normal	0.067	0.0785	0.133
	Gamma	0.07		0.103
	Lognormal	0.073		0.083
	Birnbaum-Saunders	0.073		0.081
	Inverse Gaussian	0.073		0.081
Saturday	Largest Extreme Value	0.067	0.0785	0.131
	Log-logistic	0.073		0.084
	Logistic	0.092		0.012
	Laplace	0.093		0.011
	Lognormal	0.094		0.009
Sunday	Inverse Gaussian	0.065	0.0785	0.152
	Lognormal	0.066		0.151
	Birnbaum-Saunders	0.066		0.151
	Gamma	0.071		0.101
	Largest Extreme Value	0.071		0.093

The KS statistics from Monday to Friday are less than critical value that is 0.0785. Largest Extreme Value and Inverse

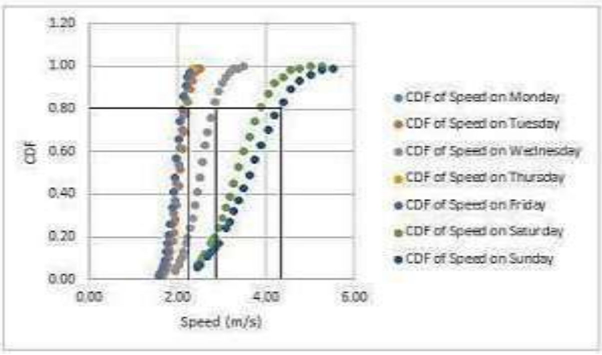

FIGURE 6: CDF for speed

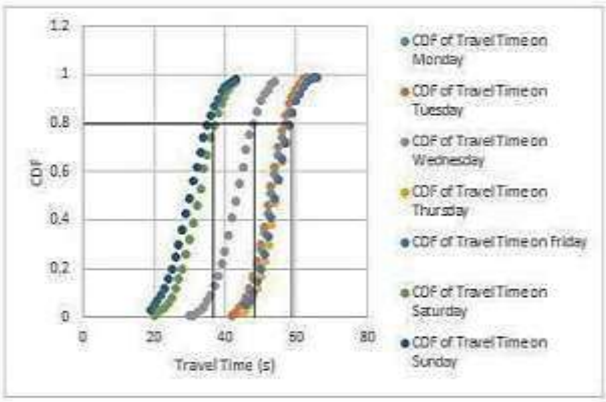

FIGURE 7: CDF for travel time

Gaussian is considered the best fit for speed observed on Saturday and Sunday, respectively. The P-value and corresponding to these days are 0.131 and 0.152, respectively. The KS statistics on, Saturday and Sunday having low density traffic are 0.067 and 0.065, respectively so according to KS and P value there is no reason to reject null hypothesis.

The histogram of speed on working days (Monday to Friday) shows that the highest frequency values i-e 1.909, 1.944, 2.500, 1.875and 1.909m/s respectively. However, on Saturday and Sunday, the highest frequency value noticed is 3.281 and 3.87 m/s respectively shown in Fig. 8.

B. Distribution of Travel Time

Table IV describes probability distribution function (pdf) and KS statistics of real time observed on site. The time delay was maximized at high density traffic which was observed from Monday to Friday. Weibull, Gamma, Normal, and Lognormal are considered best fit distribution for real time delay according to KS statistics and P-value. The best fit distribution for real time delay observed on Tuesday, Thursday, and Saturday is Normal having KS statistic and P-value of 0.069, 0.073 and 0.064, and 0.166, 0.084 and 0.168, respectively. Lognormal is considered best-fit for Friday and Sunday and having a P-value of 0.111and 0.143, respectively. Weibull and Gamma is the best fit distribution for travel time delay data observed on Monday and Wednesday with P-value of 0.112 and 0.256, respectively. P-value is greater than level of significance which means null hypothesis (observed data follow best-fit distribution) is true. According to P-value and KS statistics we cannot reject the null hypothesis. The histogram of travel time on working days (Monday to Friday) shows that the highest frequency value, i.e., 55, 54, 42, 54 and 54 respectively as shown in Fig. 9.

TABLE IV: Best-fit distribution of travel time as per KS test statistics and P-value

Travel Time (s)	**Distribution**	**KS value**	**Critical KS Value**	**P-value**
Monday	Weibull	0.069	0.0785	0.112
	Smallest Extreme Value	0.078		0.053
	Normal	0.084		0.028
	Logistic	0.087		0.021
	Log-logistic	0.092		0.012
Tuesday	Normal	0.069	0.0785	0.116
	Weibull	0.073		0.083
	Logistic	0.077		0.058
	Gamma	0.079		0.048
	Log-logistic	0.082		0.033
Wednesday	Gamma	0.059	0.0785	0.256
	Normal	0.06		0.228
	Log-logistic	0.064		0.171
	Lognormal	0.067		0.132
	Birnbaum-Saunders	0.068		0.129
Thursday	Normal	0.073	0.0785	0.084
	Logistic	0.078		0.053
	Gamma	0.081		0.038
	Weibull	0.083		0.031
	Log-logistic	0.084		0.03
Friday	Lognormal	0.069	0.0785	0.111
	Inverse Gaussian	0.07		0.108
	Birnbaum-Saunders	0.07		0.108
	Gamma	0.072		0.085
	Log-logistic	0.073		0.078
Saturday	Normal	0.064	0.0785	0.168
	Log-logistic	0.071		0.093
	Weibull	0.076		0.061
	Logistic	0.077		0.056
	Gamma	0.082		0.037
Sunday	Lognormal	0.066	0.0785	0.143
	Birnbaum-Saunders	0.066		0.142
	Inverse Gaussian	0.067		0.14
	Gamma	0.068		0.121
	Logistic	0.073		0.083

A. Cumulative distribution of speed and travel time

Cumulative distribution function (CDF) of speed and travel time shows the proportion probability for range of data. CDF of speed and travel time observed on (Monday, Tuesday, Wednesday, Thursday, Friday, Saturday and Sunday) are shown in Fig. 6 and Fig. 7. The CDF of speed shows the 80th percentile of speed observed in high density and low density traffic. Figure 6 show that 80% of vehicles on (Monday to Friday) are having speed value of (2.19, 2.23, 2.84, 2.10 and 2.10 m/s) respectively. However, in low density traffic the 80% of vehicles on (Saturday and Sunday) are having speed value of (3.89 and 4.38 m/s) respectively. The CDF of travel time shows the 80th percentile of travel time observed in high and low density traffic. Figure 7 shows that 80% of vehicles on (Monday to Friday) are having speed value of (57, 57, 48, 58 and 58 s) respectively. However, in low density traffic the 80% of vehicles on (Saturday and Sunday) are having travel time value of (37 and 35 s) respectively. Thus the above results show that in low density traffic speed increased while travel time decreased. Similarly, in high traffic the speed value gets reduced while the travel time increased.

VI. CONCLUSION

Speed and travel time delay observed at the stationary bottleneck is greatly influenced by traffic density. Week days having high density traffic show that maximum time is required to cover 105m distance. However, on Saturday and Sunday shows less delay because of the low density traffic. The maximum delay was observed on Monday that is 66 s while the minimum time taken by vehicle in covering 105 m distance in off-peak flow free flow was 9 s so the 57.6 s difference represents the travel time delay noticed in 105 m distance. Generally, Largest Extreme Value and Normal is considered the best fit for speed and travel time. The minimum average speed was observed on Thursday while maximum speed was noticed on Sunday that is 1.954 and 3.638 m/s, respectively. Similarly, minimum average travel time was observed on Sunday while maximum was noticed on Thursday that is 30.130, and 54.463 s, respectively Result of this research can be used for traffic flow prediction models [24, 25, 26, 27, 28, 29, 30, 31, 32].

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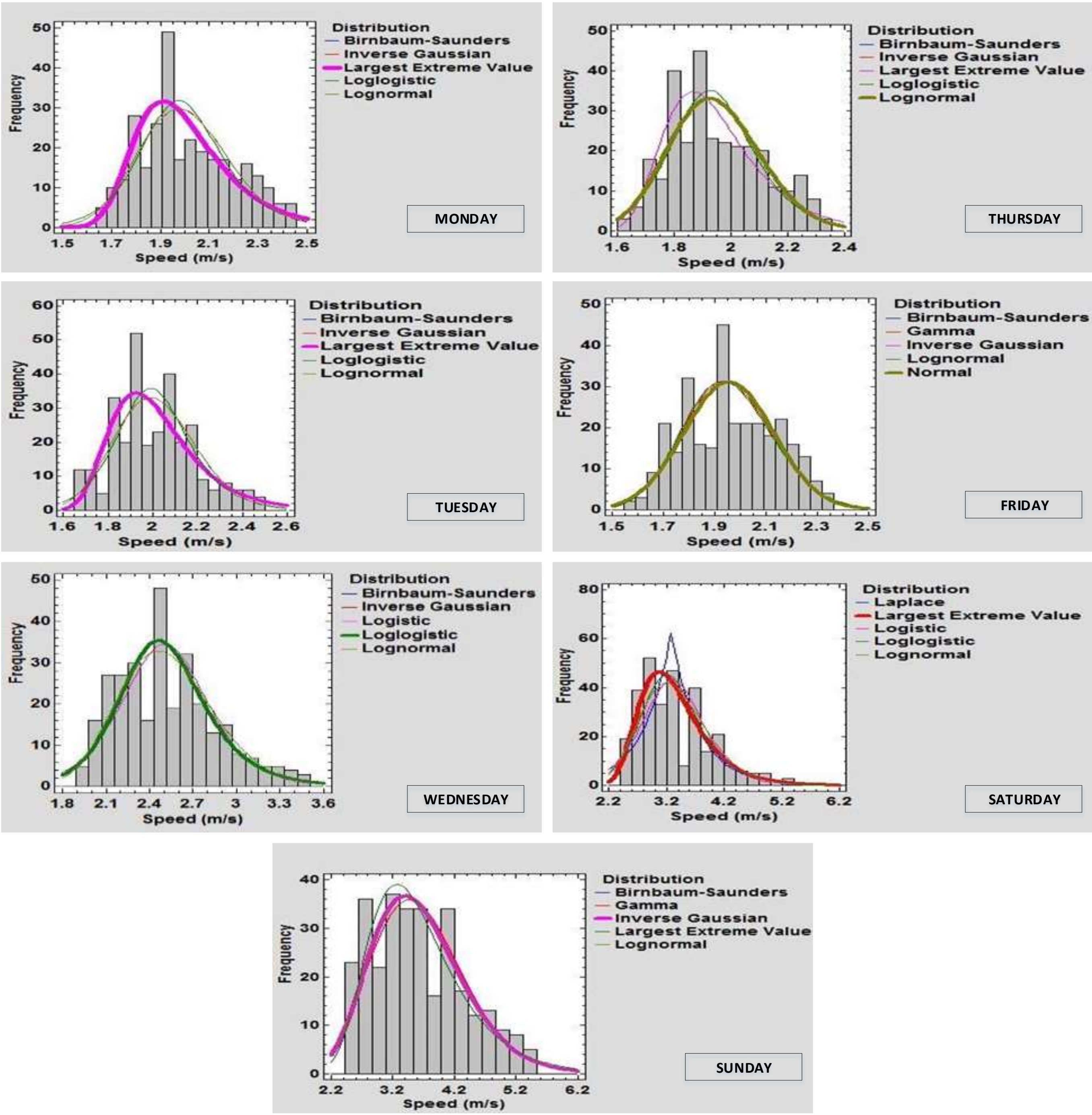

FIGURE 8: Distribution of speed (m/s)

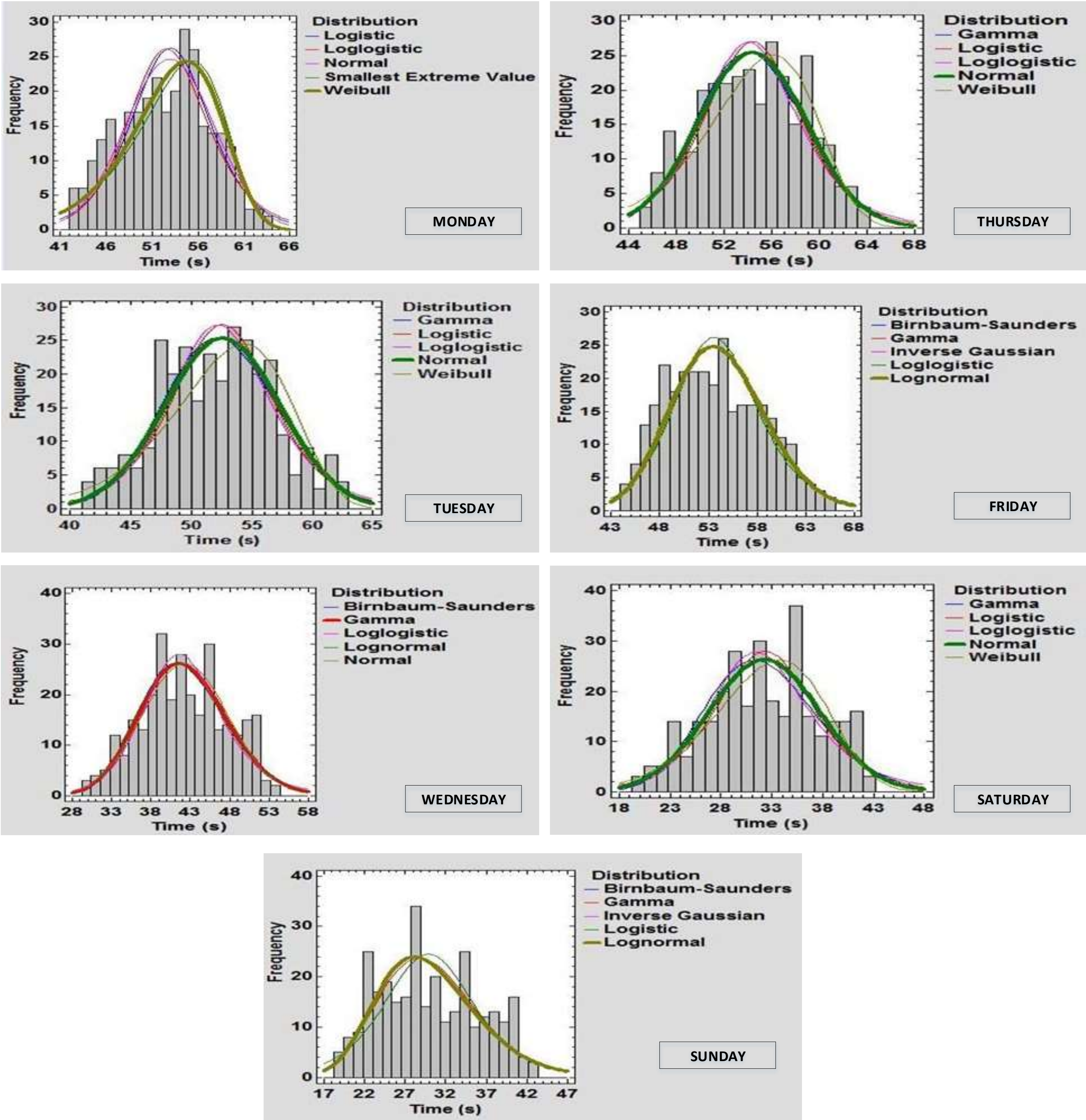

FIGURE 9: Distribution of travel time (s)