




Modeling Critical Gap of Al Turkmani Roundabout in Baghdad City

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HIGHLIGHTS

- A good fit is gained for the West and East approaches at peak periods of (1:00-2:00) pm.
- For both West and East approach, the validation showed a strong linear relationship between the observed field data and the theoretical data.
- The critical gap's value for the West and East approach is less than the range of (NCHRP 572).

ABSTRACT

Interest in how roundabouts can most effectively be used continues to increase to achieve goals of safety, efficiency, along with other benefits. This research presents the most important element of the operational performance of roundabout traffic intersections in Baghdad city on capacity analysis. The obtained results for critical headway time are (3.35 sec) and (2.8 sec) for the Main west and East approaches. Also, the critical gap value for the West and East approach is less than the range of (NCHRP 572), possibly attributed to the congested traffic volume in Al Turkman roundabout with aggressive driver behavior. Calculating in the west and East approaches peak period (1:00-2:00) pm to describe the rejected and accepted gaps with ranges from (1.00 – 5.00) sec, the main aim of this research is to model the critical headway by analyzing the data in trial and error technique to determine the shape of the data through Probability density function and Cumulative Density Function, and the Mathematical function that represented, exponential distribution functions for critical gaps with different shape functions scale (1,1.5) for accepted and rejected gaps are better fittings to the empirical distribution, and there is no significant difference. Comparing the observed field data and the theoretical data for the validation process of Rejected and Accepted Gaps are done. A good fit is obtained, and a scatterplot for observed and theoretical data has been drawn for the West and East approaches at peak period (1:00-2:00) pm.

ARTICLE INFO

Handling editor: Wasan I. Khalil

Keywords:

Roundabout
Critical Time Headway
Probability Density Function
Accepted gaps
Statistical Distribution.

1. Introduction

The minimum headway that an entry driver will find acceptable is called Critical headway, as written in the (NCHRP 572) report. The assessment of the Critical headway should be through gaps and should be observed in the field shown in Figure 1, where the observation of the critical headway is impossible. According to the NCHRP 572 report, for a multi-line roundabout, the calculation of the critical headway can be done using two methods.

The first method is by the observation of each lane independently: the gaps in the external lane used by the right lane, supposing that the entering vehicles (in the right lane) yield only to conflicting vehicles in the outer lane, and the combined gaps of the inner and conflicting outer lanes used by the left lane.

The second method (NCHRP 572) calculates the critical headway for the entire approach, combining the entering lanes and conflicting lanes into single entering and conflicting streams, respectively. The second method was used in this study, and on the same lines as single-track rotor technology, the critical gap was determined. There are three techniques for estimating critical headway, the Maximum likelihood method, the Median method Ferrari, and Giannini [2] and Raff's method. Based on Raff's definition Raff and Hart [3] a graphical method or Raff's method was used to estimate critical headway. The concept of critical headway was used by Raff, who defined it as the gap that has the number of accepted shorter gaps equal to the number of longer rejected gaps. Two cumulative distribution curves are drawn using this method: one relates gap lengths t with the number of accepted gaps less than t , and the other relates t with the number of rejected gaps greater than t .

The intersection of these two curves gives the value of t for the critical headway Garber [4]. For each observed approach, the two cumulative distribution curves are constructed. At the intersection point, each curve is a linear segment. Therefore, the curve is comprised of discrete points. Next, the equations of the segments that intersect are determined, and the system of the

equations is solved. Therefore, the value of critical headway represented by the intersection point may be determined, as shown in Figure 2.

One of the studies related to the headway time distribution modeling was the study by Al-Ghamdi [6,7]. The study explored time headway in flow rates (low, medium, high). It was found that Gamma distribution and Erlang distribution are followed by time headway at arterial streets, specifically on high flow rates. It was seen by Abtahi et al. [8] that the Gamma and lognormal distribution could fit better with the shifting parameter of (0.24 sec. and 0.69 sec). For the passing lanes and the middle lanes correspondingly because he detected that the time headway distribution for middle lanes and passing lanes in urban highways are different, especially for heavy traffic conditions. The Erlang distribution and Pearson type III distribution fit the headway distribution frequency, as Edigbe et al. [9] stated. He also said that minimal headways are induced by the overtaking.

Describing the time headway can probably be done using the Logistic probability distribution function. It can be used at the jammed arterial street of Palestine at links one and two for scales parameter ranging from 1.5 to 0.85 for link one at periods from 6:00 to 6:30 pm and from 6:30 to 7:00 pm and scale parameter 1.1 for link two at a similar period for the first link as reported by Alkaissi [10]. The traffic congestion in the roundabouts has become a big problem, especially during the peak hours in the morning

and evening, due to the obvious growth in the composition of vehicles and the lack of adherence to regulations and traffic laws. It will be difficult to get regular traffic flows, so traffic police need to intervene to regulate traffic and turn the roundabout into a signalized intersection. Other elements affecting the roundabout capacity include ineffective engineering design, consequences of bad development, and lack of proper attention by the government to plan appropriate transport to solve congestion problems. Therefore, traffic roundabout capacity is assessed for traffic movement to give a clear idea to the competent authorities of design and planning.

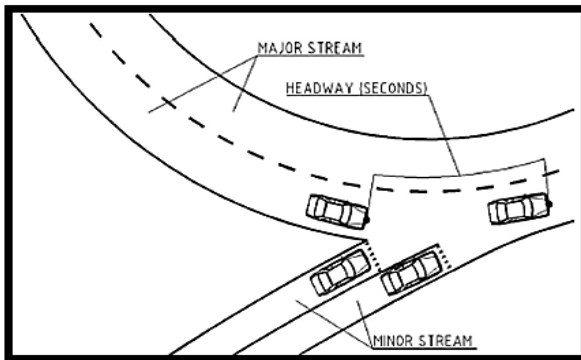


Figure 1: Definition of Critical Headway (Irvana, 2010)

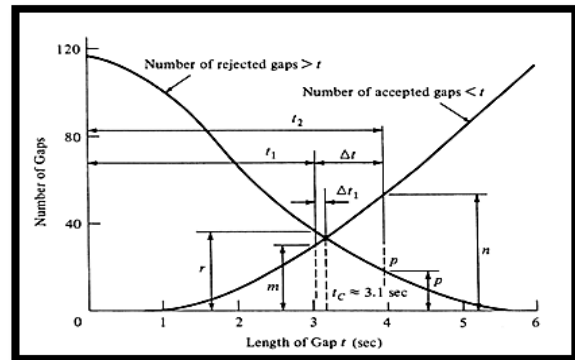


Figure 2: Cumulative Distribution Curves for Accepted and Rejected Gaps Garber, N.J. (1996)

2. Methodology and Data Collection

2.1 Selection of Roundabout Intersection

2.1.1 Al Turkmani Roundabout

Al Turkamani roundabout is one of the most significant roundabouts in Baghdad due to its imperative position connected to Palestine arterial street. It is a significant link between the areas of east Baghdad, the densely populated through the Palestinian street in the Bab Al-Moatham central station, which includes important government centers and educational institutes (Al-Mustansiriya University), and many commercial markets. This intersection has four entrances and exits, and the traffic density is high throughout official working hours. Plate 1 shows Al-Turkmani roundabout.



Plate1: Al Turkmani Roundabout

2.2 Geometric Design Characteristics

The components of Geometric Design Involve, e.g., (no. of lanes/approach, lane designation, a width of the lane, the radius of entry, a diameter of the island, and width of circulating). Figure 3 presents an illustration of Elements Al-Turkmani Roundabout drawn with AutoCAD software.

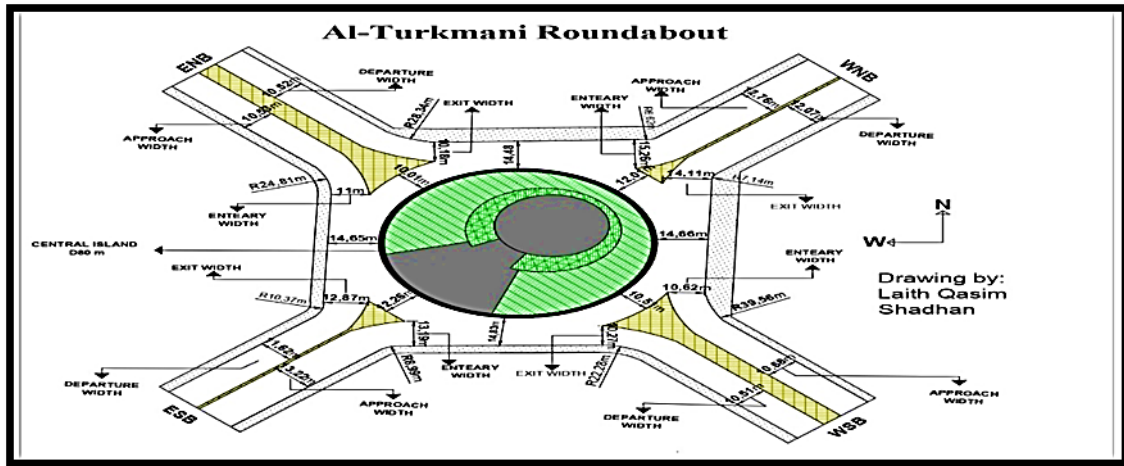


Figure 3: Geometric Elements for Al-Turkmani Roundabout

2.3 Method of Data Collection

Data collection is one of the important steps to obtain the data required to simulate traffic flow in the study area. Several factors are considered. In the 24-hour video recordings using fixed cameras, traffic data were initially calculated for two periods of two hours per period for the first week. After reaching the peak hour, the hours of calculation were reduced to one hour per period. For example, the first period is from 7:30 a.m. to 8:30 a.m., while the second period is from 1:00 pm to 2:00 pm.

Traffic data at the intersection was recorded using AHD video cameras installed on the front of buildings opposite the intersection, recording data on 12 mm videotapes and storing files within the hard drives in the camera's recording unit. The benefit of data collection in this way is the possibility of accessing and retrieving the data at any period, acting as a record to re-evaluate the results and reducing errors that the humans make as a result of collecting data manually.

The data collection equipment consists of:

- 1) Two video recording cameras (Aswar12-mm).
- 2) Hard Data storage unit (4*500 GB).

The cameras chose the best points to obtain the best clarity for the recordings and the intersection coverage to be fully connected to all the entrances and exits. A building was chosen overlooking the intersection. Two cameras were placed in parallel see Figure 4, the safety circumstances in the city of Baghdad and the refusal of the landlords of buildings to use their buildings for installing cameras. Therefore found official permission to install cameras from Baghdad Operations Command to avoid Security problems. Image antennas showing camera locations are displayed at the roundabout during data collection.



Figure 4: Location of cameras for Al Turkmani Roundabout

2.4 Critical Time Headway

The evaluation of multi-lane roundabouts need also tested how each vehicle accepts and rejects gaps at the roundabout entry. There are two different methods to estimate the critical gap (critical headway) based on (NCHRP 572). the critical gap for the whole approach can be evaluated by The technique agreed on in this research by joining the entering lane and conflicting lane into a single entering flow and conflicting flow stream, respectively, as shown in Plate 2.

The critical gap headway is predicted by using the graphical method for the West and East Approaches because they are major approaches. The west approach (Al-Jihad Street) connects Baghdad's main center (Bab Al-Muadham) with Palestine Street, where traffic volumes are high during evening Peak Period as for the east approach. Moreover, it is an extension of Al-Jihad Street, where traffic volumes are high during the morning Peak period.



Plate2: Critical Headway Estimation Technique (East Approach)

3. Estimation of Critical Time Headway

The results of gap headway time are estimated from the field-collected data for Al-Turkman roundabout. (858) a sample size of gaps is determined from the video recordings as presented in Table 1 and Table 2, (728) for West Approach and (130) for East Approach, respectively, the focus on the west Approach is due to the high traffic volumes that are causing congestion. The critical headway time was (3.35 sec.) and (2.8 sec.) for the west and East approaches, respectively, determined using the graphical method as shown in Figure 5 and Figure 6 for the West and East Approaches. The value of the critical gap for the West and East approach is less than the range of (NCHRP 572), possibly because Al Turkman roundabout in Baghdad city is congested with aggressive driver behavior.

Table 1: Estimated Results for Gap Headway of AL Turkmani Roundabout (West Approach)

<i>Gaps</i>	West Approach		Critical Headway (sec)
	<i>Mean (sec)</i>	<i>N</i>	
Accepted Gaps	3.4	364	3.35
Rejected Gaps	1.8	364	

Table 2: Estimated Results for Gap Headway of AL Turkmani Roundabout (East Approach)

<i>Gaps</i>	East Approach		Critical Headway (sec)
	<i>Mean (sec)</i>	<i>N</i>	
Accepted Gaps	3.13	60	2.8
Rejected Gaps	1.92	70	

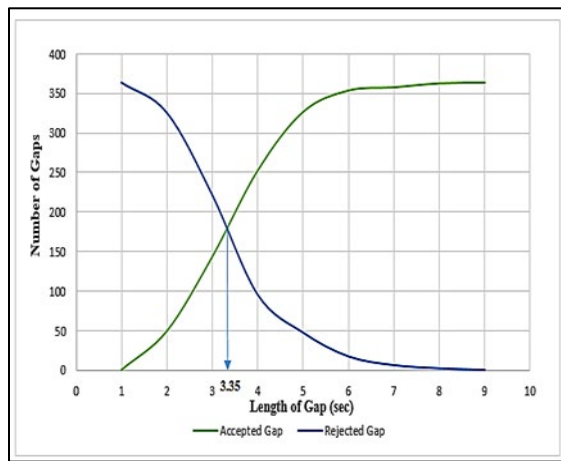


Figure 5: Accepted and Rejected Gaps in Cumulative Distribution Curves (West Approach)

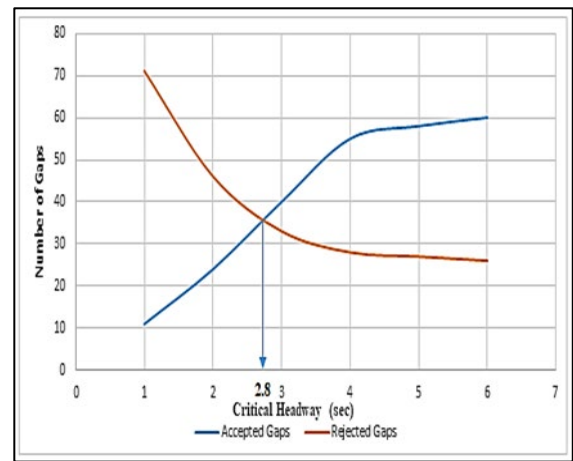


Figure 6: Accepted and Rejected Gaps in Cumulative Distribution Curves (East Approach)

4. Statistical Analysis

4.1 Probability Density Functions

4.1.1 West Approach

Assessing The Probability density function (PDF) for the West approach peak period from 1:00 pm to 2:00 pm. And the (PDF)'s shape can be shown in Figure 7 below.

The best fit for Rejected and Accepted Gaps distribution with the (PDF) of Exponential with the scale of 1,1.5 distributions that can demonstrate the important level of (p-value) bigger than (0.05) value are shown in Table 3. That means the estimated exponential distribution functions for critical gaps with different shape functions (1,1.5) for accepted and rejected gaps are better fittings to the empirical distribution, and there is no significant difference.

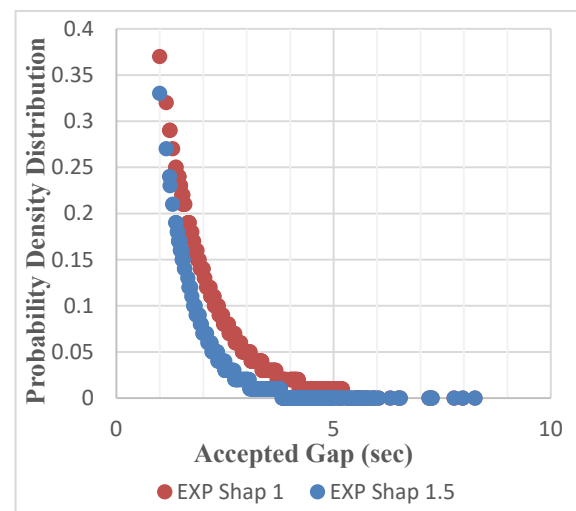
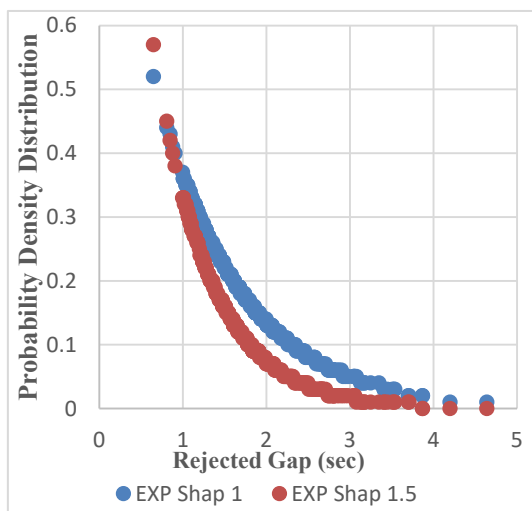


Figure 7: Probability Density Function of Rejected and Accepted Gaps Distribution for West Approach at a different scale Parameter

Table 3: Test results of the Appraised Scale Parameter for exponential density function (EDF) Distribution for peak period (West approach)

	Kolmogorov-Smirnov ^a			Shapiro-Wilk		
	Statistic	df	Sig	Statistic	df	Sig
PDF.Accepted. Scale 1	.208	363	.000	.792	363	.000
PDF.Rejected. Scale 1	.069	363	.000	.976	363	.000
PDF.Accepted.Scale 1.5	.268	363	.000	.647	363	.000
PDF.Rejected.Scale 1.5	.119	363	.000	.923	363	.000

Extra filed data were recorded (181,179) for Rejected Gaps and Accepted Gaps Respectively to validate the (CDF) of Rejected and Accepted Gaps. It can be seen in Figures 8 and 9, respectively, the contrast between the observed field data and the theoretical data of Rejected and Accepted Gaps. A good fit is obtained for the West approach peak period (1:00-2:00) pm, as shown in Figures 10 and 11.

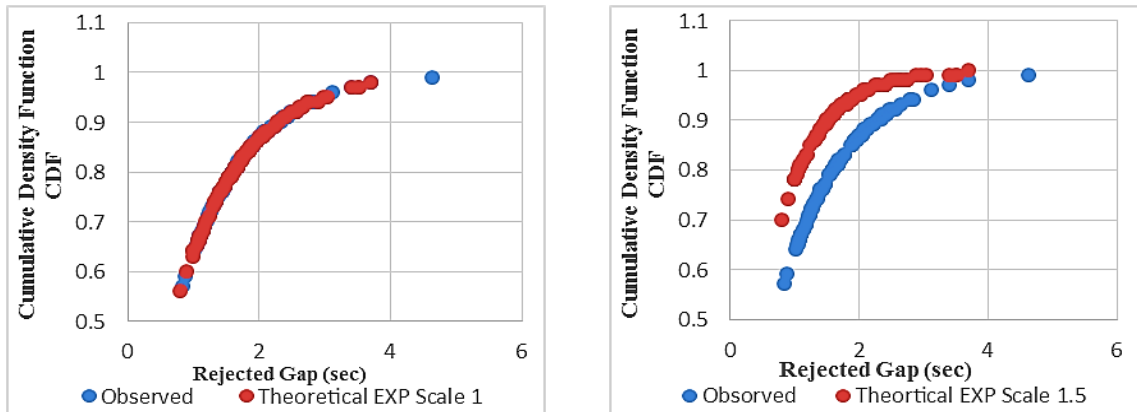


Figure 8: Cumulative Density Function to The Observed and Theoretical Rejected Gap Data for West Approach

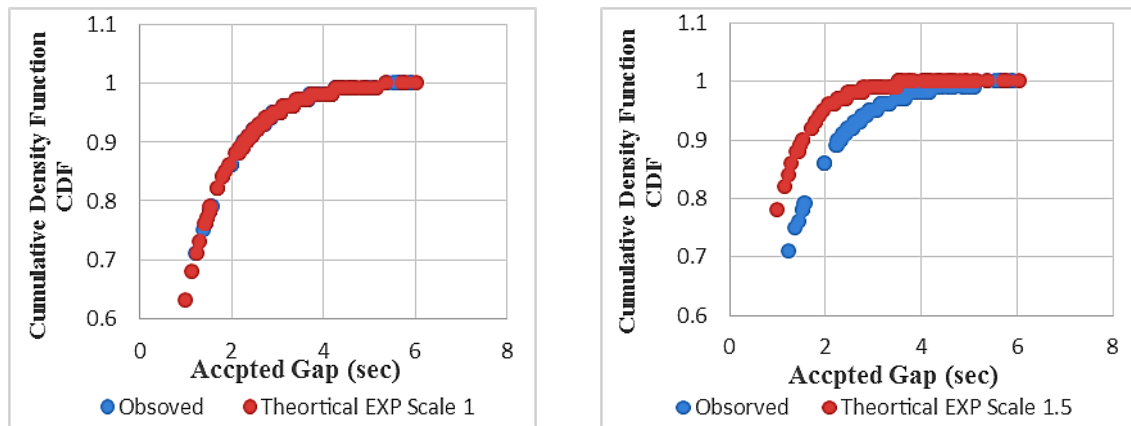


Figure 9: Cumulative Density Function to The Observed and Theoretical Accepted Gap Data for West Approach

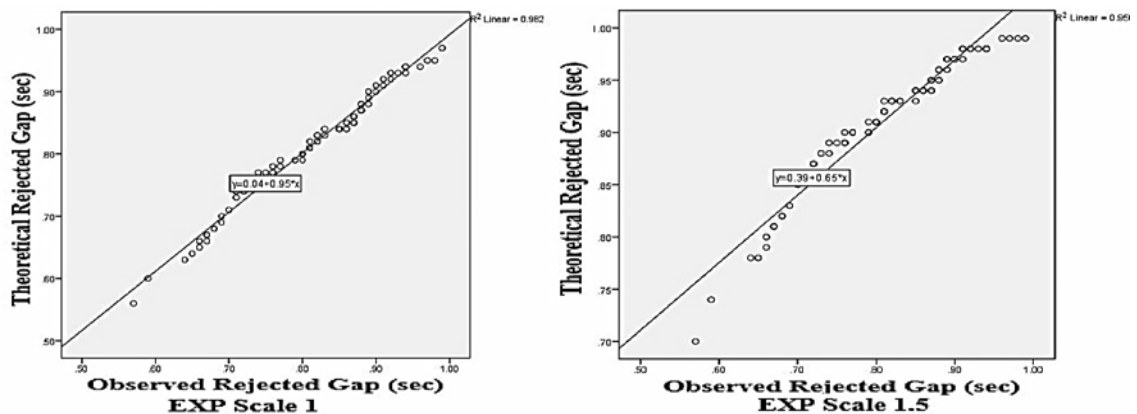


Figure 10: Theoretical Versus Observed Rejected Gaps for the West Approach

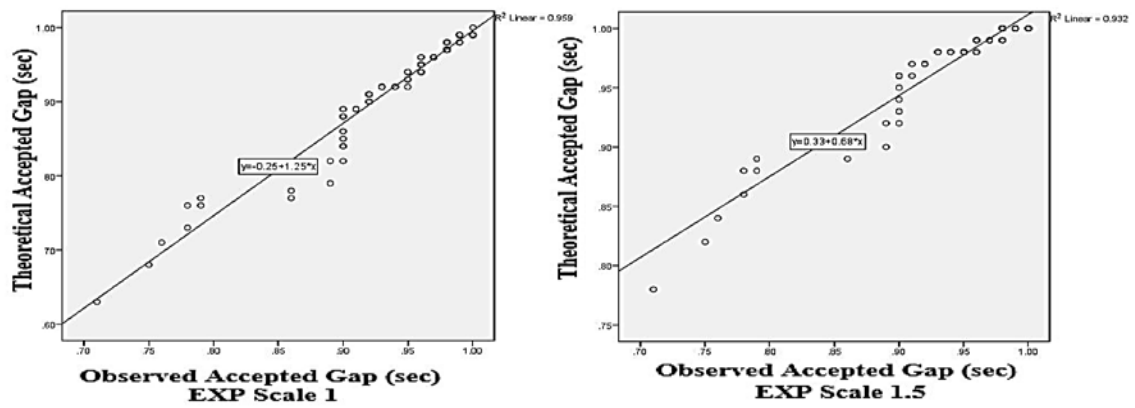


Figure 11: Theoretical Versus Observed Accepted Gaps for the West Approach

4.1.2 East Approach

The (PDF) can be estimated for the East approach (peak period). Shown in Figure 12 is the Shape for the (PDF) distribution. Presented in Table 4, the data for the best fit for Rejected gap distribution and Accepted Gaps distribution with the (PDF) of Exponential with a distribution scale of (1,1.5) that shows the important level of (p-value) that is greater than (0.05 value). Extra filed data for Rejected, and Accepted Gaps of (30,30) correspondingly were collected to validate Rejected and Accepted Gaps' Exponential probability distribution function (CDF). The observed field data and the theoretical Rejected and Accepted Gaps comparison are shown in Figures 13 and 14, respectively. A good fit is obtained for the West approach (peak period), as shown in Figure 15 and Figure 16.

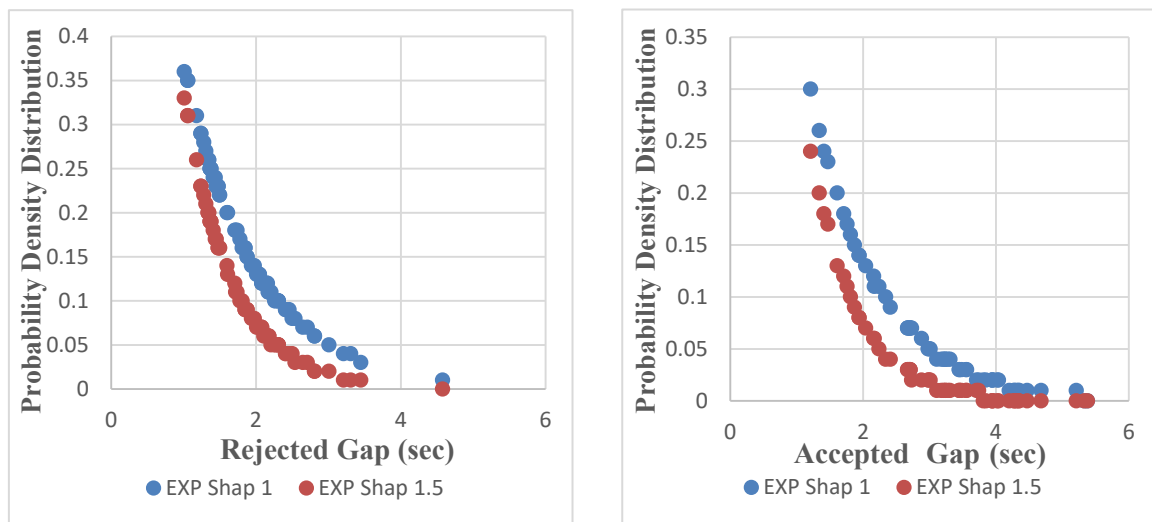


Figure 12: Probability Density Function of Rejected and Accepted Gap Distribution for East Approach at different scale Parameter

Table 4: Test Data of the Assessed Scale Parameter for (EDF) Distribution for East approach (peak period)

	Kolmogorov-Smirnov ^a			Shapiro-Wilk		
	Statistic	df	Sig	Statistic	df	Sig
PDF.Accepted.Scale 1	.146	60	.000	.923	60	.000
PDF.Rejected.Scale 1	.167	60	.000	.899	60	.000
PDF.Accepted.Scale 1.5	.219	60	.000	.818	60	.000
PDF.Rejected.Scale 1.5	.270	60	.000	.706	60	.000

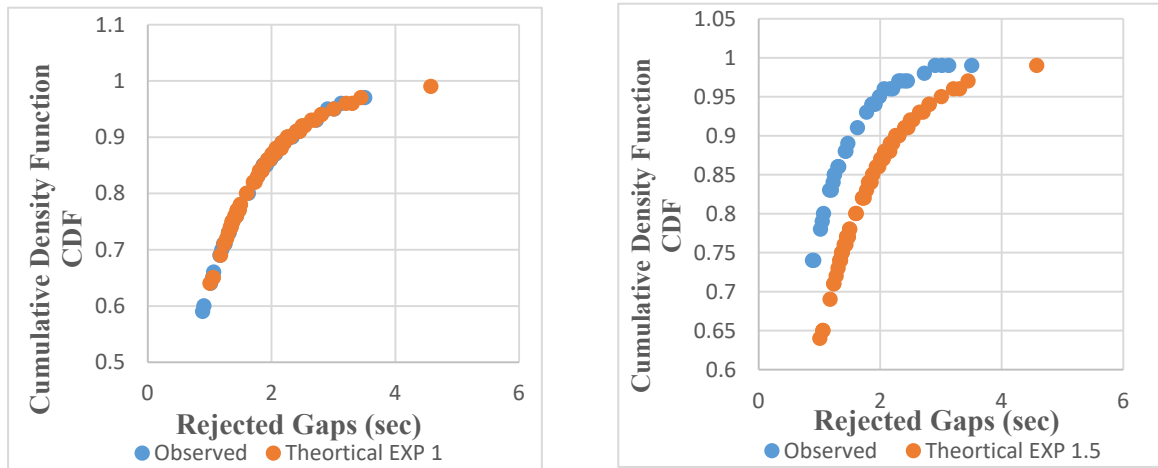


Figure 13: Cumulative Density Function to The Observed and Theoretical Rejected Gap Data for East Approach

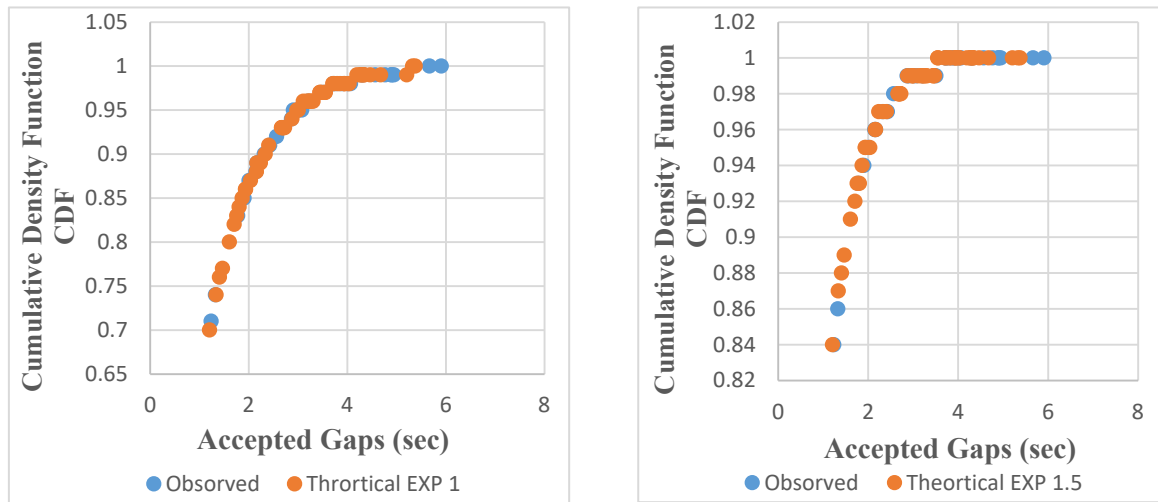


Figure 14: Cumulative Density Function to The Observed and Theoretical Accepted Gap Data for East Approach

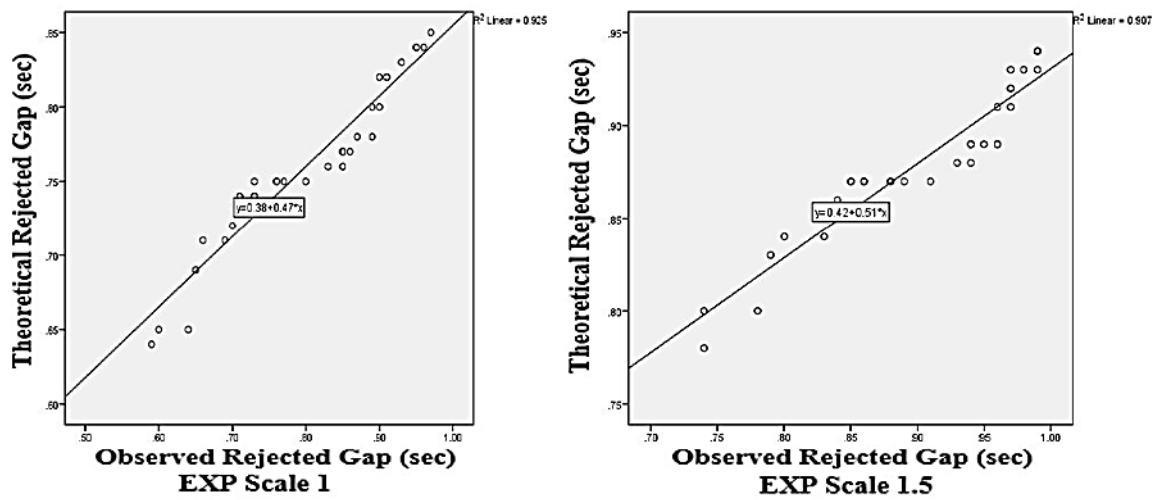


Figure 15: Theoretical Versus Observed Rejected Gaps for East Approach

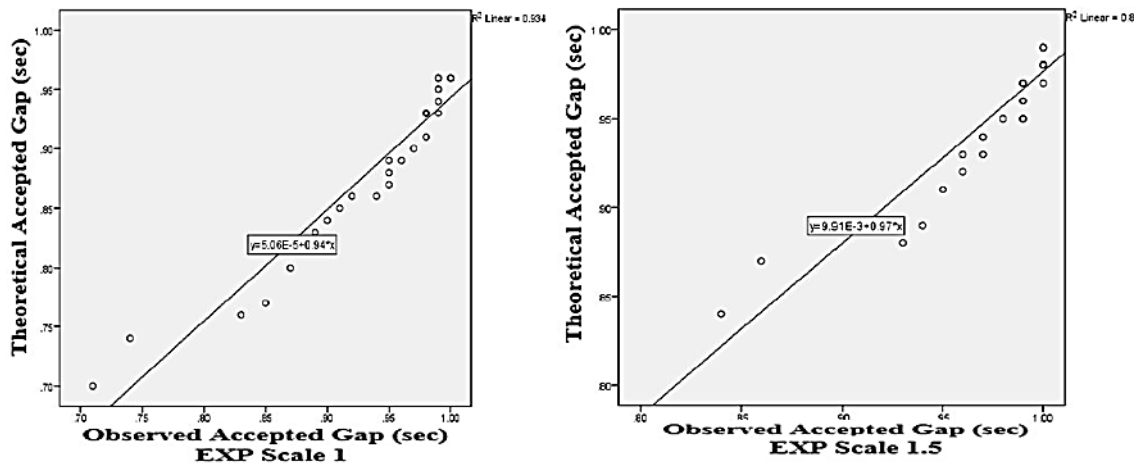


Figure 16: Theoretical Versus Observed Accepted Gaps for East Approach

5. Conclusions

The following concluding remark can be recorded:

- 1) The critical headway time was (3.35 sec) and (2.8 sec) for the west and East approaches.
- 2) The value of the critical gap for the West and East approach is less than the range of (NCHRP 572), possibly because Al Turkman roundabout in Baghdad city is congested with aggressive driver behavior.
- 3) The probability density functions are used to model the rejected and accepted gaps.
- 4) Exponential distribution functions (1, 1.5) in scale for critical gaps with different shape functions for accepted and rejected gaps are better fittings to the empirical distribution. There is no significant difference for Al Turk Mani roundabout intersection.
- 5) A good fit is gained for the West and East approaches at peak periods of (1:00-2:00) pm. The observed field data and the theoretical data for validation of Rejected and Accepted Gaps were compared.
- 6) For the West approach, the validation showed a strong linear relationship between the observed field data and the theoretical data with $R^2 = 98.2\%$ and 95.1% for the rejected gaps with a scale of (1-1.5) respectively and $R^2 = 95.9\%$ and 93.2% for the accepted gaps with a scale of (1-1.5) respectively.
- 7) For the East approach, the validation showed a strong linear relationship between the observed field data and the theoretical data with $R^2 = 92.5\%$ and 90.7% for the rejected gaps with a scale of (1-1.5) respectively and $R^2 = 93.4\%$ and 89.7% for accepted gaps with a scale of (1-1.5) respectively.

Author contribution

All authors contributed equally to this work.

Funding

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Data availability statement

The data that support the findings of this study are available on request from the corresponding author.

Conflicts of interest

The authors declare that there is no conflict of interest.

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