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ANALYSIS OF THE TRAFFIC CHARACTERISTICS DURING THE MONTH OF RAMADAN FOR RURAL HIGHWAYS

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ABSTRACT

Ramadan holds immense sacred and cultural significance within the Islamic world, profoundly impacting various aspects of daily life. This study delves into the distinct characteristics of traffic during Ramadan. Several researchers have investigated the traffic accident rate during Ramadan and compared them to the rates outside of Ramadan, however little attention has been given to the underlying traffic behavior causing these fluctuations. This study aims to investigate the traffic characteristics before, during, and after Ramadan, by analyzing the traffic data, to reveal how the traffic behavior differs. The work focuses on the Shubra-Banha Freeway, for which the traffic volume and speed were extracted from Speed Enforcement Radar (SER) and Radar for Classification and Counting (RCC), for before, during, and after Ramadan. Findings reveal that despite similar daily traffic volumes, Ramadan witnesses a significant disparity in hourly distribution. Notably, average speeds are higher during Ramadan, marked by increased standard deviations, enhancing accident risks. The investigation suggests the potential to predict normal traffic patterns based on Ramadan traffic data.

KEYWORDS: The Month of Ramadan, Shubra-Banha Freeway, Daily Traffic Distribution, Hourly Traffic Distribution, Speed Distributions.

تحليل خصائص حركة المرور خلال شهر رمضان للطرق الخلوية السريعة

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الملخص

يعتبر شهر رمضان المبارك أحد أكثر الشهور قدسية وأهمية ثقافية للعالم الإسلامي بأكمله مما يؤثر بشكل عميق على مختلف جوانب الحياة اليومية. تتناول هذه الدراسة الخصائص المميزة لحركة المرور خلال شهر رمضان. لقد قام العديد من الباحثين بالتحقيق في معدل الحوادث المرورية خلال شهر رمضان ومقارنتها بالمعدلات خارج شهر رمضان، ولكن لم يتم سوى القليل من الاهتمام بالسلوك المروري الأساسي الذي يسبب تقلبات هذه المعدلات خلال هذا الشهر. تهدف هذه الدراسة إلى تحليل خصائص حركة المرور قبل وأثناء وبعد شهر رمضان من خلال فحص البيانات المرورية للكشف عن أسباب اختلاف السلوك المروري أثناء شهر رمضان. تم عمل هذه الدراسه على طريق شبرا بنها الحر، حيث تم استخراج حجم وسرعة حركة المرور من رادار مراقبة السرعة ورادار التصنيف والعد قبل وأثناء وبعد شهر رمضان. وتوصلت النتائج إلى أنه على الرغم من تشابه أحجام حركة المرور اليومية، إلا أن شهر رمضان يشهد تباينًا كبيرًا في توزيع حركة المرور خلال ساعات اليوم. ومن الجدير بالذكر

أن متوسط السرعات يكون أعلى خلال شهر رمضان والذي يتسم بزيادة الانحرافات المعيارية مما يزيد من مخاطر الحوادث. وتشير التحليلات إلى إمكانية التنبؤ بأنماط حركة المرور العادية بناءً على بيانات حركة المرور في شهر رمضان.

الكلمات المفتاحية : شهر رمضان، طريق شبرا بنها الحر، توزيع حركة المرور اليومية، توزيع حركة المرور خلال ساعات اليوم، توزيعات السرعة

1. INTRODUCTION

The holy month of Ramadan is considered one of the most sacred and culturally significant months for the entirety of the Islamic World. It has profound meaning, and its spiritual influences permeate all aspects of life in Muslim countries. During this month, Practicing Muslims dedicate most of their time to worshiping and participating in Islamic community activities. The pattern of life during the days of Ramadan is completely different from the normal lifestyle outside this month. Most Muslim people save their vacation days to take during the month, in order to spend more of their time worshiping and travelling to the Kingdom of Saudia Arabia to complete Umrah. Moreover, Muslims typically fast from sunrise to sunset, and many prefer to break their fasts at home amongst family and community. Therefore, most of the evening commute is concentrated before sunset, and the morning commute typically starts later than normal time outside Ramadan. These unconventional activities have a notable effect on driving behavior, commuting time, traffic distributions, and characteristics, making them unique to the habitual behavior outside the month of Ramadan. There has been little to no research that investigates the distinctive traffic characteristics during the Month of Ramadan, creating a gap in the research where this study can inform.

Several researchers have conducted investigations that focused on road traffic accidents in the Kingdom of Saudia Arabia, United Arab of Emirates, and Turkey during the month of Ramadan. All of these studies compared the accident rates during the month of Ramadan with the other months of the year. One of the Saudi studies was done nationwide while the other focused on one specific region in the southwest part of the Kingdom, Jazan [1 and 2]. The nationwide Saudi study concluded that Road Traffic Injuries (RTIs) are higher during sunset time in Ramadan where most of the people are commuting swiftly back home for breaking their fasting with their families. The study suggests the creation of more traffic law enforcement during this time and the implementation of awareness programs to minimize the RTIs. The Jazan Study compared the accident rates during the months over a span of four years, the analysis of this information indicated that the month of Ramadan had the largest number of accidents during the entire year. Comparatively, Al-Houqani et. al. [3] analyzed the accident data for Al Ain City in the southeast part of the United Arab of Emirates during years 2006 and 2007. They were interested in particular types of accidents, specifically Sleep-related collisions, SRC. The SRC represented the highest on the road with 42% and the highest on the highways with 83% during the month of Ramadan. Similarly, Kalafat et.al. [4] analyzed the traffic accidents over the course of one year and compared the number of traffic accidents during the month of Ramadan with other months of the year. The number of deaths and injuries during the month of Ramadan was significantly higher than the other months of the year. Analysis of these results revealed that the traffic behavior during the month of Ramadan differs vastly. However, none of the following studies investigated traffic characteristics such as traffic volume, and traffic distribution during the month, weeks, or days of the month of Ramadan and compare it to the remainder of the year.

Al-Masaeid et. al. [5] have also examined the impact of fasting on traffic accidents. They collected traffic volumes and accident information from 2013 to 2017 for twelve major multilane segments in Amman, Jordan, comparing the traffic characteristics (volumes, peak hours, and accidents) before, during, and after the month of Ramadan. Their traffic analysis indicated that the peak hour volumes in the month of Ramadan were comparable with outside the month of Ramdan but the peak hour times in Ramadan was shifted due to the change in the working hours. Even

though the traffic volumes were relatively the same, the accident rates during the month of Ramadan were significantly higher than in other months of the year. This increase in accidents is largely due to a change in habits and shifts in the typical daily routines of the passengers during the month. For instance, Friday showed the largest number of daily accidents during the weeks of Ramadan due to the increase in social activities and family gatherings during the holidays.

Yıldırım-Yenier et.al. [6] conducted a study comparing several driving behavioral shifts which included: speeding, horn honking, and seat belts use during the Month of Ramadan compared to the other months. They measured 1885 speed by hand-held radar, recorded 2106 seat belts and 720 minutes of horn-honking using a hidden camera on 8th Street south of Dumlupinar Boulevard in the City of Ankara, Turkey. The measurements were taken during three weekdays during and after Ramadan at different times of the day. Though this study has its limitations, it revealed how various driver behaviors differ during Ramadan as opposed to non-Ramadan days.

Since the shift in traffic patterns and characteristics during the month of Ramadan can be considered a seasonal change, it is important to consider research [7 and 8] that has comprehensively investigated and modeled the impact of seasonal variation on traffic and accidents. Both studies included the effects of seasonality and changes in driving behavior, which were not accounted for before, on modeling traffic accidents. Accounting for the seasonal variation by introducing an independent variable has led to significant improvement in the prediction model. The analysis methodology used in this research can be of great inspiration to the current study. Moreover, Macioszek and Kurek [9] thoroughly analyzed the traffic volume in the city before and during COVID-19 through video remote sensing. They were able to collect continuous traffic volume before and during the COVID-19 period. The continuous traffic data allowed them to investigate and compare the daily, weekly, and seasonal distribution of traffic volume and calculate traffic indicators which can be used to convert short term traffic volume into Average Daily Traffic. A similar methodology can be applied to investigate the traffic characteristics during the month of Ramadan to predict the design parameters as a normal traffic distribution before and after Ramadan.

Oftentimes, transportation engineers need to conduct traffic evaluations or traffic impact studies to evaluate the current state of the roads which require traffic surveys for the volume, speed, and peak hour traffic as well as several other traffic characteristics. Since most transportation engineers know that during the month of Ramadan, the traffic behavior is different, they tend to postpone this analysis until after the month of Ramadan. The current study aims to investigate the traffic characteristics before, during, and after the month of Ramadan, and by analyzing the traffic data, it will reveal how the traffic behavior is different and whether this difference is significant or not. In addition, the results will answer the question of "Can Transportation Engineers continue to do their traffic evaluations during the month of Ramadan or not?". By using the traffic data gathered during the month of Ramadan, the normal traffic characteristics can be predicted and vice versa, which can help Transportation Agencies/Engineers as well as traffic law enforcement to plan their future work.

2. STUDY LOCATION AND TRAFFIC COUNT

This study was conducted on one of the major rural freeways that have been constructed in the last ten years, the Shubra-Banha Freeway. The road connects Cairo with about ten governorates on the northside of Egypt. The length of the freeway is about 39 km between Cairo Ring Road and Regional Ring Road with four travel lanes in each direction, see **Fig.1**. The Banha-Shubra Freeway Command allowed the authors to extract the traffic data from the control room database server of the road for the purpose of this research. The traffic data was obtained from Speed Enforcement Radar (SER) and Radar for Classification and Counting (RCC). These Radars are supported on gantry signs in both directions of the road. Gantry number 5 (G5) on Banha direction near Regional Ring Road and Gantry 8 (G8) on Shubra direction near the tool gate. The traffic volumes, speed, and classification for each lane in both directions of the road were continuously available from January to December 2022. Traffic volume information showed that the 2022 Average Annual

Daily Traffic (AADT) ranged from 21000 to 39000 vehicles per day for each direction. Heavy truck traffic ranged from 1 to 3 % of the total traffic volume. The posted speed of the road is 120 km/hour, while the actual speed ranged from 38 to 150 km/hour depending on the time of the day.

3. TIMING OF THE TRAFFIC ANALYSIS

The traffic volume information was available from January to December 2022 for the purposes of this study. During which, the Islamic calendar was compared with the Gregorian calendar to find out the beginning and ending of the month of Ramadan. In the year of 2022, the month of Ramadan started on Saturday April 2nd and ended on Sunday May 1st in Egypt. An investigation on both calendars was done to exclude any significant holidays that could impact the traffic volume. The first week of Ramadan (W14) usually has light traffic volume since many people prefer to take vacations on the first days of Ramadan. In addition, the Egyptian Easter (Sham Alnesiem) which is a statutory holiday for both Muslims and Coptic Egyptians occured during the last week of Ramadan (W17), April 25th. Most people took the entirety of the last week (W17) off together with the statutory holidays. The weeks that had usual and normal traffic patterns during the month of Ramadan were the middle two weeks (W15 and W16). Similar investigations were done for the months before and after Ramadan, March, and May. Three weeks were identified in each month with normal traffic behaviors, week 10, 11 and 12 in March and week 19, 20, and 21 in May. Two weeks (W10 and W11) before the month of Ramadan and two weeks (W19 and W20) after Ramadan were used for the comparison with Ramadan traffic. One week before Ramadan (W12) and one week after Ramadan (W21) were saved for traffic validation later in the study. It should be noted that the comparison for before and after the month of Ramadan was kept closer to the month of Ramadan to avoid traffic growth and traffic interruption by vacations, holidays, and seasonal variation of the traffic volume. The following analysis will be for W10 and W11 for before, W15 and W16 for Ramadan and W19 and 20 for after.

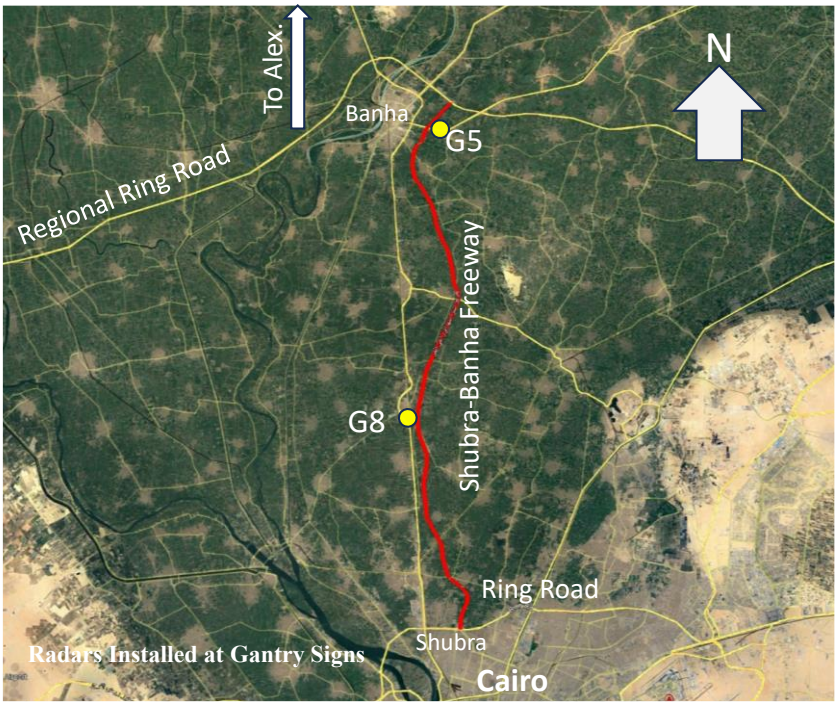


Fig. 1: Shubra-Banha Freeway Location.

4. TRAFFIC DISTRIBUTIONS

4.1. Daily Volume Distributions

It is very important to investigate the distribution of the traffic during the days of the week for the study periods before, during and after the month of Ramadan. To characterize the daily

traffic volume and its variability, the Daily Peak Factor (DPF) for each day of the weeks were calculated from the following Equation:

$$\text{Daily Peak Factor (DPF)} = \left[\frac{Daily\ Traffic\ Volume}{Weekly\ Traffic\ Volume}\right] * 100 \qquad \textbf{Eq. 1}$$

The DPFs for all days during the six weeks were calculated for both directions of the road, Shubra-Banha (G5) and Banha-Shubra (G8). **Fig. 2** and **3** shows the DPF for both directions of the road. The following observations can be drawn from the figures:

- Mondays and Tuesdays are "working days" with normal traffic volume for both travel directions.
- Thursdays are the weekly peak traffic days for Banha-Shubra (G5) direction. This is due to the fact that this is the end of the week, and most people travel back home. Whereas Saturdays are the weekly peak traffic days for Banha-Shubra since people commuting back to their jobs in Cairo.
- Fridays are a common weekend for majority of people, and the traffic volumes are the lowest during the week for both directions.
- The data showed that the traffic during the two weeks of Ramadan (W15 and W16) was a little less than the weeks before and after the month of Ramadan. This is due to the fact that some people prefer to take their vacations during the month of Ramadan.

Based on the above observations, **Table 1** summarises the traffic patterns that will inform the analysis conducted in this study.

Table 1. Normal Traffic, Peak Traffic, and Off-Peak Traffic for Both Travel Directions

Travel Direction	Normal Traffic Days	Peak Traffic Day	Off-Peak Traffic Day
Shubra-Banha (G5)	Monday & Tuesday	Thursday	Friday
Banha-Shubra (G8)	Monday & Tuesday	Saturday	Friday

4.2. Hourly Volume Distributions

The traffic volume for both travel directions on the road was utilized to investigate the hourly traffic volume distributions. The hourly traffic volume distributions of normal, peak, and off peak for before, during and after the month of Ramadan are illustrated in **Fig. 4**. The hourly distributions indicated the following observations:

- Directly after sunset time (Iftar), the traffic volume in both directions of the road during the month of Ramadan is lower than before and after Ramadan.
- During sunset time of normal, peak, and off day in the direction of Shubra-Banha the peak hours have the highest traffic volume during the month of Ramadan, see **Fig. 4a, b** and **c**.

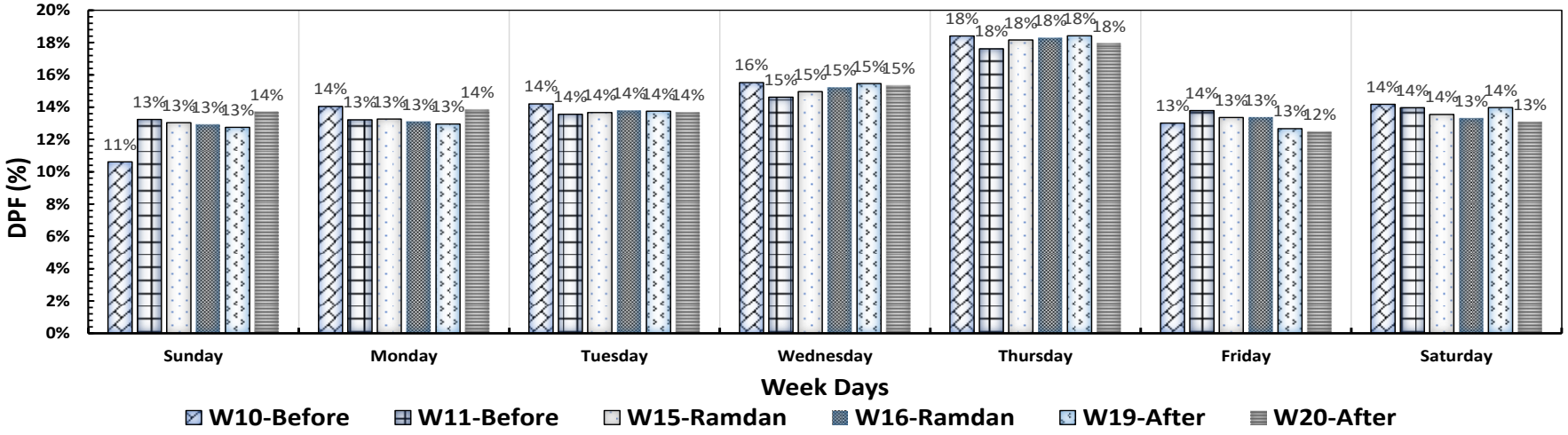


Fig. 2. Daily Peak Factor (DPF) Before, During, and After Ramadan for the Whole Week – Shubra - Banha (G5)

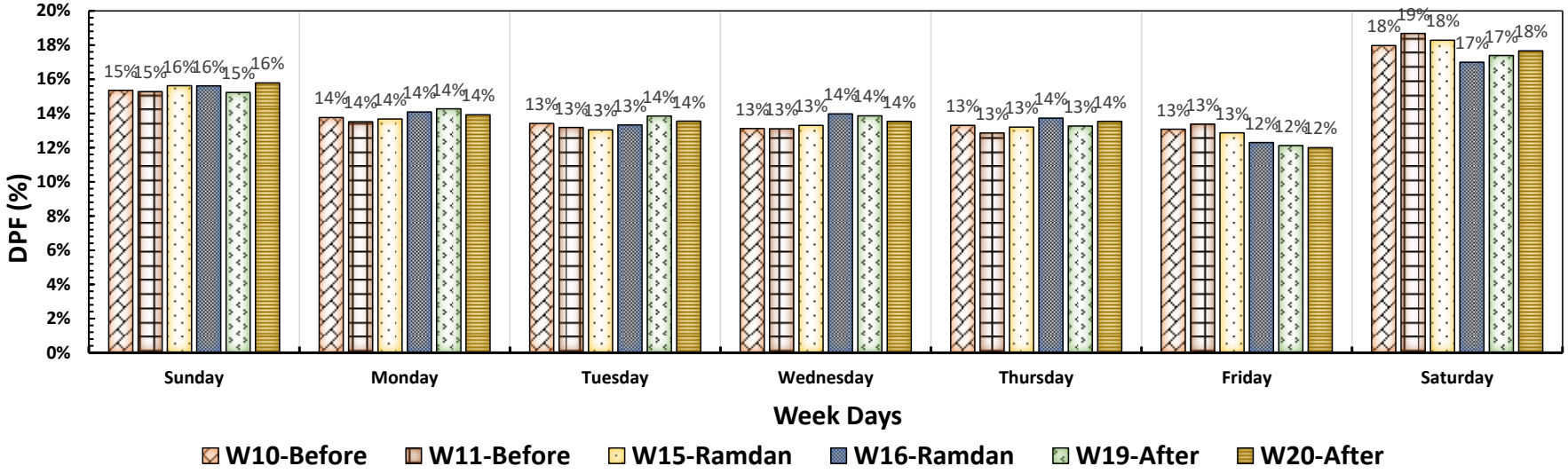


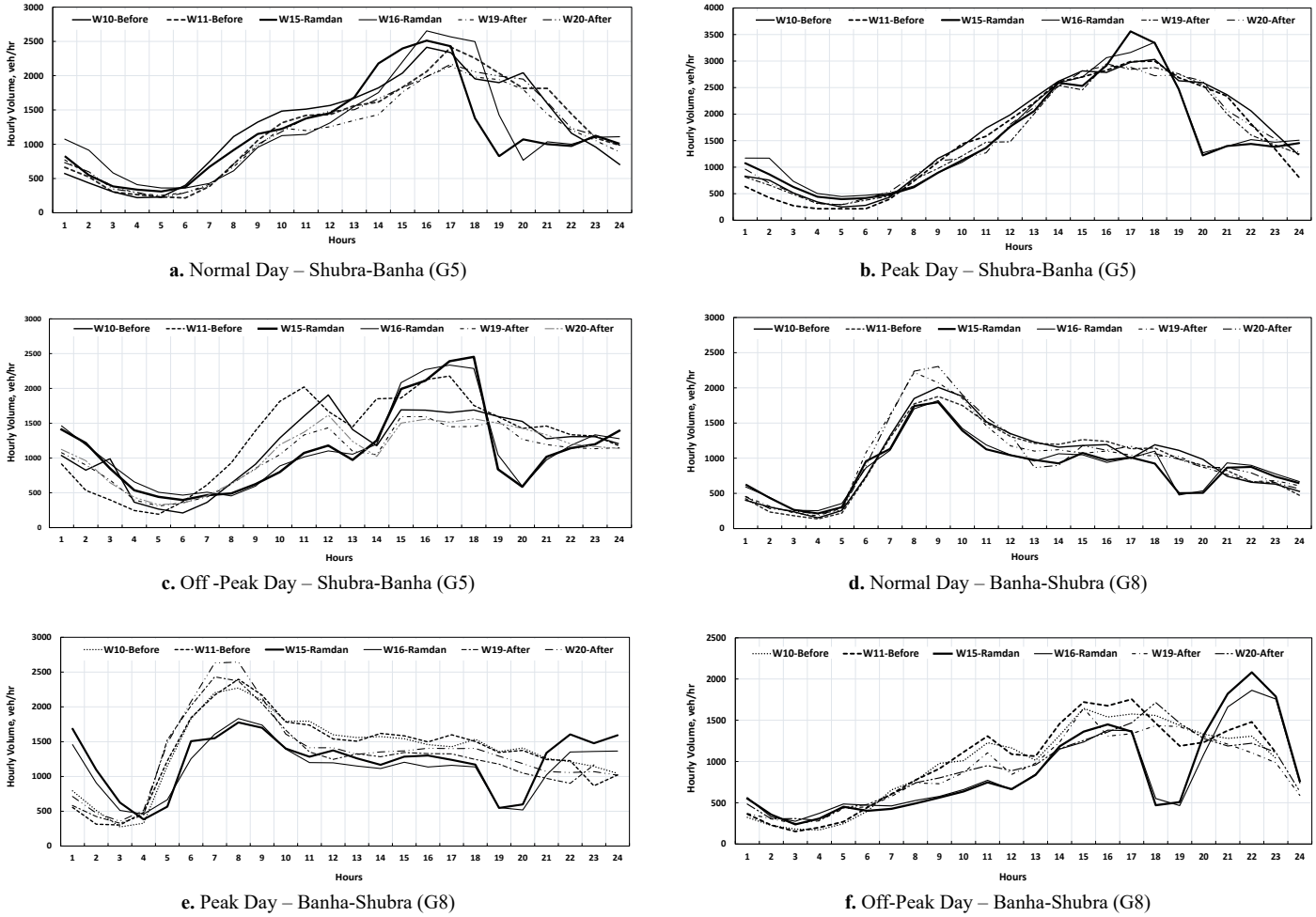
Fig. 3. Daily Peak Factor (DPF) Before, During, and After Ramadan for the Whole Week – Banha - Shubra (G8)

- During the month of Ramadan, the traffic volume late at night is always higher than before and after Ramadan. This is largely due to the fact that people prefer to travel after breaking their fast and praying.
- Banha-Shubra direction showed higher traffic volume for normal, peak and off-peak during the night than Shubra-Banha Freeway compared to the same traffic before and after the month of Ramadan, whereas the Ramadan traffic volume is always less than before and after Ramadan, see **Fig. 4 d**, **e**, and **f**. This indicates that people tend to rest during the day and be active during the night.

The hourly and daily traffic distributions showed that the traffic before and after the month of Ramadan is very similar and can be dealt with as the same parameter. In addition, The Analysis of Variance (ANOVA) showed there is no significant difference between them.

ANALYSIS OF SPEED

The Individual Vehicle Speeds (Average) along with the Speed Variations (Standard Deviations) play a major risk factor in road safety. Several studies [10] have shown that the relationship between the change in speed and the change in accident rates follow a power function. The higher the speed the more severe the accidents and injuries. Drivers with higher speed will 1) ravel longer distances before they react to an emergency, 2) need longer distances to stop their vehicles, 3) increase the risk of maneuvering and may lead to losing control of their vehicles, and 4) increase the impact energy that is needed to dissipate and will cause more severe injuries in case of accidents.



a. Normal Day – Shubra-Banha (G5)

b. Peak Day – Shubra-Banha (G5)

c. Off -Peak Day – Shubra-Banha (G5)

d. Normal Day – Banha-Shubra (G8)

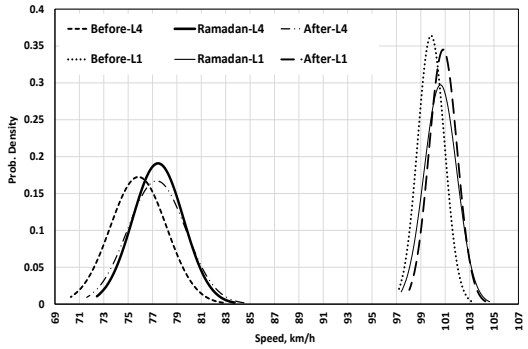
e. Peak Day – Banha-Shubra (G8)

f. Off-Peak Day – Banha-Shubra (G8)

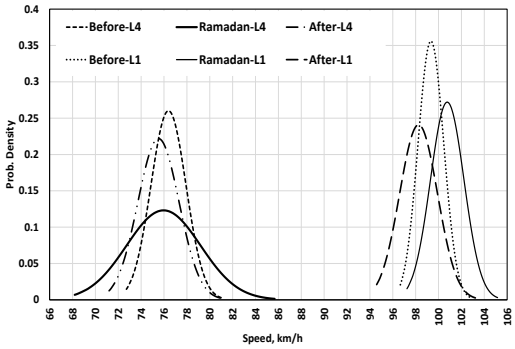
Fig. 4. Hourly Traffic Volume Distribution Before, During and After Ramadan.

Sunset is considered a critical time for all fasting Muslims and they are desperate to rush back home to break their fast with the family. In this section, the distribution of the traffic speed during the peak hours, which were during sunset, of normal, peak, and off-peak days for the Shubra-Banha direction is compared with before, during and after the month of Ramadan. For the Banha-Shubra direction, even though the peak hours were during the morning, sunset time is where the speed will be more critical during the month of Ramadan. Hence, the speed distributions during sunset time were compared for before, during and after the month of Ramadan.

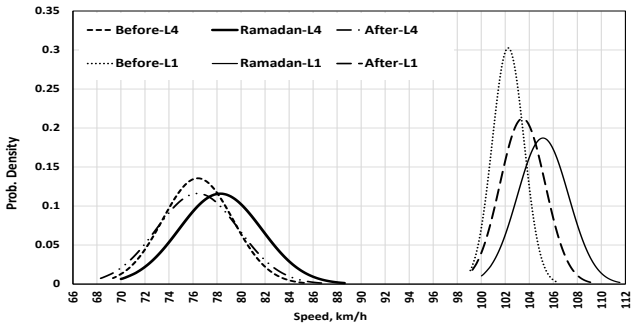
The Shubra-Banha Freeway consists of 4 lanes in each travel direction. The traffic data extracted from Speed Enforcement Radar (SER) includes the speed for all vehicles on all travel lanes. The probability distributions of the speed which represent the number of times each speed values occurs during the peak hours/sunset times were calculated for lane number 1 (L1 – fast lane) and lane number 4 (L4 – slow lane) with the assumption that the speed behaviour on the middle two lanes (L2 & L3) will have similar characteristics. These distributions were calculated for L1 and L4 before, during and after the month of Ramadan, as shown in **Fig. 5**. The figure displays the following observations:



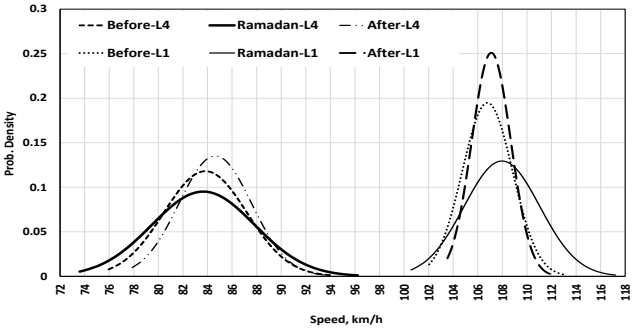
a. Normal Day (Peak/Sunset) – Shubra-Banha (G5)



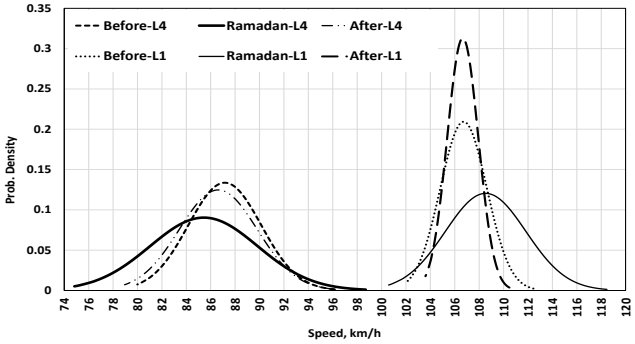
b. Peak Day (Peak/Sunset) – Shubra-Banha (G5)



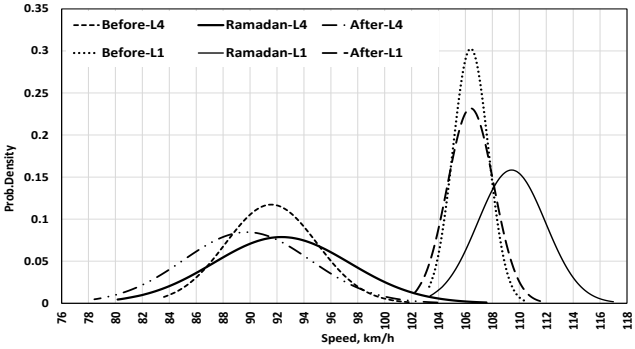
c. Off Day (Peak/Sunset) – Shubra-Banha (G5)



d. Normal Day (Sunset) – Banha-Shubra (G8)



e. Peak Day (Sunset) – Banha-Shubra (G8)



f. Off Day (Sunset) – Banha-Shubra (G8)

Fig. 5. Speed Distribution during Peak Hours and Sunset of Lane 1 and 4 for Before, During and After Ramadan.

- The average speed on Lane 1 (fast lane) tended to be higher than the average speed before and after the month of Ramadan, which indicates that people traveling back home after their work (sunset time) are speeding, driving in a rush to break their fast with their family.
- The average speed on Lane 4 (slow lane) tended to be higher with larger standard deviation during the month of Ramadan compared to before and after Ramadan. Higher variability of the speed on the traffic lane imposes more risk of traffic accident and hinders the safety of travelers.
- Comparison between the overall speed in both directions of the road (G5 and G8) showed that the direction of Banha-Shubra has higher speed during the month of Ramadan in lane 1 by about 6% (108 verses 102 km/h) and lane 4 by about 11% (87 verses 77 km/h). This increase in speed in Banha-Shubra direction refers to the fact that the traffic volumes are always less than the other direction which give drivers the chance to speed.
- The distribution of the speed showed that the Banha-Shubra (G8) direction has more variability in the speed than Shubra-Banha, Lane 1 has 2.97 verses 1.38 and Lane 4 has 4.56 verses 2.92. This indicates that when the traffic volume is low some of the slow vehicles keep driving on fast lanes and some of the fast vehicles drive on the slow lanes which creates higher risk and an increase the probability of accidents.

Traffic speed plays an important role in traffic characteristics, and it is one of the main risk factors that cause traffic accidents. Al-Masaeid et. al. [5] showed in their study that the maximum number of accidents was during Friday (off day) in the month of Ramadan, this is largely caused by the fact that Friday contains the maximum number of social activities in the week. The current study showed that off-peak (Friday) has higher speeds in both directions of the roads for fast and slow lanes with larger standard deviation during the month of Ramadan than before and after which impact the safety and create more accident rates, see **Fig. 5**.**c** and **f**.

ANALYSIS OF VARIANCE (ANOVA)

Visual observations of the daily and hourly traffic volumes before and after the month of Ramadan showed similarity with the values and distributions as shown in **Fig. 2** and **3** above. The analysis of variance (ANOVA) for the traffic volumes before and after the month of Ramadan was conducted to ensure that both can be combined as one variable in the proceeding analysis. ANOVA was performed to test the null hypothesis that both means of traffic volumes have no difference and that the level of significance (α) is higher than 0.05. **Table 2** shows the results of the ANOVA for the traffic volumes before and after the month of Ramadan in both directions of the road. As can be seen in the table for all traffic conditions in both directions of the road, the sum of the square between groups is less than the sum of the square within groups, which makes the F-statistic of the ANOVA lower and the P-value higher (p-value > 0.05). The ANOVA results showed acceptance of the null hypothesis and indicated that the traffic volumes before and after the month of Ramadan insignificantly differ and can be dealt with as one variable against the traffic volume within the month of Ramadan.

Table 2. ANOVA for Traffic Volumes Before and After the Month of Ramadan for Different Traffic Conditions

Direction of Travel	Traffic Condition	Source of Variations	Sum of squares	df*	Mean square	F*	Sig.*
Shubra-Banha	Normal	Between Groups	160394	1	160394	0.380	0.539
		Within Groups	39684112	94	422171		
		Total	39844506	95			
	Peak	Between Groups	64015	1	64015	0.074	0.787
		Within Groups	81653806	94	868658		
		Total	81717821	95			
	Off-peak	Between Groups	424935	1	424935	1.782	0.185
		Within Groups	22415843	94	238466		
		Total	22840778	95			
Banha-Shubra	Normal	Between Groups	27983	1	27983	0.095	0.758
		Within Groups	27553952	94	293127		
		Total	27581935	95			
	Peak	Between Groups	112888	1	112888	0.369	0.545
		Within Groups	28737250	94	305715		
		Total	28850139	95			
	Off-peak	Between Groups	5296	1	5296	0.027	0.869
		Within Groups	18321964	94	194915		
		Total	18327260	95			

*df = Degree of Freedom, F = F-statistics, and Sig. = Statistical Significance

TRAFFIC PREDICTION

One of the main objectives of this study is to use the traffic count during the month of Ramadan in order to predict the corresponding traffic volume outside Ramadan which allow the transportation Engineers to continue conducting their transportation evaluation even during the month of Ramadan. The extracted traffic data during the normal, peak, and off-peak days during the month of Ramadan were utilized along with the same days outside Ramadan to build simple liner regression models for each traffic condition. A thorough investigation of the daily and hourly distributions along with the ANOVA analysis for before and after the month of Ramadan showed that the traffic volumes and its distributions are very similar (see **Fig. 4**) with no significant difference and can be combined as one parameter. The SPSS software was utilized to build regression models where the traffic volume before and after the month of Ramadan is a dependent variable and the corresponding traffic volume during Ramadan is an independent variable. Several options for the trend line that can best fit the relationship between the traffic volume were proposed to select the most suitable function with the highest correlation coefficient. It appears that the second order polynomial function fits the data with the highest correlation coefficients (R2). **Table 3** shows the regression models, correlation coefficients, and the standard error of the estimate for each model.

Table 4 shows the ANOVA for the prediction models. The table shows that some of the F-statistics have higher values for the models, which indicates that the models are accounting for a larger amount of the total variance of the data. One can rank these models based on the F test and R2 as follows:

Table 3. Model Summary for Traffic Volume Prediction

Direction of Travel	Model Type	Equation	R*	R^2	Adjusted R^2	SE of the estimate
Shubra-Banha	Normal	**$y = -0.0003 X^2 + 1.758 X – 270.57$**	0.856	**0.734**	0.728	337.87
	Peak	$y = -0.0002 X^2 + 1.7895 X – 433.19$	0.923	0.852	0.849	365.21
	Off-peak	$y = - 0.0003 X^2 + 1.5159 X – 10.256$	0.704	0.496	0.485	352.07
Banha-Shubra	Normal	**$y = 7E-05 X^2 + 1.1078 X – 52.259$**	0.921	**0.848**	0.844	212.49
	Peak	$y = 0.0004 X^2 – 0.0321 X + 798.91$	0.557	0.310	0.295	462.64
	Off-peak	$y = 0.0008x2 + 2.4009x - 284.36$	0.758	0.574	0.561	302.33

Y= Predicted traffic volume before and/or after the month of Ramadan – dependant variable
X= Counted traffic volume during the month of Ramadan – independent variable
* R = correlation coefficient, Adjusted R^2 = adjusted for the number of predictors in the model, SE = Standard error

1) Shubra-Banha – Peak ($R^2 = 0.849$ & $F = 268$),

2) Banha-Shubra – Normal ($R^2 = 0.844$ & $F = 259$),

3) Shubra-Banha – Normal ($R^2 = 0.734$ & $F = 128$),

4) Banha-Shubra – Off-peak ($R^2 = 0.607$ & $F = 61$),

5) Shubra-Banha – Off-peak ($R^2 = 0.496$ & $F = 46$), and

6) Banha-Shubra – Peak ($R^2 = 0.310$ & $F = 21$).

The models for normal days in both directions of the road are the most reliable and accountable among the others since the model works in both directions of the road with higher R^2, higher F-statistics and lower standard errors for the estimate. Figures 6a and b show the prediction of the traffic volume before and after Ramadan for normal days in both directions of the Freeway. It should be noted that the peak model for the Shubra-Banha direction has very good statistic tests, however the peak model for the other direction is worse and this is because most of the people traveling to Cairo, are doing so at nighttime (after Iftar), see **Fig. 4e**, Ramadan hourly distribution. To ensure that the regression models for normal days have reliable prediction, the models' residual were examined as shown in Figures 6c and d. The figures show reasonable scatter around the unity line with no significantly unusual patterns that could impair the prediction models.

Table 5 shows the summary statistics for the independent (Ramadan) and dependent (before and after Ramadan) traffic volumes used to develop the liner regression models. It should be noted that these regression models are used within the range of the traffic volume presented in **Table 5**. Moreover, the models were developed for a rural freeway that connect Cairo, which is a vibrant epicenter of urban employment, and several remote governorates in the north side of Egypt. Hence, any use of these models should be for roads with similar circumstances, otherwise similar studies

can be developed for the roads/study areas. It is recommended to conduct further studies to update the traffic indicator during the month of Ramadan which can be used for converting short term traffic volume into Average Daily Traffic, ADT.

MODELS VALIDATION

As discussed above, the most reliable and accountable prediction models in this study were during the normal traffic days where the model for both directions of traffic had higher F-statistics and lower P-value (< 0.05) as indication of good prediction values. There was one normal week of traffic volumes before (W12) and after (W21) the month of Ramadan that were not used in any of the above analysis and were saved for the model validations. Additionally, one day within the normal days of traffic during the month of Ramadan was not included in building the prediction model which is Monday.

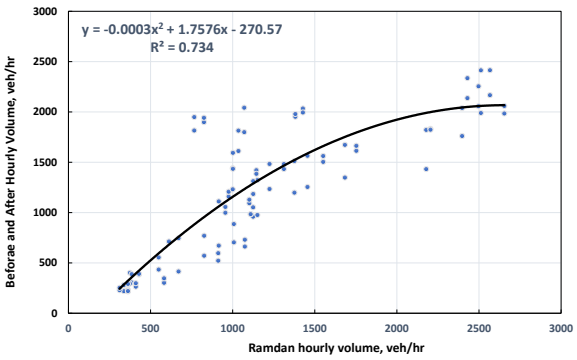
These traffic volumes were utilized to validate and ensure the integrity of the prediction models. **Fig. 7** shows the actual hourly volume versus the predicted hourly traffic volume during the normal traffic day for both directions of the road. The figure shows a reasonable traffic volume prediction with slight scatter around the unity line (45o line). There are a few points that are away from the unity line which could be during the Iftar time in the month of Ramadan where most of the people are at homes and the traffic on the road is very minimal while outside Ramadan time the traffic is higher on the road.

Table 4. ANOVA for linear regressions of Traffic Volume Predictions.

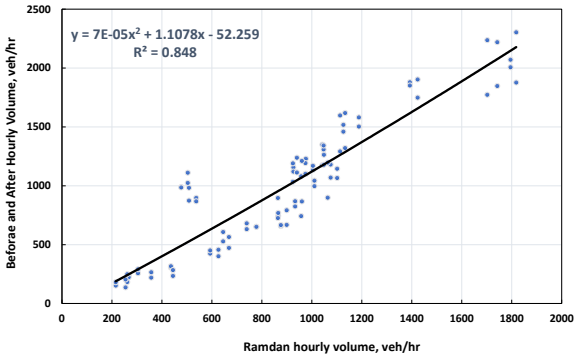
Direction of Travel	Model Type		Sum of Squares	df	Mean Square	F	Seg.
Shubra-Banha	Normal	Regression	29227774	2	14613887	128	0.000
		Residual	10616732	93	114158		
		Total	39844506	95			
	Peak	Regression	71540958	2	35770479	268	0.000
		Residual	12404121	93	133378		
		Total	83945079	95			
	Off-peak	Regression	11331601	2	5665800	46	0.000
		Residual	11527767	93	123954		
		Total	22859368	95			
Banha-Shubra	Normal	Regression	23382696	2	11691348	259	0.000
		Residual	4199239	93	45153		
		Total	27581935	95			
	Peak	Regression	8944856	2	4472428	21	0.000
		Residual	19905283	93	214035		
		Total	28850139	95			
	Off-peak	Regression	10332092	2	5731395	62	0.000
		Residual	7774616	92	91403		
		Total	18106708	95			

Table 5. Summary Statistics for Traffic Volume Used in Regression Models.

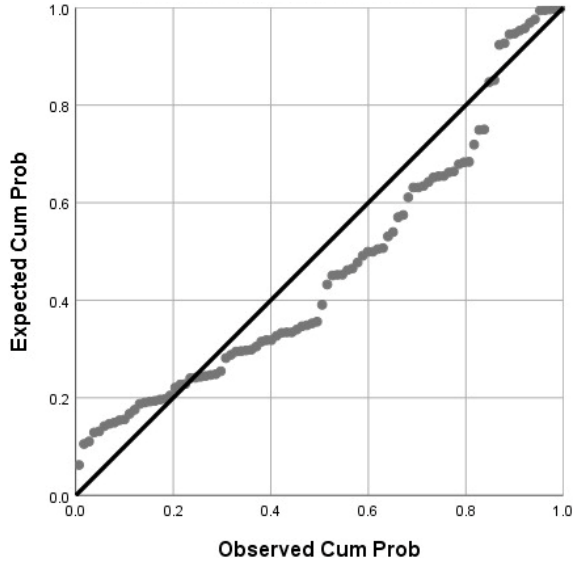
Direction of Travel	Model Type	Time	Mean	SE	Minimum	Maximum
Shubra-Banha	Normal	Ramadan	1189	68	311	2654
		Before & after	1208	66	217	2415
	Peak	Ramadan	1539	93	396	3561
		Before & after	1573	96	215	3032
	Off-peak	Ramadan	1130	59	397	2453
		Before & after	1143	50	192	2178
Banha-Shubra	Normal	Ramadan	886	41	215	1818
		Before & after	991	55	137	2304
	Peak	Ramadan	1184	39	383	1833
		Before & after	1342	56	274	2644
	Off-peak	Ramadan	855	51	238	2081
		Before & after	937	47	152	1755



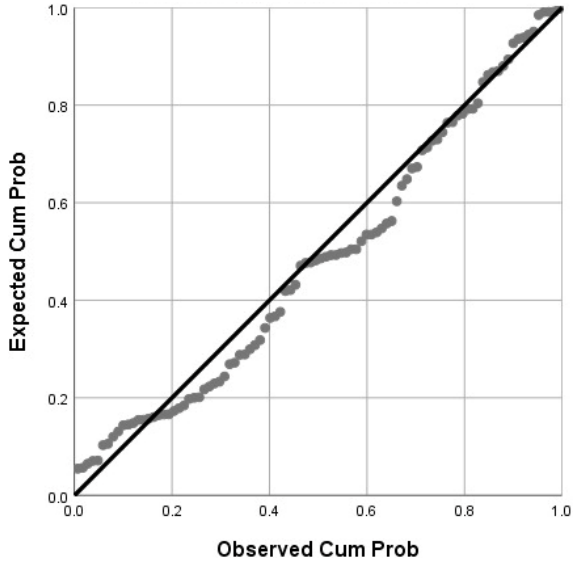
a. Prediction for Shubra-Banha (G5)



b. Prediction for Banha-Shubra (G8)

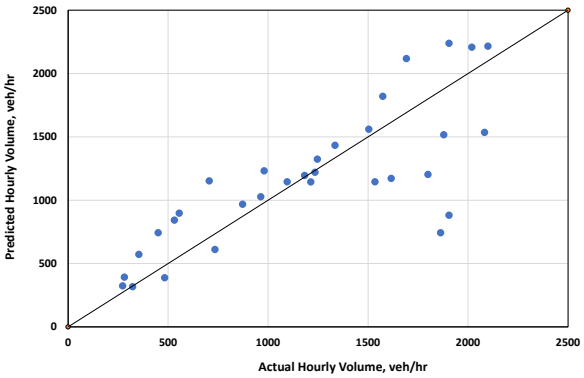


c. Residual for Shubra-Banha (G5)

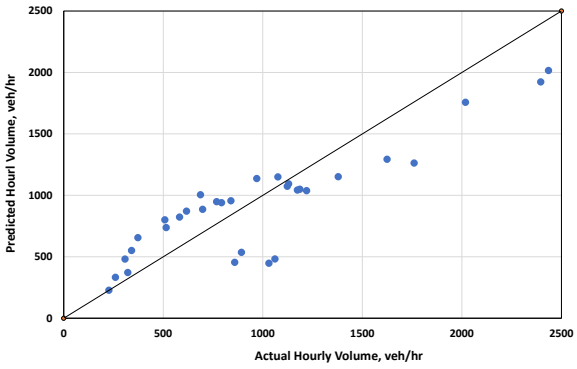


d. Residual for Banha-Shubra (G8)

Fig. 6. Prediction and its Residual of the Traffic Volume Before and After Ramadan.



a. Shubra-Banha (G5)



b. Banha-Shubra (G8)

Fig. 7. Actual Verses Predicted Hourly Volume for Normal Traffic.

CONCLUSIONS

The holy month of Ramadan holds immense sacred and cultural significance across the Islamic World, profoundly impacting various aspects of life in Muslim nations. This unique period of time influences daily routines, including traffic patterns, which significantly differ from regular non-Ramadan times. The traffic characteristics during the month of Ramadan were compared with the traffic before and after Ramadan in term of daily distribution, hourly distribution, and predictions. Analysis of the traffic data before, during and after the month of Ramadan reveled the following conclusions:

- Even though the total daily traffic volume during the month of Ramadan could be very close to the traffic volume before and after Ramadan, the hourly distribution during the month of Ramadan is completely different.
- During the month of Ramadan, the traffic volume late at night is always higher than before and after Ramadan. This is because people prefer to travel after breaking their fast and praying.
- The average speed during the sunset hours for peak days and off-peak days of the month of Ramadan tend to be higher than before and after the month of Ramadan peak hours. This might cause a higher number of accidents as concluded in other similar studies for accident during the month of Ramadan.
- The average speed on slow lanes tends to be higher with larger standard deviation during the month of Ramadan compared to before and after Ramadan. Higher variability of the speed on the traffic lane imposes more risk of traffic accidents and hinders the safety of the travels.
- Six simple linear regression models were developed to predict the traffic volume before and after the month of Ramadan from Ramadan traffic counts. Two reliable models can be used with good prediction during the normal traffic days.
- The developed regression models should be used within similar traffic volume and circumstance to Shubra-Banha Freeway.

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