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Impact of Fasting on Traffic Accidents

Hashem R. Al-Masaeid [1)*], Subhi M. Bazlamit [2)], Audai E. Al-Zedaneen [3)] and Hazem M. Al-Mofleh [4)]

[1)] Civil Engineering Dept., Jordan University of Science and Technology, Irbid, Jordan.
* Correspondent Author. E-Mail: hashem@just.edu.jo
[2)] Civil and Infrastructure Engineering Dept., Al-Zaytoonah University of Jordan,
Amman, Jordan. E-Mail: s.bazlamit@zuj.edu.jo
[3)] Civil Engineering Dept., E-Mail: Jordan University of Science and Technology,
Irbid, Jordan. E-Mail: aealzeidaneen16@eng.just.edu.jo
[4)] Dept., of Mathematics, Tafila Technical University, Tafila, Jordan. E-Mail: almof1hm@cmich.edu

ABSTRACT

In the Islamic religion, fasting is considered as one of the Islam's cornerstones. In Jordan, there is a belief that traffic accidents are higher in the month of Ramadan compared with other months of the year. The major objectives of this study were to investigate the impact of fasting on traffic accidents and model traffic accidents in Ramadan. To achieve these objectives, twelve major urban multilane segments in Amman, the capital of Jordan, were selected. Data on hourly, daily and monthly traffic volumes and accidents from 2013 to 2017 were obtained from related sources.

Analysis results revealed that daily traffic volume values and hourly peak volume values in Ramadan as well as before and after Ramadan are approximately comparable. In contrast, results indicated that daily accident rate and number of accidents in Ramadan were found to be significantly larger than those before or after Ramadan. Using time-series analysis, ARIMA (9, 8) and ARIMA (7, 4) were found to be suitable to model daily accident rate and number of accidents in Ramadan, respectively. Finally, it was recommended to conduct behavioral and medical studies in order to clarify the issue of accident increase in Ramadan.

KEYWORDS: Fasting, Ramadan, Traffic volume, Traffic accidents, Time-series analysis.

INTRODUCTION

The number of Muslims in the world is about 1.6 billion people constituting about 23% of the population of the world and living in more than 57 countries around the world. In the Islamic religion, fasting is considered as one of the Islam's cornerstones, where every sane and able Muslim should fast during the month of Ramadan throughout the day from dawn to sunset. The essence or core of fasting is to improve a person's patience, forgiving, and sense of empathy with poor people. In this month, behavior and lifestyle of fasting people change, so that most family members are present before sunset for fasting break.

Some Islamic countries are inclined to reduce official working hours in Ramadan days. In Jordan, for example, official working hours in Ramadan are from 10 AM to 3 PM instead of from 8 AM to 4 PM for the rest of the year months. The private sector also reduces the working hours, but not necessarily in the same pattern. Because of changes in working hours, nature of Ramadan month and behavior of drivers in Ramadan, it is expected that the volume of traffic and number of road accidents in Jordan are influenced.

In Jordan, there is a belief that traffic accidents are higher in Ramadan compared with other months of the year. Thus, the major objectives of this study were to compare traffic volume and traffic accidents in Ramadan with those in other months, investigate the impact of fasting on traffic accidents and model traffic accidents in Ramadan. The scope of the study included traffic accident and volumes along arterial streets in Amman city, the capital of Jordan, where traffic accident and volume data was available at hourly, daily and monthly bases. Therefore, this study will explore the

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possible impact of Ramadan month on traffic accidents and traffic volumes in detail, in a predominantly Muslim country, where about 97% of the population are Muslims.

BACKGROUND

Limited studies were conducted to investigate the effect of fasting on traffic accidents. Tolon and Chernoff (2007) studied the effect of Ramadan on road accidents in Turkey. Numbers of accidents from 1984 to 2005 were monthly investigated. Because of the long period for which data was taken, the period of Ramadan changed with different seasons. The study found that the impact of Ramadan on accidents amounts to 10% starting from two weeks after the beginning of Ramadan. It was also found that accidents decrease in winter and increase in summer. However, the authors recommended investigating the impact of Ramadan on traffic accidents in countries with greater ratios of commited Muslims, which may give better and more accurate results. However, no further attempts were carried out to investigate the impact of fasting on traffic volume or accidents.

Wang et al. (2013) presented a review of studies related to the factors that affect traffic accidents. They concluded that the increase in traffic volume increases the probability of traffic accidents and that the relationship between the rate of traffic accidents and traffic volume per hour has a U-shape. Yu and Abdel-Aty (2013) studied the difference between accidents during weekdays and weekends. The study concluded that in congested segments, there is a greater probability of the occurrence of traffic accidents during the weekdays, while in free flow conditions, road accidents mostly occur during weekends. Several studies conducted in the State of New York, Jordan and France indicated that the increase in the number of accidents commensurate with the increase in traffic volume (Vataliano and Hold, 1991; Peirson et al., 1998; Martin, 2002; Al-Masaeid, 2009; Al-Omari et al., 2019). Also, similar results were obtained in studying traffic accidents in London area (Dickerson et al., 2000).

Sanusi et al. (2016) analyzed traffic accidents in Nigeria during the years from 1960 to 2011. In the analysis, they used time-series (ARIMA) models or Box-Jenkins method for minor, serious injuries, fatalities and total cases of traffic accidents. The data from 2012 to 2013 was used test the effectiveness and to validate the models. They found that ARIMA (1, 1, 1), ARIMA (1, 1, 0) and ARIMA (0, 1, 1) were suitable to model total, serious and fatal accidents, respectively. Junus et al. (2017) studied the factors that contributed to traffic accidents in Malaysia, such as climate factors, calendar effects, economic factors and intervention policies. In the analysis, structural time-series models were used to forecast traffic accidents in Malaysia.

METHODOLOGY AND DATA COLLECTION

To achieve the objectives of the study, twelve urban major arterial segments were selected. Each segment consists of a 6-lane divided arterial, starting at 50 m from the upstream intersection and ending at 50 m from the downstream intersection (Al-Zedaneen, 2019). All selected segments are located in the city of Amman, the capital of Jordan. Traffic volumes for the selected segments, on an hourly basis, were obtained from Greater Amman Municipality (GAM). At the beginning and the end of each segment, traffic cameras were installed at intersections by GAM since 2013. As such, this study investigated the effect of Ramadan on traffic volume and traffic accidents during the years from 2013 to 2017. Also, data on traffic accidents on an hourly basis was obtained from Traffic Department, Jordan Traffic Institute and Public Security headquarters. In the Islamic calendar, Ramadan consists of 30 or 29 days. In the years from 2013 to 2017, there were 148 days of Ramadan. Therefore, for each arterial segment, the data included 148 observations of daily traffic volumes or accidents and 3552 of hourly observations. Table 1 presents the names of the selected segments and their lengths.

Table 1. The selected multilane segments and their lengths

Segment number	Street name	Segment length
1	King Abdullah street	2400 m
2	King Abdullah street	900 m
3	Musaab Ben Omeir street	700 m
4	Musaab Ben Omeir street	600 m
5	Al-Shahid street	1400 m
6	Al-Shahid street	1100 m
7	Al-Shahid street	3000 m
8	Al-Quds street	1900 m
9	Al-Quds street	1300 m
10	Al-Hurriyah street	650 m
11	Al-Hurriyah street	2000 m
12	King Abdullah street	2450 m

In the study, traffic volume patterns and accident experience in Ramadan were compared with the corresponding values in months before and after Ramadan. Before and after Ramadan months were selected to avoid possible seasonal effects or changes in traffic volumes or accidents. Traffic volumes in Ramadan, the month before and the month after were compared based on average weighted hourly, daily and monthly variations for all the selected segments. However, accident experiences on these months were compared according to the average weighted of the observed number of accidents or accident rates for all selected segments. For each selected segment, hourly, daily or monthly accident rate was computed as follows:

$$AR = (A * 10^6)/(VKT) \quad (1)$$

$$VKT = V * L \quad (2)$$

where:

AR = Accident rate: accidents per million vehicle-kilometers of travel.

A = Number of accidents in the selected period, hourly, daily or monthly.

VKT = Vehicle – kilometers of travel in the selected period.

V = Traffic volume, hourly, daily or monthly.

L = Segment length, kilometers.

Appropriate parametric or non-parametric statistical tests were carried out to explore possible differences in traffic volumes or accident experiences in Ramadan and before or after Ramadan months (Corder and Foreman, 2014). Also, traffic volumes and accident experiences in these months were graphically investigated.

In the study, the average weighted daily traffic accident rate or the number of accidents was modeled using time series. The time series is defined as a sequential group of historical data points collected at regular periods, such as annually, monthly or daily, used to forecast future values. The time series was used here, because the data was related to time and because the time series includes all the known and unknown factors of the previous values to give best prediction. The daily traffic accident rate or the number of accidents is represented here as a dependent variable, while the sequence (or code) of day is represented as the independent variable. In this study, the time series is discrete and univariate, since we used time to predict only the average daily traffic accident rate or the number of accidents in Ramadan.

In modeling, a program was built, using the *R* 3.5.1 Statistical Program, to choose the optimal model used to predict the daily accident rate or the number of daily accidents for the average of major arterial segments during the month of Ramadan (Maxime, 2018; Crawley, 2013; Metcafe and Cowpertwait, 2009). In the analysis, the following steps were followed:

1. Plotting the time series to show its nature; stationary or non-stationary.
2. Applying stationary Augmented Dickey-Fuller (ADF) test and plotting the Autocorrelation Function (ACF) test and Partial Autocorrelation Function (PACF) test. If the series is non-stationary (found trend), convert it into a stationary series by applying differences.
3. Selecting the best model by Akaike's Information Criterion (AIC).
4. Estimated the parameters of the model, by Conditional Sum of Squares (CSS) method.
5. Checking the residuals by Box-Ljung test and Jarque-Bera test (Thadewald and Buning, 2007).
6. Calculating the value of mean absolute percentage error (MAPE) and forecasts.

The above steps are summarized in Figure 1. It is worth noting that daily accident data of Ramadan months from 2013 to 2016 was used in the development of accident rate and number of accident models, while accident data of 2017 was utilized in model validation (Al-Zedaneen, 2019).

ANALYSIS AND RESULTS

Traffic Patterns

Figure 2 presents the average weighted monthly volumes (ADTs) for the selected segments during the analysis period (2013-2017). Although ADTs in Ramadan are less than in the months before or after Ramadan, differences in ADTs between Ramadan and the other two months are really small for all included years. Patterns of daily ADT variations are illustrated in Figure 3. In Jordan, official workdays are Sunday through Thursday and the ADTs of these days in Ramadan are almost similar to their counterparts for the months before or after Ramadan. In contrast, Fridays in Ramadan experienced lower ADTs compared with Friday in other months.

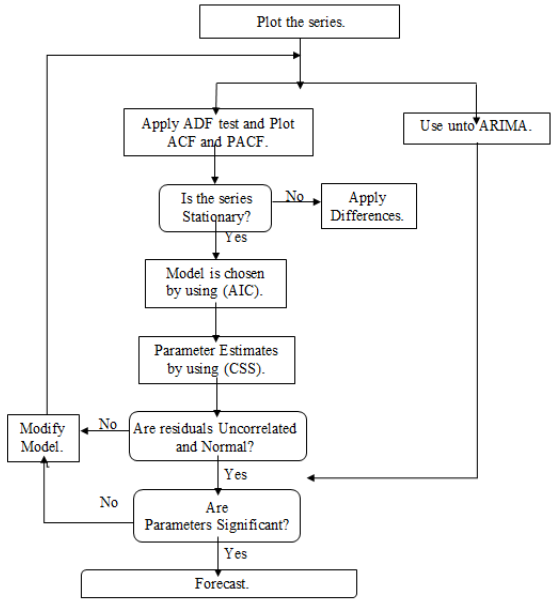

Figure (1): Box-Jenkins modeling steps

Finally, Figure 4 shows the average weighted hourly volume variations on a typical workday in the months before and after Ramadan and in Ramadan month. The figure indicates that there are two peaks in the months before and after Ramadan. These peaks occurred from 7:30 to 8:30 AM and from 4:30 to 5:30 PM. Ramadan peaks occurred from 9 to 10 AM and from 12 to 1 PM. Compared with the months before and after Ramadan, in Ramadan, there was a lagging shift in the morning peak by 1.5 hours and a leading shift in the evening peak by 4.5 hours. In Ramadan, the Iftar (fasting break) time in the summer season is around 7:30 PM and this time exhibited the lowest hourly volume in the evening, as shown in Figure 4. However, after Iftar, vehicle trips tend to increase up to midnight and then declined, but in general, they are greater than those values in other months.

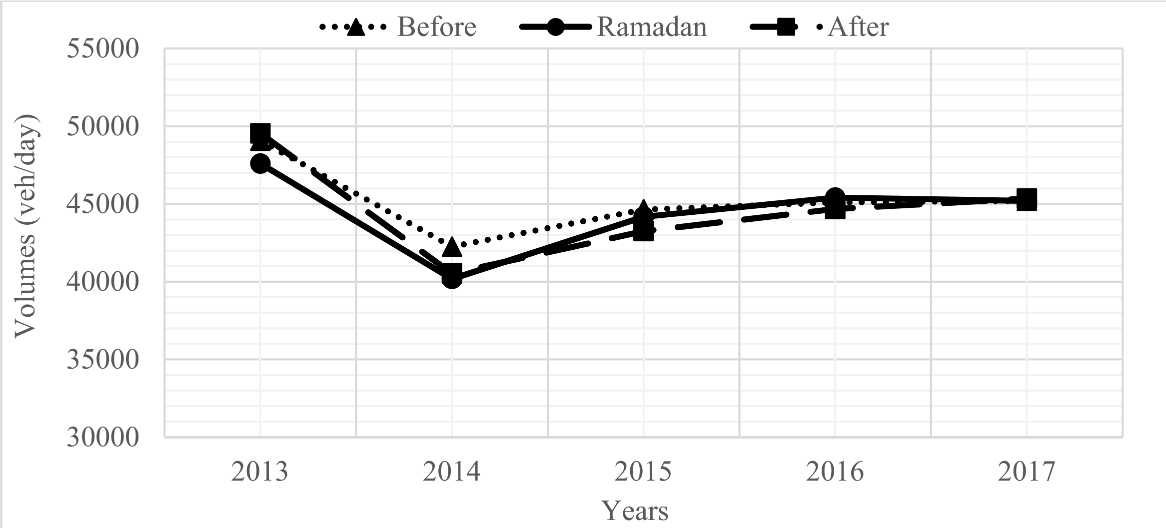

Figure (2): Monthly ADT distribution for the average weighted of segments

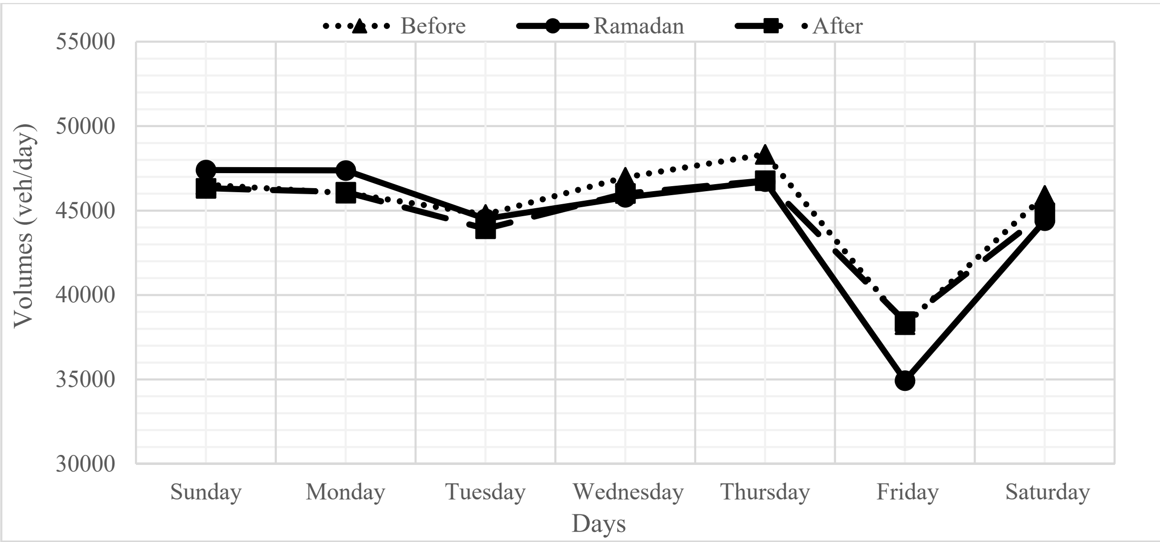

Figure (3): Average weighted daily traffic volumes, ADT

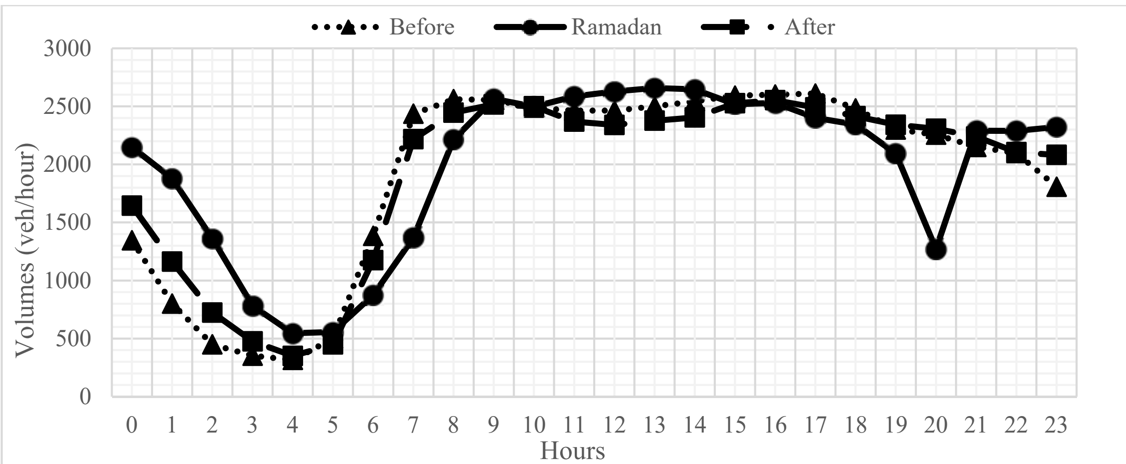

Figure (4): Average weighted hourly traffic volumes during working days

Traffic Accident Variations

For the investigated segments, Figure 5 indicates that accident rates in Ramadan are larger than accident rates in the months before or after Ramadan. Figure 6 shows the average number of accidents in Ramadan and in the months before or after Ramadan during the investigated years.

Figure 7 presents weekly accident rates in Ramadan and in the months before or after Ramadan. The figure illustrates that weekly accident rates in Ramadan are higher than accident rates for the corresponding weeks in other months. Although Friday experienced the lowest ADT in Ramadan (see Figure 3), Figure 8 illustrates that the daily accident rate on Friday had the highest value among all weekdays.

Finally, Figure 9 presents the average hourly accident rates in typical workdays in Ramadan and other months. In Ramadan, the highest accident rates occurred from 9 to 10 AM, which is commensurate with the peak morning volumes.

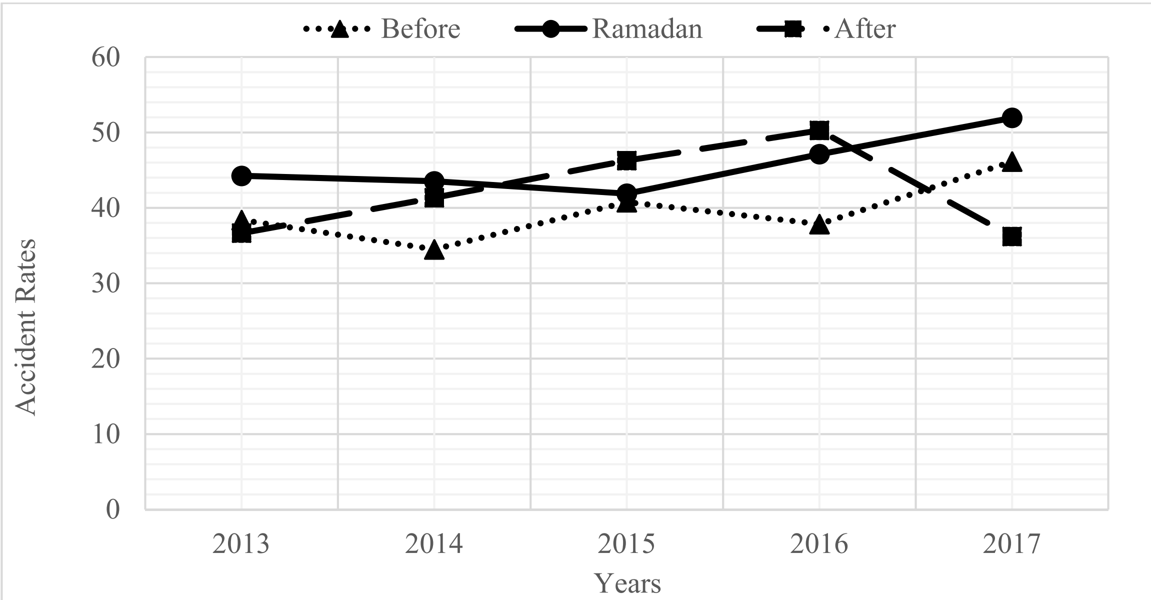

Figure (5): Average weighted monthly traffic accident rates, (acc./million veh.-km)

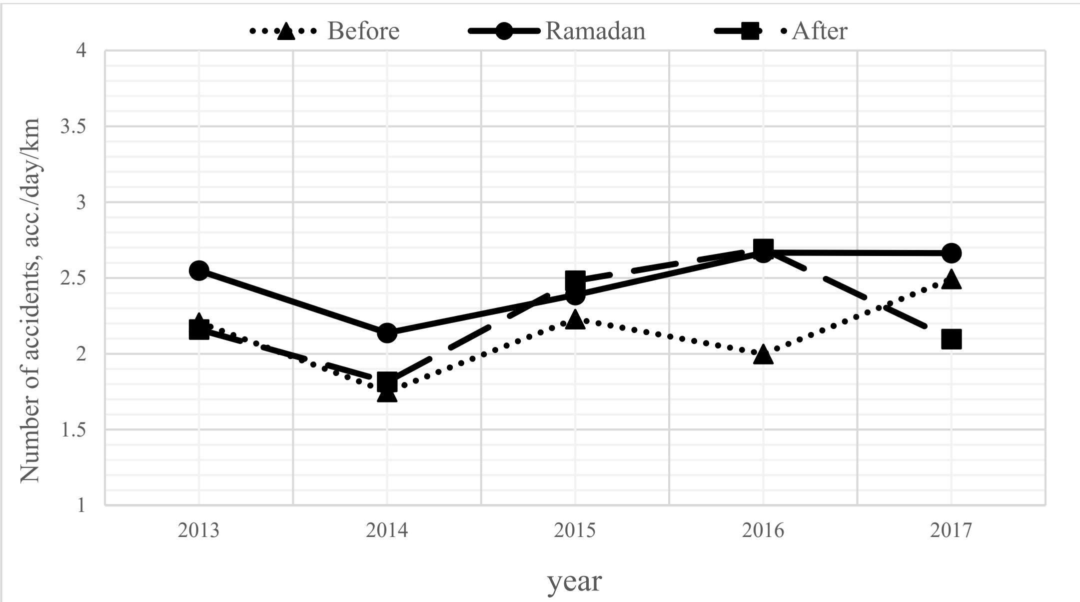

Figure (6): Average weighted monthly number of accidents in each month (acc./day/km)

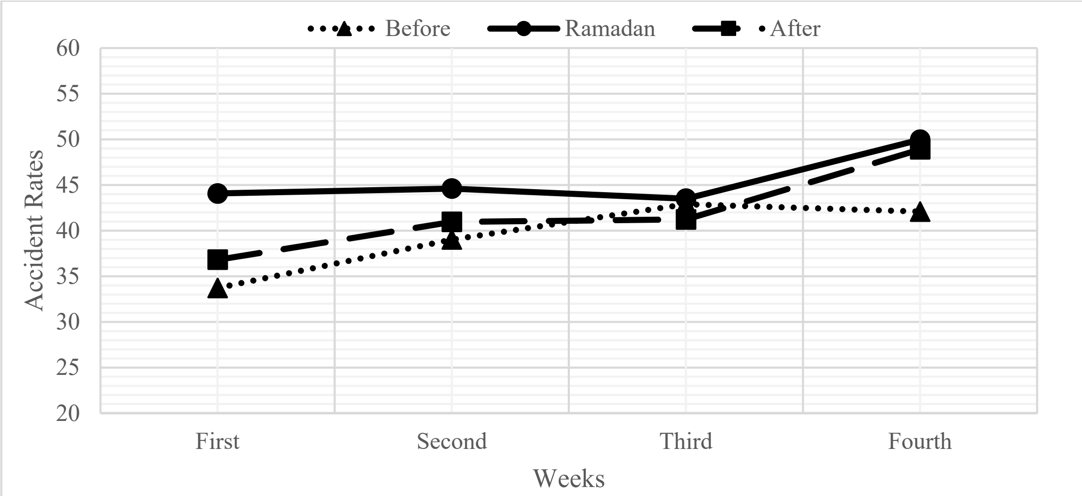

Figure (7): Average weighted weekly traffic accident rates (acc./million veh.-km)

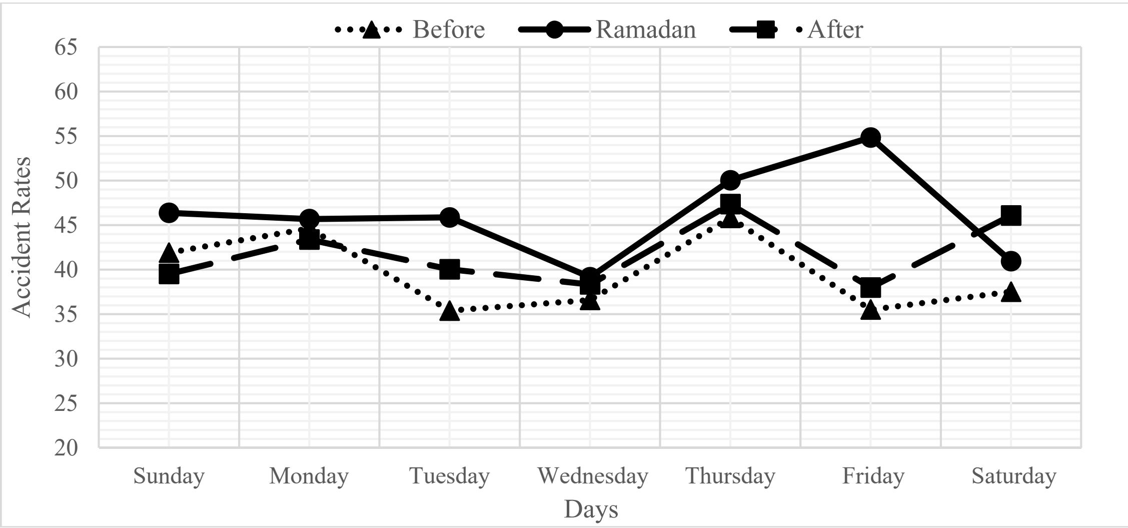

Figure (8): Average weighted daily traffic accident rates (acc./million veh.-km)

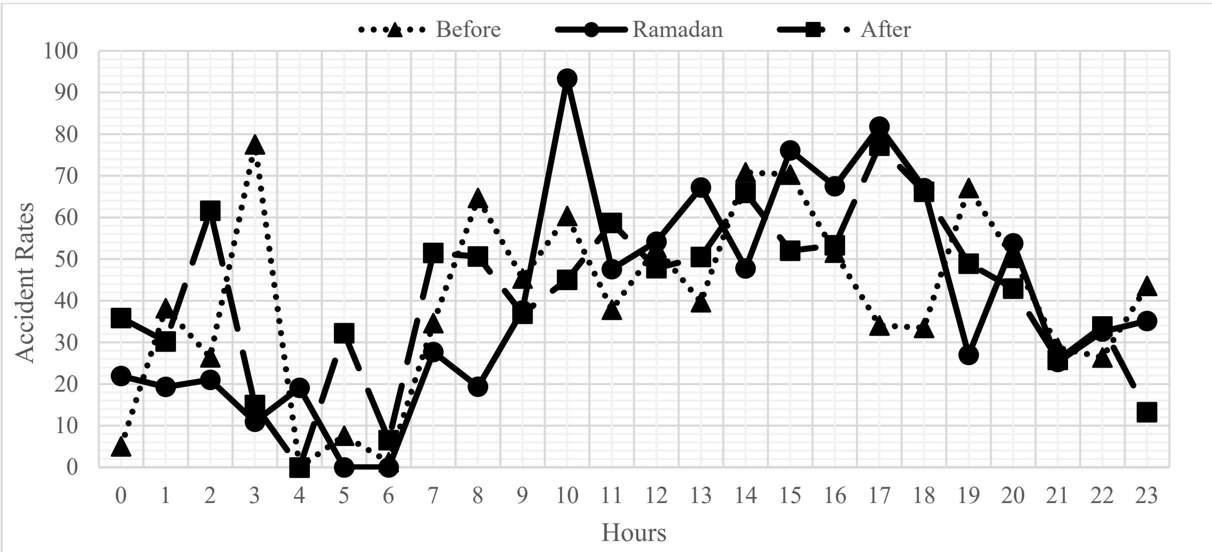

Figure (9): Average weighted hourly traffic accident rates during working days

Effect of Fasting Period of Ramadan

To determine the effect of the fasting period of Ramadan, on traffic volumes, road accidents and accident rates, two steps were carried out. In the first step, normality test of daily traffic volumes, road accidents and accident rates was performed on the data of Ramadan month, before Ramadan month and after Ramadan month, separately, by using the Shapiro-Wilk test. This test was chosen, because it is the most powerful and effectual one from among the other normality tests, like Anderson-Darling, Lilliefors and Kolmogorov-Smirnov tests (Razali and Wah, 2011). The results of this step indicated that traffic volume data, accident data and accident rate data are not normally distributed for each of the aforementioned months. For example, Table 2 presents the results of the Shapiro-Wilk test of normality for daily accident rates.

Table 2. The results of Shapiro-Wilk test for accident rates

Month	W-value	p-value	The decision at α = 0.05
Before Ramadan	0.84323	3.491e-11	Is NOT Normally Distributed
Ramadan	0.86435	2.942e-10	Is NOT Normally Distributed
After Ramadan	0.93169	1.738e-06	Is NOT Normally Distributed

In the second step, a non-parametric or distribution-free test was conducted to explore possible differences between these months. Since traffic volumes, traffic accidents and accident rates for each month are dependent, Mood's Median test or Kruskal-Wallis test for comparing three or more non-parametric dependent populations was performed. Mood's Median test was utilized, because it uses the median value and is more robust when there are outliers in the data (Schenkelberg, 2018).

Application of Kruskal-Wallis test to traffic volumes (ADTs) in Ramadan, before Ramadan and after Ramadan data indicated that all medians are equal (χ^2 = 2.69, P-value = 0.26 and average medians of ADTs in Ramadan, before Ramadan and after Ramadan were 45235, 45769 and 44855 vpd, respectively). On the other hand, the application of the test to average medians of the accident number or accident rates showed that at least one median is different from the other accident number or accident rate medians. However, using *post-hoc* pairwise Mood's Median test revealed that the average accident number median or average accident rate median in Ramadan is significantly larger than those values in the months before or after Ramadan. Table 3 and Table 4 show the results of the test using accident rates and number of accidents, respectively. It is worth mentioning that the average medians of accident rates in Ramadan, before Ramadan and after Ramadan were 42.39, 36.12 and 36.98 acc./million veh-km, respectively. Moreover, the average number of accident median in Ramadan, before Ramadan and after Ramadan were 2.42, 2, and 2.17 acc./day/km., respectively.

Table 3. The results of the *post-hoc* test: pairwise Mood's Median test for accident rates

Comparison	p −value	The decision at α = 0.05
Before *vs.* Ramadan	0.01945	They are different
Before *vs.* After	0.34990	They are NOT different
Ramadan *vs.* After	0.03545	They are different

Table 4. The results of the *post-hoc* test: pairwise Mood's Median test for number of accidents

Comparison	p −value	The decision at α = 0.05
Before *vs.* Ramadan	0.00719	They are different
Before vs After	0.24250	They are NOT different
Ramadan *vs.* After	0.02633	They are different

Modeling Accidents in Ramadan

Traffic accident data of Ramadan from 2013 to 2016 was used to develop daily accident rate and number of accident models. From 2013 to 2016, the total number of fasting days was 118. Thus, a total of 118 accident rates or number of accidents was used in the analysis. Based on the steps outlined in the methodology, Figure10 shows daily accident rates for the included years. The result of the Augmented Dickey-Fuller test indicated that the time series was stationary

(D-F value = -7.677, P-value = 0.01). For accident rate, the optimal model based on the lowest value for an AIC was $ARIMA(9,0,8)(0,0,0)_{29}$. The parameters of the accident rate model were estimated by the Conditional Sum of Squares (CSS) method and the estimated values are shown in Table 5. Table 6 illustrates the parameter estimates for the daily number of accident model. At the level of risk of 5 per cent, Box-Ljung test of residuals indicated that the model did not exhibit a lack of fit and the Jarque-Bera test showed that the residuals were normally distributed and not correlated. Therefore, validations of the developed models for accident rate and number of accidents in Ramadan are not questionable. Table 7 summarizes the accident rate and the number of accident models and values of MAPE for each model. Based on the MAPE values, the developed accident rate and the number of accident models provided medium accuracy (Lewis, 1982). Comparisons between actual and predicted accident rates and numbers of accidents on specific days of Ramadan in 2017 are shown in Table 8. According to the developed accident rate model, Figure 11 illustrates the predicted daily accident rates in 2018 and 2019, using 80 and 95 per cent confidence levels.

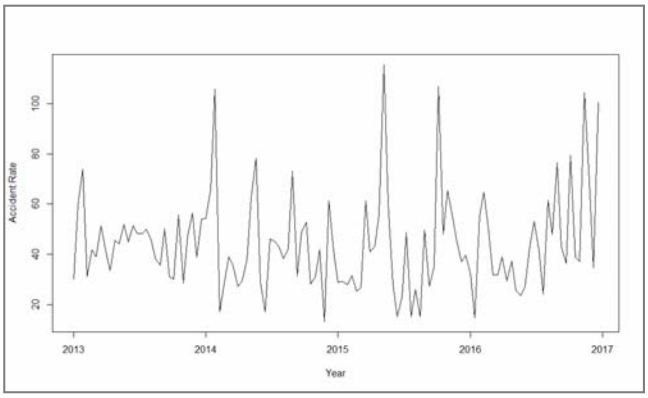

Figure (10): Time-series accident rates during Ramadan

Table 5. The estimation of accident rate model parameters

Coefficients	Estimated Parameter	Standard Error
δ	49.7068	0.3832
α_1	−0.0766	0.0278
α_2	−0.1489	0.0283
α_3	0.2502	0.0356
α_4	0.2499	0.0276
α_5	−0.2080	0.0362
α_6	−0.2520	0.0263
α_7	−0.1165	0.0131
α_8	−0.5847	0.0142
α_9	0.1872	0.0417
β_1	0.3105	0.0187
β_2	−0.1680	0.0227
β_3	−0.1734	0.0247
β_4	−0.4554	0.0188
β_5	0.3974	0.0279
β_6	0.3881	0.0372
β_7	0.1158	0.0292
β_8	1.0294	0.0323

Table 6. The estimation of number of accident model parameters

Coefficient	Estimated Parameter	Standard Error
δ	2.4289	0.0096
α_1	-0.3560	0.0051
α_2	0.5180	0.0058
α_3	-0.4912	0.0068
α_4	-0.5533	0.0033
α_5	0.1812	0.0032
α_6	-0.1736	0.0046
α_7	0.0016	0.0053
β_1	0.5667	0.0088
β_2	-0.6551	0.0051
β_3	0.6035	0.0076
β_4	1.1868	0.0105

Table 7. Summary of Ramadan's daily accident rate and number of accident models

Measure	Model	MAPE	Accuracy
Accident Rates	ARIMA $(9,0,8)(0,0,0)_{29}$ or ARIMA(9,8)	33.7843	Medium
Number of Accidents	ARIMA $(7,0,4)(0,0,0)_{29}$ or ARIMA(7,4)	29.0834	Medium

Table 8. Actual and expected data during 2017 based on the time-series model

Month	Day	Accident Rates		Number of accidents	
		Actual	Expected	Actual	Expected
Ramadan	2	32.65394	35.567966	1.6666667	2.359933
	12	43.98983	42.502184	1.5833333	1.974129

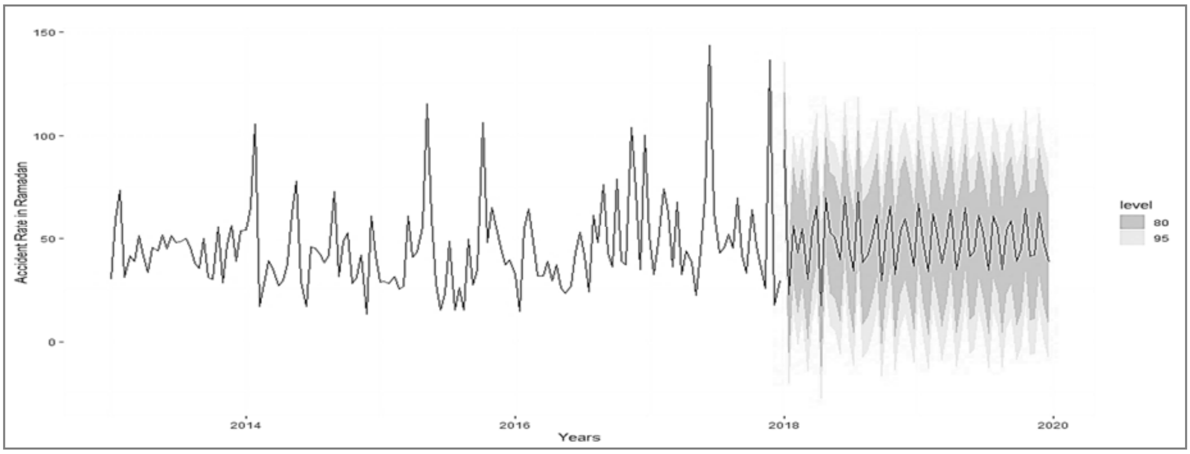

Figure (11): Accident rate forecasting in Ramadan for the years 2018 and 2019

DISCUSSION

This study revealed that daily accident rates and numbers of accidents in Ramadan were found to be significantly higher than accident rates and numbers of accidents in the months before or after Ramadan. On the other hand, daily traffic volumes and hourly peak volume values in Ramadan and in the months before and after Ramadan are approximately comparable. Compared with months before or after Ramadan, however, hourly volume variations indicated that there are considerable shifts in morning and evening volume peaks in Ramadan. These shifts are attributed to government policy decisions to reduce and shift official working hours.

Thus, fasting in Ramadan increases traffic accidents despite the fact that Islam teachings assume that Muslims in Ramadan are more merciful, tolerable and forgiving in their behavior with others. In contrast, a considerable number of fasting people show nervous, less patient and intolerable behaviors. Probably, such aggressive behaviors might contribute to the increase in accidents in Ramadan. Another probable cause may be attributed to drivers' exhaustion due to fasting on a long summer day. In Jordan, fasting time sometimes extends to about 16 hours in the summer season. Empirical evidence as well as Figure 8 indicate that hourly accident rate in Ramadan increases from 2 to 5 PM, while during this period, traffic hourly volumes decrease continuously (see Figure 4). Thus, we recommend conducting further studies to highlight the issue of accident increase in Ramadan from medical and behavioral viewpoints.

Furthermore, empirical data indicated that the largest daily accident rate occurred on Fridays of Ramadan, despite the fact that this day experienced the lowest traffic volume. On Fridays, it is common to invite relatives for Iftar as one of the Ramadan traditions in Jordan and other Muslim societies. These trips are normally executed in rush and just before the Iftar and may contribute to such an increase in accident rates on Fridays.

Finally, daily accident rate and number of accidents were modeled using a time-series approach. In this study, it is worth noting that the autoregressive integrated moving average ARIMA is an adequate model to interpret, predict and forecast daily accident rates and numbers of accidents during Ramadan months in Jordan. Furthermore, parameter estimates of the developed ARIMA models had small standard deviations (see Tables 4 and 5). The obtained models did not exhibit a lack of fit and residuals were found to be normally distributed. Thus, ARIMA models developed in this study are a reasonable choice to model accidents in Ramadan, stressing that they provide a medium level of accuracy.

CONCLUSIONS

Although peak hourly traffic volumes in Ramadan as well as in months before or after Ramadan were comparable, peak volumes in Ramadan were shifted as a result of the governmental policy regarding official working hours. The results of the study indicated that ADT values in Ramadan were insignificantly different from ADT values in months before or after Ramadan. In contrast, traffic accident rates and numbers of accidents in Ramadan were found to be significantly higher than the corresponding values in months before or after Ramadan. Also, results indicated that the largest daily accident rate occurred on Fridays of Ramadan, despite the fact that this day experienced the lowest traffic volume. Using time-series analysis, ARIMA (9, 8) and ARIMA (7, 4) were found to be suitable to model accident rates and numbers of accidents in Ramadan, respectively. Compared with observed values, however, these models provided moderate accuracy. Finally, further studies are needed to explore reasons for the increase in accident experience in Ramadan from behavioral and medical perspectives.

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