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Characteristics of red light running violations in urban areas in Tabuk, Kingdom of Saudi Arabia

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ABSTRACT

This paper aims to assess the characteristics of red light violations in Tabuk city of the Kingdom of Saudi Arabia. The paper also analyzes the effect of intersection characteristics, such as geometric design, control system and location, on number of violations. Data on traffic characteristics and violations, intersection geometric design (road width, number of lanes, speed) were collected at 38 intersections in Tabuk using video cameras. Statistical analysis reveals that number of approaches, speed, road width, speed on cross road, and width of cross road significantly affects red light violation. Regression analysis implies that road width, red time and speed are the most important factors affecting red light violation.

1. Introduction

Traffic violations, particularly red light violation, are one of the major causes for traffic accidents. Al-Ghamdi [1] indicated that red light running at intersections is the major cause for accidents in Saudi Arabia. It is a big challenge to the transport professionals in the Kingdom of Saudi Arabia (KSA) because of the rise of human fatalities and associated financial losses which result from red light violations. The number of deaths resulting from accidents on national level was 6124 in 2010. Arriyadh Development Authority (ADA) [2] estimated the financial losses to exceed 13 billion Saudi Riyals in the year 2005.

The main goal of installing a traffic signal is to increase the level of traffic safety at intersections by giving priority to each direction and eliminating conflicts. Al-Ghamdi [3] indicated that the main cause for accidents at intersections is running the red lights. The study shows the danger of running a red light and its impact on the level of safety at traffic intersections.

Despite the continuous efforts from local authorities and awareness campaigns in different media means, traffic violations and accidents continue to increase and claim the lives of hundreds of people in the KSA every year. Despite the challenges represented by the traffic violations, there exists dearth of literature and studies that investigate those accidents and their causes through comprehensive data collection and analysis. This lack of literature signifies the importance of this study which aims at studying the characteristics of red light running in Tabuk and identifying the factors that affect them.

The subsequent sections of the paper present the aim of the study, the relevant literature review, research methodology and data analysis. Finally discussions of the results and the conclusions are also included.

2. Research aim

This paper addresses the problem of red light running in Tabuk city of the KSA. The paper aims to analyze the extent of the problem in the city and examine the effects of geometric properties and spatial characteristics of the intersection in Red Light Running (RLR).

3. Literature review

Bonneson and Zimmerman [4] identify the vehicle that runs the red light as: "a vehicle that enters the intersection or passes the stop line after the red light turns on". This means that it is legal for a motorist to pass the stop line when the light is yellow.

Federal Highway Administration has estimated that the cost of red light running crashes amounted to more than 7 billion dollars in the year 1998 [5]. Table 1 shows the red light running rates from previous studies. From the table, it can be seen that the rates vary widely. Most of the previous studies of red light violation focused on analyzing the extent of traffic violations. Retting et al. [6] observed red light running violation rate of 1.3 for every 1000 vehicles in the United States, and that the rate is 3 violations an hour. Another study reported rates ranging from 0.45–38.5 violations for every 1000 vehicle [7,8].

Studies have shown that the frequency red light running violations increase with the volume of traffic and with the increase of the time

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Table 1
Red light running rates in different countries.
Source: [9].

Location	Number of intersections	Average violations per 1000 vehs	Max reported rate of red light violations	Min reported rate of red light violations
Oxnard, CA	14	1.32	NA	NA
Fairfax, VA	9	3.68	NA	NA
Arlington	2	3	NA	NA
Iowa	13	NA	38.5	0.45
Texas	5	4.1	10.8	NA
Australia	15	3.9	NA	NA
Tuscaloosa, AL	3	5.3	29	0.47

of the signal cycle [7,10]. Baguley [11] noted the negative correlation between the volume of traffic and the number of red light running violations (i.e. red light running violations increase with volume of traffic). He also found that there is a negative relationship between the number of violations and volume of traffic in the minor street of the intersection. Bonneson and Zimmerman [12] investigated the effect of changing the yellow light interval on red light running violations. The study showed that increasing the yellow light interval results in lowering the number of red light violations. Datta et al. [13] claimed that the design of the signal cycle is an effective factor on increasing or decreasing red light running violations.

Local studies such as Al-Ghamdi [3] showed that most types of accidents that take place at intersections in Riyadh are usually the right-angle collisions which explain the fact that the red light is not very efficient in preventing side-crashes between vehicles at intersections. The study of Koushki and Al-Ghadeer [14] indicated that Saudi drivers are non-compliant of traffic rules as compared to drivers of other countries. The study revealed that red-light running, moving during red-light phase, and speeding up to pass through during yellow phase are highly prevalent at intersections in Riyadh. Al-Ghamdi [3] emphasized on the scarcity of research in KSA on the characterization of traffic violations at intersections and devising solution techniques.

Review of the literature of local studies reveals the scarcity of research that analyzes the characteristics of red light running violations. In this study, the volume of traffic at the intersection, the width of the street, the speed limit and the number of lanes will all be studied as variables that determine the engineering attributes of the intersections affecting red light violation. The study will also focus on the effect of intersections location on red light violation through distance from the nearest signalized intersection and distance from the central business district (CBD).

4. Data collection

This research deals with the problem of red light running traffic violation in Tabuk city. Tabuk is one of the largest and rapidly growing cities in the Kingdom of Saudi Arabia. It is situated in the north of the country and is strategically important for its role as the gateway to the Mediterranean countries. Its population is about 0.5 million with a rate annual growth of 2.5%. Tabuk is an example of a typical Saudi city that is mainly car dependent. Car ownership rate is about 1.8 cars/household. Urban density of Tabuk is very low (100 person/hac).

Data collection has been carried out during the period between 17th September to 24th October, 2011. All traffic surveys were carried out during working days of the week (Saturday to Wednesday), during morning period (6.00 am to 9.00 am) and evening period (6.00 pm to 9.00 pm). The study focused on collecting the following data which are relevant to the nature of the research:

- Intersection engineering characteristics. These include the type of the intersection (number of legs in each intersection), number of lanes in each leg, width of the road, speed limit in each intersection leg and the signal cycle.
- Intersection location characteristics. These include the distance of the nearest signalized intersection and the distance to the CBD.
- Traffic characteristics of the intersection. These include volume of traffic in each leg and the total volume of traffic of the intersection.
- Red light running violation. This includes the number of vehicles that runs the red light as compared to the number of cars allowed to pass the intersection.

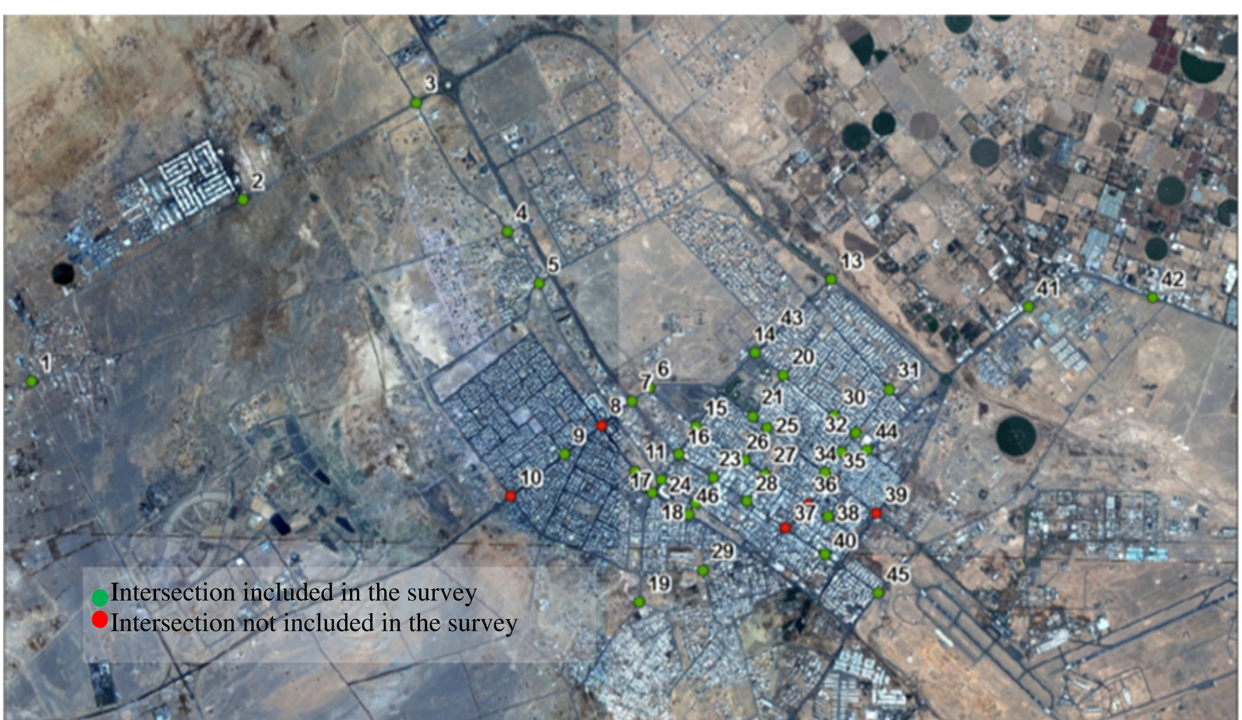

Fig. 1. The locations of controlled intersections in Tabuk.

Table 2
Descriptive statistics of red light violation in Tabuk city.

Variable	Mean	Minimum value	Maximum value	Standard deviation
Total number of violations in the period of the survey (6 hours)	503	155	1073	225
Average of vehicles that had the chance to run the red light	2245	1363	4048	514
Traffic volume at the intersection during the period of the survey (6 hours)	15035	5022	29480	6584
Average of violations to every 1000 vehicles	31.5	2.95	178	22.83
The rate of violation to the number of vehicles that could run the intersection during the survey (6 hours)	22	7.8	45	6.82

Out of forty-six controlled signalized intersections in Tabuk, thirty-eight were included in the field survey because surveys were not allowed in the other six intersections due to security restrictions and maintenance work being carried out at the other two of the intersections. Fig. 1 shows the location of traffic light signals included in the study.

Preliminary data were collected by field measurements of the engineering characteristics of the intersections and data related to the traffic volume and red light traffic violations were collected by using video camera recordings.

5. Research variables

The variables included in the study are summarized below:

1. Traffic directions: The direction of the traffic affects the violations because of the relationship between visibility and direction. For example, in the case of Tabuk, during the morning period, it is supposed that traffic that moves towards east is affected by the limited visibility.
2. Speed: Speed was recorded by using speed limit signs on the roads. Speed was estimated on roads that do not have speed signs by taking the speed on roads with similar characteristics. The study assumes that by increasing the speed of the vehicles, violations increase because of the difficulty in controlling deceleration in the right time.
3. The speed of traffic in the cross road: This gives an indication of the type of the cross road. The study assumes that by increasing the speed of traffic in the cross road, the red light running violations become fewer because the driver on the target road becomes afraid of accidents while running a red light.
4. The width of the cross road: It is the distance that a driver passes when they run a red light. The study assumes that the wider the cross road is, the more hesitant the driver is to run the red light.
5. The traffic volume of the intersection: This includes the volume of traffic of all the legs of the intersection. The study assumes that by increasing the volume of traffic, the number of violations will decrease.
6. The number of traffic lanes of the direction under consideration: This variable records the number of lanes in the direction of the traffic movement. The higher the number of lanes, the more traffic violation there will be.
7. The red light interval: This is the time that cars stop at the traffic light. It is assumed in this study that the longer the red light interval is, the more violations will happen because drivers try to avoid the long wait.

6. Data analysis

Different statistical methods were used to analyze the data collected for this study. In addition to that, statistical parameters that include percentages, averages and standard deviations of all the independent variables were investigated for the scaled data. This study also uses the analysis of the independent variance and the other variables using the t-test and the Chi-square test. Regression analysis was used to identify the size of the effect of independent variable in the dependent variance. The SPSS software was used to acquire the results of the descriptive and statistical analysis.

The independent t-test assumes the variances of two groups in the data to be equal. If the variances are unequal, this can affect the Type I error rate. The assumption of homogeneity of variance can be tested using Levene's Test of Equality of Variances, which is produced in SPSS when running the independent t-test. This test for homogeneity of variance provides an F statistic and a significance value (p-value). If the significance level is greater than a pre-set critical value of significance (for example 0.05), the two groups' variances can be treated as equal. However, if $p <$ the defined critical p-values, the variances will be unequal and we have violated the assumption of homogeneity of variance. If the Levene's Test for Equality of Variances is statistically significant, and therefore indicates unequal variances, we can correct for this violation by not using the pooled estimate for the error term for the t-statistic.

6.1. The descriptive analysis of red light running violations

The average of red light violations at the sample intersections during the surveyed period is 503 violations per intersection, with an average of 84 violations per hour for each intersection. The highest number of violations observed was 1073 and the lowest number was 155. The rate of the vehicles that ran the red light compared to the vehicles that had the chance to run the light was 22%, which means that one of every 5 vehicles, having the opportunity, runs the red light. Table 2 shows that the rate of the vehicles that run the red light is 32 for 1000 vehicles at the intersection which is ten times higher than the frequency of red-light violations observed in other countries [9].

Table 3 illustrates the change of the characteristics in red light running violations according to the time period (the morning period and the evening period). From the table, it is clear that about 30% of the drivers is more inclined to run the red light in the evening period more than in the morning period (24% violations compared to those who had chance to run the red light during evening period compared to 20% during morning period).

The study also examines the significance of the relationship between the number of violations for every 1000 vehicles and the independent variables using the t-test and the analysis of variance (ANOVA). ANOVA is used in this research to examine the null-hypothesis of positive and significant relationships between violation rate (dependent variable) and the independent variables. The study shows statistical significance at 5% level of significance variance in the average of traffic violation depending on:

- The type of the intersection (Table 4): In this case, we test the null hypothesis for the independent t-test that the population means

Table 3
Temporal characteristics of red light violation in Tabuk.

Period		Number of violation in 3 hours	Violations compared to those who had the chance to run the red light
Morning period	Mean	219	20%
	Minimum value	59	7%
	Maximum value	482	39%
	Standard deviation	107	0.06
Evening period	Mean	284	24%
	Minimum value	90	8%
	Maximum value	707	68%
	Standard deviation	151	0.01

Table 4
t-Test for interaction between rate of red light violation and type of intersection.

		Independent samples test								
		Levene's Test for Equality of Variances		t-Test for equality of means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean difference	Std. error difference	95% confidence interval of the difference	
									Lower	Upper
Violation to 1000 vehicle at the intersection	Equal variances assumed	8.154	.005	3.009	256	.003	3.28	1.092	1.135	5.434
	Equal van axes not assumed			3.022	241.840	.003	3.28	1.087	1.144	5.426

from the two groups of intersections (three-legged intersection, four-legged intersection) are equal. From the results presented in Table 4, it is clear that the significance value (p-value) is less than the critical p-values and therefore we reject the null hypothesis of equal variances between the two types of intersections. Therefore, there are evidence for the effect of the type of intersection and the number of violations. This will be further investigated using regression analysis as discussed later.

- Speed limits (Table 5): ANOVA tests reveal statistically significant F-statistics of the averages of the numbers of violations grouped by the speed limits (40, 60, 80, 110 km/h) on the roads where the violation happens as shown in Table 5. The results imply that the speed of vehicles significantly affect red light violation propensity at signalized intersections.

In this case, we test the null hypothesis for the independent t-test that the population means from the four groups of speeds are equal. From the results presented in Table 5, it is clear that the significance value (p-value) is less than the critical p-values and therefore we reject the null hypothesis of equal variances between the four groups of speeds. Therefore, there are evidence for the effect of the speeds and the number of violations. This will be further investigated using regression analysis as discussed later.

- Speeds on the cross roads (Table 6): The following table reflects the existence of a statistically significant variance between the number of the violation and the speed on the crossed road.

Similarly, Table 6 shows evidence of statistical significance of speeds of the cross roads on the red light violations ($p < 0.05$). The averages of red light running violations also vary significantly with the width of the road as indicated in Table 7.

- Road widths (Tables 7 and 8): Results presented in Tables 7 and 8 show the statistical significance of widths of the target roads and the width of the cross roads on the red light violations. In both cases the significance values are less than the critical values and therefore, there are evidences to suggest that we can reject the null hypothesis of equal variances between the tested groups.

To conclude, the statistics described above reveal marginal relationships among the rate of red light violations and attributes of intersection like speed and width of the crossed road and cross roads. All the variables were found to be statistically significant, and therefore, it can be claimed that all these variables have effects on the red light violations. To assess these effects on the rate of red light violation, regression analysis is used as presented in the following section.

6.2. Regression analysis

In order to assess the effect of the independent variables on the number of red light running violations as the dependent variable at the sampled intersections, a simple regression model has been calibrated. The estimated parameters and statistics of the model are described in Table 9 below.

$$Y = 24.8 - 0.247X_1 – 0.152X_2 - 0.10X_3 + .145X_4 + .001X_5 + .002X_6$$

where

Y	number of violations in each leg/1000 vehicle at the intersection
X_1	width of cross road (m)
X_2	red interval length (seconds)
X_3	speed (km/h)
X_4	road width (m)
X_5	distance to city center (m)
X_6	total traffic volume for each leg (vehicle).

Table 9 shows the coefficient estimates, the t-values, the significance and the R2 of the calibrate model. From the table, it appears that most of the estimated parameters were found to be statistically significant at 95% level of significance, with the exception of the speed of traffic on the target road which is statistically significant at 90% level. The table also shows that red light violations decrease with the increase of each width of cross road, red cycle length and the speed. The model further reveals that red light violations increase with the increase of the width of the approach road. Also, the propensity of red light violation increases with the increase in the distance from CBD and traffic volumes at the rate of 1 violation for each 1 km of distance from CBD and 2 violations for each 1000 traffic.

Although the goodness of the model is low ($R^2 = 0.24$), the model provides significant insight of relative importance of different parameters

Table 5
Statistics for red light violation among intersections classified by approaching vehicle speed.

ANOVA					
Violation 1000 vehicle					
	Sum of squares	df	Mean square	F	Sig.
Between groups	1724.799	3	574.933	7.834	.000
Within groups	18642.090	254	73.394		
Total	20366.889	257			

Table 6
Statistics for red light violation among intersections classified by speed of cross road.

ANOVA					
Violation to 1000 vehicle at the intersection					
	Sum of squares	df	Mean square	F	Siq.
Between groups	1130.194	3	376.731	4.974	.002
Within groups	19236.695	254	75.735		
Total	20366.889	257			

Table 7
Statistics of red light violation among intersections classified by width.

ANOVA					
Violation 1000 vehicle at the intersection					
	Sum of squares	df	Mean square	F	Sig.
Between groups	1166.702	7	160.672	2.170	.037
Within groups	19200.188	250	76.801		
Total	20366.889	257			

affecting the rate of red light violations at signalized intersections. It should be noted here that one important use of such models is that it provides useful tools for policy makers to assess the impacts of each of the independent variables in the model on the rate of red light violation, and predicts numerical values for changing these variables, hence reducing the rate of red light running to acceptable rates.

7. Discussions

This study clearly reveals the problem of red lights running in the Saudi cities, where the average rate of violation is 32 for every 1000 vehicles which is ten times higher than the rate in the USA and Australia. It also reflects the aggressive driving behavior of the Saudi drivers relative to drivers in other countries. This is clear from the high percentage of vehicles that run red light to those drivers who had the chance to run the red light as one out of five vehicles actually commits the violation having the opportunity.

This study provides evidence of the importance of engineering characteristics of road width, speed on the road, the width of the crossed road, the speed on the cross road, and the volume of traffic which significantly affects the rate of red light violations.

This study reflects the significance of the effective traffic control in intersections in controlling red light violations. The interval of the red light affects the number of the violations with negative relation between the red light time interval and the number of traffic violations. It also shows the importance of the distance to the city's center, where the number of violations increases in areas away from the city center.

Further research is needed to be undertaken to study the impact of socio-economic characteristics of the Saudi driver and their driving behavior towards red light violation. Also, further research in areas such as awareness and enforcement is important to reach better understanding of red light violations in KSA.

8. Conclusions

This study shows that the average level of red light running in Tabuk, Saudi Arabia, is about ten times higher than in the US or Australia. These levels are unacceptable and therefore indicate that traffic signals there are an ineffective way of controlling traffic. A solution needs to be found in order to reverse these trends. The solution could be by raising awareness of drivers and more education measures to be introduced as well as more vigorous enforcement measures to be implemented in the Kingdom.

Table 8
Statistics of red light violation among intersections classified by the width of cross road.

ANOVA					
Violation to 1000 vehicle at the intersection					
	Sum of squares	df	Mean square	F	Sig.
Between groups	2100.615	7	300.088	4.107	.000
Within groups	18266.274	250	73.065		
Total	20366.889	257			

Table 9
Estimated parameters of the regression model.

Model summary				
Model	R	R square	Adjusted R square	Std. error of the estimate
1	.486[a]	.236	.218	7.072

ANOVA[b]					
Model	Sum of squares	df	Mean square	F	Sig.
1 Regression	4812.045	6	802.008	12.942	.000[a]
Residual	15554.844	251	61.971		
Total	20366.869	257			

Variable	Coefficients (t-value)	Significance
Constant	24.844 (6.669)	0.000
Cross road width (meters)	−0.247 (−4.868)	0.000
Red cycle length (seconds)	−0.152 (−4.433)	0.000
Speed (km/h)	−0.101 (−1.915)	0.057
Road width (m)	0.145 (2.570)	0.011
Distance to CBD	0.001 (2.653)	0.008
Total traffic volume (3 h)	0.002 (3.009)	0.003
R^2	0.236	

[a] Predictors: (Constant), total traffic volume (3 h), red cycle Length, speed, road width of cross road, road width, distance to CBD(m).
[b] Dependent variable: Violation to 1000 vehicle.

Moreover, the study reveals that the average level of red light running correlates positively with road width, distance to city center, and total traffic volume on each leg, while it correlates negatively with width of crossed road, length of red interval, and speed. The study recommends further research into the factors that affect this phenomenon and conduct further research on the characteristics of the drivers who commit such violations because social factors are expected to have a role in causation of this problem in Saudi cities.

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