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# Red-light Violations at Urban and Sub-urban Traffic Signals in Jordan

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## ABSTRACT

This study aimed to investigate red-light violations and their influencing factors at traffic signals in four major cities in Jordan. Field data was collected from 30 traffic signals in Amman, Zarqa, Jerash and Irbid cities. The intersection type, leg grade and speed of the subject's approach data was collected through field surveys and measurements, while the red-light violation data was collected from the recorded videos. The study analysis showed that among 3,444 drivers who had the chance to violate a red light, 436 (12.66%) drivers ran a red light. Pickup drivers had the highest violation rate among all drivers, with a rate of 21.4%, while heavy-vehicle drivers showed the lowest percentage of violation, at 11.18% for buses and 8.24% for trucks. The analysis showed that four-leg intersections had a higher violation rate than three-leg intersections. Also, drivers tended to show more violations on upgrade intersection approaches, with almost the same violation behavior on level and downgrade intersection approaches. According to traffic movement type, the analysis results showed that through-moving vehicles had the highest violation rate among all movement types, followed by left-turners, while the lowest violation rate was observed among U-turn movements. Referring to the location of the intersection, the violation rate was 13.48% in urban areas and 11.37% in sub-urban areas. The results showed that drivers tend to violate red lights more during fall than in spring. It was found that about 21% of drivers who arrived at the intersection at the beginning of red time violated the red light, while only 3.53% violated the red light during the rest of the red time interval. In addition, the percentage of red-light violations was directly proportional to the subject approach speed and total traffic volume entering the intersection and was inversely proportional to the conflicting traffic volumes.

**KEYWORDS:** Intersection safety, Traffic signal, Traffic violation, Urban, Sub-urban, Red light, Driver behavior.

## INTRODUCTION

Intelligent transportation systems (ITSs) can use artificial intelligence (AI) to predict traffic conditions and driver behavior on specific road segments and intersections (Alomari et al., 2020). At signalized intersections, incorrect driver decisions can result in right-angle collisions, left-turn collisions, rear-end collisions or red-light violations (RLVs). RLV and inconsistency in stopping are risk factors for traffic accidents at signalized intersections (Hussain et al., 2020). Several RLVs occurred due to drivers remaining in dilemma zones during the yellow phase. At the start of the yellow phase, dilemma zones appear upstream of the approach to the intersection (Elmitiny et al., 2010). Wang et al. (2016) defined a "red-light runner" as a vehicle that passes through the intersection after the traffic signal light turns red. Several studies have investigated the RLV problem. In Jordan, a study was conducted at traffic signals in rural and sub-urban areas and found that 12.9% of drivers who had the chance of violation ran red lights (Al-Omari & Al-Masaeid, 2003). A similar study in Saudi Arabia showed that 22% of

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drivers who had the chance of violation ran red lights (Al-Atawi, 2014).

Some studies found that male drivers were more likely to run red lights (Wang et al., 2016; Retting et al., 1999; Gopaul et al., 2016), as well as motorcycle riders (Jensupakarn & Kanitpong, 2018). Although Wang et al. (2016) have observed that safety belts and hand-held cell phones did not significantly affect RLV, Retting and Williams (1996) noted that red-light runners at urban intersections were less likely to wear seat belts. In Virginia, United States, the primary driver-influencing factors were using safety belts and ethnicity, as unbuckled and non-Caucasian drivers were more likely to run red lights (Porter and England, 2000). Also, a study in Trinidad showed that Indo-Trinidadian drivers display a higher tendency towards RLV (Gopaul et al., 2016). Younger drivers tend to run red lights more than older drivers, as concluded from previous studies (Retting et al., 1999; Retting & Williams, 1996; Al-Omari & Al-Masaeid, 2003; Porter & Berry, 2001). Furthermore, red-light runners among motorcycle riders tend to be younger and do not always wear helmets (Porter & England, 2000).

A study in the United States showed that red-light runners were more likely to have prior moving violations and convictions for driving, while intoxicated had invalid driver's licenses and have consumed alcohol prior to the crash (Retting et al., 1999). Red-light runners also had poorer driving records and drove smaller and older vehicles (Retting & Williams, 1996). Frustration was not as significant in predicting red-light running, as it was for other driving behaviors, such as speeding and tailgating (Porter & Berry, 2001).

The road environment also influences RLV behaviors at the intersection (Jensupakarn & Kanitpong, 2018). Several studies have shown that the intersection geometry significantly affects the frequency of RLVs. Al-Atawi (2014) found that the RLV rate is directly proportional to road width and distance from the city center. Also, Chen et al. (2017) found that wider exits are responsible for higher RLV frequencies. In addition, Y-shaped intersection had a higher percentage of RLV than T-shaped and cross-shaped intersections (Al-Omari and Al-Masaeid, 2003).

Al-Atawi (2014) and Chen et al. (2017) found that the RLV rate increases with the total traffic volume at the intersection. However, the percentage of RLV was found to be inversely proportional to the conflicting traffic volumes (Al-Omari & Al-Masaeid, 2003) and directly proportional to the flow rate on the subject approach (Bonneson and Son, 2003). The operating speed has played a significant role in RLV rates (Elmitiny et al., 2010). RLV rates increase with the increase of the subject's approach traffic speed (Al-Omari & Al-Masaeid, 2003; Al-Atawi, 2014) and the decrease of the crossroad traffic speed (Al-Atawi, 2014).

Red-light cameras are one type of enforcement countermeasures that are used worldwide to reduce RLV rates (Shaaban & Pande, 2018). The main aim of camera enforcement is to alter drivers' behavior by respecting red lights at intersections (Ahmed & Abdel-Aty, 2015). Red-light cameras have successfully reduced RLV rates by nearly 42% after the enforcement program began in the city of Oxnard, CA (Retting et al., 1999). Another study in Davenport found that red-light cameras effectively reduced overall traffic crashes and RLV-related crashes (Hallmark et al., 2010). Al-Mistarehi et al. (2021) investigated the factors influencing driver performance during the yellow phase at signalized intersections equipped with or without red-light running (RLR) cameras. Results showed that only 33.3% of drivers came to a complete stop before the stop line, while 7% committed RL violations. The findings also indicated that drivers were more likely to stop before the stop line during the yellow phase in locations equipped with RL cameras, green-light flashing devices, pavement markings, pedestrians and four-leg intersection.

Red-light violation (RLV) is a traffic-safety problem at traffic signals in Jordan and worldwide. This problem has been investigated in different countries with less attention in Jordan that had only few previous studies for RLV at rural and sub-urban traffic signals (Al-Omari & Al-Masaeid, 2003; Al-Mistarehi et al., 2021). This research aimed at studying RLV inside four major cities in Jordan and identifying the main influencing factors.

## DATA COLLECTION AND REDUCTION

A total of 30 traffic signals located at four major cities in Jordan (Amman (the capital), Zarqa, Jerash and Irbid) were selected for the purpose of this study. The intersections have good pavement conditions, different geometric and operational characteristics and no police

presence or red-light camera enforcement. Data was collected during evening peak periods of fall 2018 and spring 2019 (Friehat, 2019). The intersection type, grade and speed of the subject approach data was directly collected from the field, while the rest of data was collected from the recorded videos.

The 85$^{th}$ percentile speed was considered as the operating speed. It was calculated at each selected intersection subject approach from the measured speeds of 100 random vehicles that were in free-flow conditions before deceleration to slow down at the intersection utilizing a trap of 30 meters (vehicle speed equals the division of 30 meters by the vehicle crossing time over the trap).

## ANALYSIS AND RESULTS

This study has focused on observing 3444 drivers who had a chance of violation (arrived at the traffic signal during the red time and had to choose between stopping or running the red light). A total of 436 drivers violated the red light, constituting 12.66% of all observed drivers at the 30 selected traffic signals. This is very close to the finding of a previous study at traffic signals in rural and sub-urban areas of Jordan that found an RLV rate of 12.9% (Al-Omari & Al-Masaeid, 2003). The following analysis presents the effect of each considered factor on RLV.

### Effect of Vehicle Type

The results of the analysis, as presented in Table 1, showed that pickups had the highest violation rate of 21.39% and heavy vehicles (buses and trucks) had the lowest violation rates of 11.18% for buses and 8.24% for trucks.

**Table 1. Driver violation rates for different vehicle-type categories**

| Vehicle type | Number of drivers who had a chance for violation | Number of violations | Percentage of violation (%) |
|---|---|---|---|
| PPC | 2271 | 277 | 12.2 |
| Pickup | 201 | 43 | 21.39 |
| Taxi | 311 | 37 | 11.9 |
| Van | 233 | 39 | 16.74 |
| Bus | 161 | 18 | 11.18 |
| Truck | 267 | 22 | 8.24 |

Detailed analysis showed that private passenger car (PPC) and taxi vehicles had similar violation rates of about 12%, while vans had a violation rate of 16.74%. The effect of vehicle type is significant at 95% confidence ($\chi^2$ = 11.698, d.f. = 5, p = 0.00 <0.05). By comparing this result with a previous study conducted in Jordan by Al-Omari & Al-Masaeid (2003), which concluded that truck drivers showed the highest violation rates, in this study, truck drivers had the lowest violation rate. This difference may be explained by the expected different truck-driver behaviors in urban and rural areas. In addition, both studies revealed that bus drivers showed a low violation percentage among all vehicles, which can be referred to as drivers' commitment toward passengers.

### Effect of Intersection Type

The study has included 16 three-leg intersections and 14 four-leg intersections. From the 1794 drivers who had a chance for violation at the three-leg intersections, 193 drivers ran red lights (14.73%), while from the 1650 drivers who had a chance for violation at the four-leg intersections, 243 drivers ran red lights (10.76 %). The four-leg intersections had a higher violation rate with significant differences at 95% confidence ($\chi^2$ = 17.11, d.f. = 1, p = 0.002 <0.05).

### Effect of Movement Type

The results of the analysis, as presented in Table 2, showed that right-moving vehicles had the highest violation rate of 15%, followed by through-moving vehicles with 14.15% and then left turn-moving vehicles

with 9.75%. The lowest violation rate was observed among U-turn-moving vehicles with 5.8%. However, this difference was not significant at 90% or 95 % confidence ($\chi^2$= 17.636, p =0.127). By combining all turning movements together (left, right and U-turn) and comparing them with those of through-moving vehicles, the results showed an RLV rate of 9.96% for the turning vehicles with a significant difference from the through-moving vehicles at 90% confidence ($\chi^2$= 9.219, p = 0.056). This result agrees with the results obtained by an observational study conducted by Wang et al. (2016) at four intersections in Shanghai, China, which showed that, among the RLR vehicles, 62% went straight and 38% turned left at the onset of red.

**Table 2. Driver violation rate for different movement types**

| Movement type | Number of drivers who had a chance for violation | Number of violations | Percentage of violation (%) | |
|---|---|---|---|---|
| Through | 2219 | 314 | 14.15 | 14.15 |
| Left | 1056 | 103 | 9.75 | 9.96 |
| Right | 100 | 15 | 15 | |
| U-turn | 69 | 4 | 5.8 | |

**Effect of Grade**

The results of the analysis, as presented in Table 3, show that the highest violation rate of 18% was committed by drivers on upgrade approaches, with violation rates of 12.03% on level approaches and 10.66% on downgrade approaches, with a significant difference at 95% confidence ($\chi^2$ = 23.69, d.f. = 2, p = 0.003 <0.05).

**Table 3. Driver violation rate for different grades**

| Grade | Number of drivers who had a chance for violation | Number of violations | Percentage of violation (%) |
|---|---|---|---|
| Upgrade | 495 | 89 | 17.98 |
| Downgrade | 572 | 61 | 10.66 |
| Level | 2377 | 286 | 12.03 |

**Effect of Arrival Time**

Considering the time of vehicles' arrival with respect to the start of red time (vehicles that arrived at the beginning of or during red time), the results of the analysis showed that from the 1803 drivers who had a chance for violation at the beginning of red time, 378 drivers ran red lights (21%), while from the 1641 drivers who had a chance for violation during the red time, 58 drivers ran red lights (3.53%). The effect of vehicles' arrival time with respect to the start of red time is significant at 95% confidence ($\chi^2$ = 138.8, d.f. = 1, p < 0.05).

**Effect of Season**

The collected data included 1003 drivers who had a chance for violation during the fall season and 2441 drivers who had a chance for violation during the spring season. The results of the analysis showed that the percentage of violation during the fall season (16.95%) is higher than that during the spring season (10.9%), with a significant difference at 95% confidence ($\chi^2$ = 21.429, d.f. = 1, p < 0.05).

**Effect of Intersection Location (City)**

A total of 30 signalized intersections were selected for this study; 10 intersections in Irbid city, 8 intersections in the capital Amman city, 7 intersections in Zarqa city and 5 intersections in Jerash city. As presented in Table 4, the analysis results show that Jerash had the highest violation rate with 21.63%, which is much higher than for the other three cities that had violation rates of around 12%. This may refer to more

police enforcement and the common presence of red-light cameras in these relatively large cities compared to the smaller size of Jerash city. The city effect is significant at 95% confidence ($\chi^2 = 46.398$, d.f. = 3, $p < 0.05$). This result agrees with the findings of a study conducted on six intersections located in three Southeast Virginia cities by Porter and England (2000), which concluded that the weather factor was not significant, while the city and time factors were significant in predicting RLV frequency.

**Table 4. Driver violation rate for different cities**

| City | Number of drivers who had a chance for violation | Number of violations | Percentage of violation (%) |
|---|---|---|---|
| Irbid | 1390 | 161 | 11.58 |
| Jerash | 453 | 98 | 21.63 |
| Zarqa | 905 | 106 | 11.71 |
| Amman | 813 | 97 | 11.93 |

**Effect of Intersection Location (Inside the City)**

The selected locations included 18 urban intersections and 12 sub-urban intersections. From the 2107 drivers who had a chance for violation at urban intersections, 284 drivers ran red lights (13.48%), while from the 1337 drivers who had a chance for violation at sub-urban intersections, 152 drivers ran red lights (11.37%). The urban intersections had a higher violation rate than the sub-urban intersections, with a significant difference at 90% confidence ($\chi^2 = 9.088$, df = 1, p=0.059).

**Effects of Traffic Volume & Speed**

Traffic volume, speed and driver violation data was collected for each selected approach of the 30 signalized intersections, based on 15-minute time intervals. While observing red-light violations for a specific approach (subject approach), the traffic volumes were also measured at the subject and conflicting (right-hand and left-hand crossing) approaches. To account for the combined effect of the above variables, multiple linear regression modeling was utilized with the possible transformations producing the following model:

$$RLVR = 12.02 + 3.85*10^{-6}S^3 + 4.46*10^{-12}V_t^3 - 8.16*10^{-11}V_c^3 \quad (1)$$

where:

- RLVR: Red-light violation rate (%).
- S: 85$^{th}$ percentile speed.
- $V_t$: Total traffic volume entering the intersection.
- $V_c$: Conflict traffic volume to the subject approach (from left and right approaches).

The regression model and its parameters are all significant at 90% confidence with an $R^2$ of 0.38 and a standard error of the estimate of 0.0871. It can be concluded from the model that the percentage of red-light violations is directly proportional to the subject approach speed and total intersection traffic volume and is inversely proportional to the conflicting traffic volume. This result emphasized the results obtained by Al-Atawi (2014) and Chen et al. (2017). They found that the rate of red-light violations increases with the total traffic volume at the intersection. In addition, the results of a study conducted in Jordan by Al-Omari & Al-Masaeid (2003) indicated that the percentage of red-light violations was found to be inversely proportional to the conflicting traffic volumes and directly proportional to the subject approach speed.

## CONCLUSIONS AND RECOMMENDATIONS

Based on the results of this study, the following main conclusions were drawn:

- The study found that among 3,444 drivers who had a chance for violation during the study period, a total of 436 drivers violated red light with a rate of 12.66%.
- Pickups had the highest violation rate among all vehicle categories with about 21.39% while heavy vehicles (busses and trucks) showed the lowest percentages of violation rates of 11.18% for busses and 8.24% for trucks.
- Four-leg intersections had a higher violation rate (14.73%) than that of three-leg intersections (10.76 %).

- Around 18% of observed drivers on upgrade approaches violated red light, while level and downgrade approaches had fewer violation rates of 12.03% and 10.66%, respectively.
- Right-moving vehicles had the highest violation rate of 15%, followed by through-moving vehicles with 14.15% and then left turn-moving vehicles with 9.75%, while the lowest violation rate was observed among U-turn-moving vehicles (5.8%).
- Jerash city showed the highest violation rate with 21.63%, as compared to the other larger three cities where violation rates were almost the same (around 12%).
- Violation rates were higher at urban traffic signals (13.48%) than at sub-urban traffic signals (11.37%).
- Drivers show more violations of red light during the fall semester than during the spring semester.
- About 21% of the vehicles that arrived at the beginning of red time violated red light, while only 3.53% violated red light during the rest of the red time.
- The percentage of red-light violations was found to be directly proportional with the subject approach speed and total intersection traffic volume and inversely proportional with the conflicting traffic volume.

Further research is recommended to find the effects of other factors on RLV rates, such as the presence of enforcement by police, intersection geometry, road classifications, land use, time of the day, relationship with other violations and driver characteristics.

## REFERENCES


Ahmed, M., and Abdel-Aty, M. (2015). "Evaluation and spatial analysis of automated red-light running enforcement cameras". Transportation Research-Part C: Emerging Technologies, 50, 130-140.

Al-Atawi, A. (2014). "Characteristics of red-light running violations in urban areas in Tabuk, Kingdom of Saudi Arabia". IATSS Research, 37 (2), 119-123.

Al-Mistarehi, B., Alomari, A.H., Obaidat, M.T., and Al-Jammal, A.A. (2021), "Driver performance through the yellow phase using video cameras at urban signalized intersections". Transport Problems, 16 (1).

Al-Omari, B., and Al-Masaeid, H. (2003). "Red-light violations at rural and sub-urban signalized intersections in Jordan". Traffic Injury Prevention, 4 (2), 169-172.

Alomari, A.H., Al-Omari, B.H., and Al-Hamdan, A.B. (2020). "Validating trip travel time provided by smartphone navigation applications in Jordan". Jordan Journal of Civil Engineering, 14 (4).

Bonneson, J., and Son, H. (2003). "Prediction of expected red-light-running frequency at urban intersections". Transportation Research Record: Journal of the Transportation Research Board, 1830, 38-47.

Chen, P., Yu, G., Wu, X., Ren, Y., and Li, Y. (2017). "Estimation of red-light running frequency using high-resolution traffic and signal data". Accident Analysis & Prevention, 102, 235-247.

Elmitiny, N., Yan, X., Radwan, E., Russo, C., and Nashar, D. (2010). "Classification analysis of driver's stop/go decision and red-light running violation". Accident Analysis & Prevention, 42 (1), 101-111.

Friehat, R. (2019). "Red-light violation at urban and sub-urban signalized intersections in Jordan". MSc Thesis, Civil Engineering Department, Jordan University of Science and Technology, Irbid, Jordan.

Gopaul, C., Singh-Gopaul, A., and Chadee, D. (2016). "Red-light running in Trinidad". Journal of Transportation Technologies, 6 (5), 219-238.

Hallmark, S., Orellana, M., McDonald, T., Fitzsimmons, E., and Matulac, D. (2010). "Red-light running in Iowa". Transportation Research Record: Journal of the Transportation Research Board, 2182 (1), 48-54.

Hussain, Q., Alhajyaseen, W.K., Brijs, K., Pirdavani, A., and Brijs, T. (2020). "Innovative countermeasures for red-light running prevention at signalized intersections: A driving simulator study". Accident Analysis & Prevention, 134, 105349.

Jensupakarn, A., and Kanitpong, K. (2018). "Influences of motorcycle rider and driver characteristics and road environment on red-light running behavior at signalized intersections". Accident Analysis & Prevention, 113, 317-324.

Porter, B., and Berry, T. (2001). "A nationwide survey of self-reported red-light running: Measuring prevalence, predictors and perceived consequences". Accident Analysis & Prevention, 33 (6), 735-741.

Porter, B., and England, K. (2000). "Predicting red-light running behavior". Journal of Safety Research, 31 (1), 1-8.

Retting, R., and Williams, A. (1996). "Characteristics of red-light violators: Results of a field investigation". Journal of Safety Research, 27 (1), 9-15.

Retting, R., Ulmer, R., and Williams, A. (1999). "Prevalence and characteristics of red-light running crashes in the United States". Accident Analysis & Prevention, 31 (6), 687-694.

Shaaban, K., and Pande, A. (2018). "Evaluation of red-light camera enforcement using traffic violations". Journal of Traffic and Transportation Engineering (English Edition), 5 (1), 66-72.

Wang, X., Yu, R., and Zhong, C. (2016). "A field investigation of red-light running in Shanghai, China". Transportation Research-Part F: Traffic Psychology and Behavior, 37, 144-153.