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Transportation Research Procedia 45 (2020) 947–954

Transportation Research Procedia

www.elsevier.com/locate/procedia

AIIT 2nd International Congress on Transport Infrastructure and Systems in a changing world (TIS ROMA 2019), 23rd-24th September 2019, Rome, Italy

Comparison of Red-Light Running (RLR) and Yellow-Light Running (YLR) traffic violations in the cities of Enna and Thessaloniki

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Abstract

This paper investigates the characteristics of Red-Light Running (RLR) and Yellow-Light Running (YLR) traffic violations at three signalized intersections which are located in the city of Enna, Italy, and four signalized intersections which are located in the city of Thessaloniki, Greece. The trigger for this particular research is that there are cases in the literature in which the driving styles, as far as compliance with the Highway Code regulations is concerned, change from city to city and from country to country. Two sets of counts were used in the framework of this paper in order to investigate this phenomenon. The first one concerns the year 2018 in Enna and the second one the year 2015 in Thessaloniki. Descriptive and inferential statistics were used in order to analyze the collected data and more specifically to investigate the correlation between the violations at signalized intersections in both cities. One of the most important findings of the specific research is that private cars are the responsible for the vast majority of the violations at the signalized intersections. In addition, it was found that traffic lane plays a significant role in the under study traffic violations.

Keywords: Red-Light Running (RLR), Yellow-Light Running (YLR), Traffic violations, Compliance, Road safety.

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10.1016/j.trpro.2020.02.072

1. Introduction

Signalized intersections have been replaced over the years by roundabouts in many cases in order to minimize the points of conflict between vehicular traffic and pedestrians. It is important to notice at this point that in the case of a 4-armed signalized intersection there are 32 vehicle conflict points. On the contrary, a roundabout has only 8 vehicle conflict points. In addition, non-conventional roundabouts reduce conflicts even further, thus reducing the collision between vehicles in accordance with Tollazzi et al. (2000). In cases where the introduction of roundabouts is not appropriate, emphasis must be given to the effective and safe organization of the conventional signalized intersections. Several studies investigate the propensity of this phenomenon in relation to the traffic light phases. These studies have analyzed and compared different geometrical layouts in order to investigate the most critical component involved. Some studies have also tried to examine the phenomenon of Red-Light Running (RLR) through the use of traffic micro-simulation software, while other studies have evaluated the propensity of users to transgression through logistical models of linear regression (Porter et al., 2000 & Ren et al., 2016). Generally, the study of these violations is essential in order to calibrate the fines to be imposed on offenders, although often the assessment is not easy because it includes several environment/infrastructure and behavioral factors (Baratian-Ghorghi et al., 2016). Another study investigated the traffic violations and risk perception in Greece (Papaioannou et al., 2000). Traffic signal violations at interurban intersections require special attention for motorcycles during left and right turns in the case of low traffic volumes, in accordance with Kokkalis et al. (1997, 2017). The RLR phenomenon also increases with traffic flow, speed, and density. RLR violations were also reduced with the increasing of cycle length and cross-street width (Bonneson & Son, 2016). As far as methodologies for the estimation of the phenomenon are concerned, there are studies related to the technique of machine learning (Jahangiri et al., 2015) or related to the use of high-resolution traffic signal data (Chen et al. 2017). Few studies address the propensity linked to the Yellow-Light Running (YLR) because the yellow phase of the traffic light cycle is considered as a precautionary interval time within which, under certain safety circumstances and Highway Code provisions, it is allowed to cross the intersection without stopping. It is well known that the driving behavior significantly contributes to road safety. When drivers encounter the beginning of the yellow light, they choose to stop or go. A useful tool for safety assessment is the stopping probability curve that model's driver attitude or the discrete choice models. Gazis et al. (1960) analyzed stop probability curves using logistic regression and discussed various scenarios with different approach speeds. Sheffi and Mahmassani (1981) were the first to propose a probit model to characterize the arrest probability curve.

Methods of traffic detection through the acquisition of images from video cameras help towards not only the road safety assessment but also for the detection of traffic data in the various stages of the traffic light cycle. Several studies in the literature consider the different propensities to stop and go of drivers at the interspersed areas (Wu et al., 2012).

Other studies have allowed evaluating how the yellow traffic light can define the "safety zone", "stop zone", "dilemma zone" and "option zone" through the evaluation of the driver's reaction time and the speed of acceleration or deceleration (Lu et al., 2015). However, these values may change based on drivers and vehicles. In accordance with Gialatioto et al. (2012) the dilemma locations vary between different groups of drivers and are so dynamic, the subdivision of the above mentioned dilemma locations (which is based on fixed parameters) can be highly questionable. Therefore, it was considered useful in this paper to compare the results related to different cities, such as Enna and Thessaloniki, in order to allow the propensity of drivers to commit RLR and YLR.

The results of the descriptive and inferential statistics concerning the two cities are presented. Finally, the results for each city, the comparison analysis and the suggestions for future research are presented in.

2. Material and Methods

Two similar observational surveys were carried out at seven different locations (intersections). The first survey was conducted in 2018 in Enna, Sicily and the second one in 2015 in Thessaloniki, Greece. The difference between the two surveys is that audiovisual equipment was used in the first survey in order to record the violations while in the second study, conventional field measurements with observers were used for the necessary data collection. Therefore, Enna's data cover more parameters of the phenomenon. Some key facts about the surveys and the cities are presented herein.

Data collection process was based on random sampling method. It should be noted at this point that the descriptive and inferential statistical analysis was performed with aid of the SPSS v23.0 software. In order to analyze the collected data, descriptive and inferential statistics is used. At first, a descriptive statistical analysis was conducted to understand the factors and the characteristics of RLR and YLR violation in both cities. Subsequently, inferential statistics was carried out to investigate the factors that increase these violations as well as their interrelationship. This analysis was done to draw results for each city separately and also results for a quality comparison between these two cities.

3. Case study

3.1. Enna signalized intersections

The considered signalized intersections considered are the only ones within the urban context of Enna. The analyzed roads are characterized by lane widths of 2.75m and a longitudinal gradient of 15-20%. The vehicle flow was recorded during rush hour on weekdays and holidays and shows a 35-40% reduction over the weekend. Fig.1 shows the location of the three interspersed intersections located in Enna, a small city that rises in the center of Sicily at an altitude of about 1000mt on the sea level. Each case study took into consideration the respective Origin – Destination (O/D) matrices to understand the distribution of the flows associated with the various types of maneuvers. Examined intersections are characterized by the absence of dedicated lanes to buses or heavy vehicles. It must be noted that there are lanes dedicated to the pre-selection of directions.

Fig.1. City center of Enna and Armando Diaz, Monte Cantina and Scifitello intersections (Source: Google, n.d.).

The three intersections serve high volumes of heavy vehicles and buses during the weekdays. Data were recorded from 06:00 a.m, to 23:00 p.m. The highest values concerning vehicular traffic flows appear between 8:00 a.m.-9:00 a.m., 13:00 p.m.-14:00 p.m. and 17:00 p.m.-18:00 p.m. This happens due to arrivals and departures from offices and schools as well as the market opening. The investigated roads also allow reaching logistically important areas such as the open market, the bus terminal and the hypermarkets. They are also interconnected with each other through the provincial road that connects Enna Bassa to Enna Alta, which is one of the main roads connecting the investigated area. The monitored intersections are characterized by 3 or 4 arms and include Viale Diaz, Monte Cantina and Scifitello. The Viale Diaz intersection is closed to the schools and offices in an area adjacent to the city's historic centre. The other two intersections are located near one of the main routes that lead to the city of Enna and therefore they are among the busiest intersections of the area. The environment around the intersection in Viale Diaz is characterized by a high presence of commercial activities and other important land uses (e.g., administration). The other two intersections serve access to the urban area and are characterized by low building density and pedestrian flows. The evaluation of flows and movements was carried out on a daily basis and the derived values were referred to the peak period. Data acquisition took place between September and October 2018. All traffic light cycles last 84 seconds including 30 seconds for green, 49 seconds for red and 5 for yellow light.

3.2. Thessaloniki signalized intersections

The second survey was carried out in July 2015 (Basbas et al., 2017) in the eastern part of Thessaloniki which is

the second largest city in Greece. The case study road axis serves significant traffic flows on a daily basis from suburban areas to the city centre. The land use system in the impact area of the under study road axis is mainly characterized by residential areas and commercial land uses. The case study is a one-way arterial street with three lanes used by the traffic (when the counts took place) directing to the city centre (namely Vassilissis Olgas Str. – Vasileos Georgiou Str.). Four intersections (4-arms intersections) were examined during the period of counts (Vasilissis Olgas Str. – Gravias Str., Vasilissis Olgas Str. – Kriezotou Str., Vasilissis Olgas – Markou Mpotsari Str., Vasileos Georgiou Str. – Napoleontos Zerva Str.) The vehicle categories considered for the purposes of the research include passenger cars, buses, trucks and motorcycles/bicycles. It must be mentioned at this point that the RLR/YLR traffic violations recorded refer to the arterial streets and not to the secondary streets of the intersections. The survey was conducted from the 14th to the 23rd of July 2015. Furthermore, the time period for these measurements was between 8:30-14:30 and 17:00-21:30. Observation time periods have been determined in the most efficient way, so that RLR/YLR can be studied under various traffic volume conditions. More specifically, the observations concerned the following data:

- The indication of traffic light at the time of violation (red/yellow).
- The traffic lane where the violation took place.
- The type of vehicle involved in every violation.

4. Results and discussion

Data collection was followed by analysis in terms of descriptive and inferential statistics. A database was developed in order to facilitate data processing. The statistical analysis was conducted separately for the two surveys. The overall purpose was the comparison between the two datasets in qualitative terms.

4.1. Enna results

The processed data indicates that there are more violations during the first week. These results can be justified by the fact that the first week of the data collection was characterized by better weather condition, when compared to the other two weeks (when the visibility condition were worst). Another fact that may have led the drivers to comply and reduce violations is the place where cameras are placed. The cameras used in the data collection process are located near the road and the drivers may think that these cameras are for enforcement purposes. Fig. 2 shows the trend of the RLR and YLR in the three Italian monitored intersections.

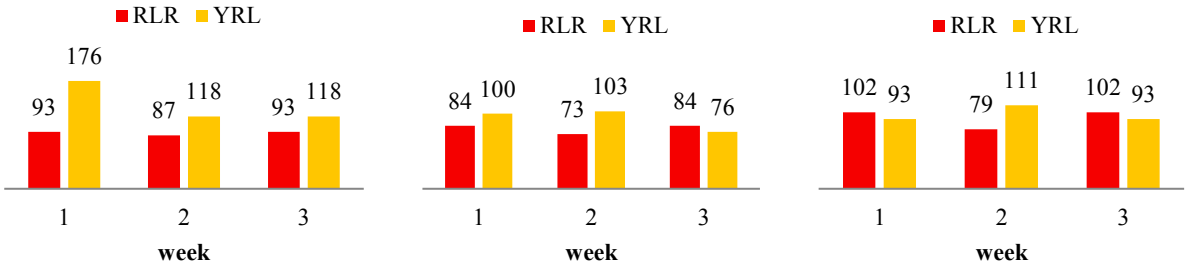

Fig.2. (a) Viale Diaz violations with a peak flow of 1600veh/h (b) Monte Cantina violations with a peak flow of 1400veh/h (c) Scifitello violations with a peak flow of 1300 veh/h.

Having in mind the absence of enforcement, it is noted that the Viale Diaz intersection RLR and YLR violations are equal to 8% and 10% respectively in a situation where the average flow is 1155 veh/h (mediating the peak flow of the weekdays and holidays). The respective values for the Scifitello intersection are 9% and 8%. It is noted that the Scifitello intersection has an average flow of 1385veh/h. Finally, Monte Cantina intersection has respective values of

less than 5% and 6%, with an average flow of 1095veh/h. Fig. 3 presents the violations of RLR and YLR linked to gender. Males are more likely to violate the signalized intersections than the females in Enna.

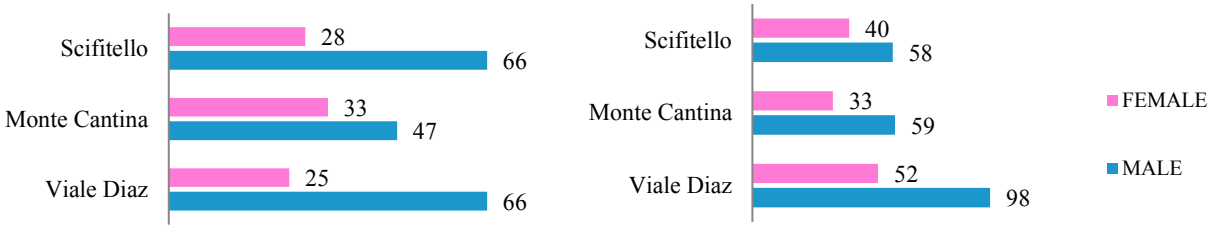

Fig.3. (a) RLR phenomenon linked to gender (b) YRL phenomenon linked to gender (right)

Furthermore, it must be noted that the majority of violation were made by light vehicles(car, light trucks, etc.). This result is included in Fig. 4 (a)-(b) for RLR and YLR violations respectively. Similar results are derived from other case studies as well. This can be justified by the fact that the trajectory of heavy vehicles and buses is larger and therefore they need more time to leave the intersection. Also, two-wheeled vehicles have fewer violations due to the fact of adverse weather conditions. This situation leads to more careful driving by the users.

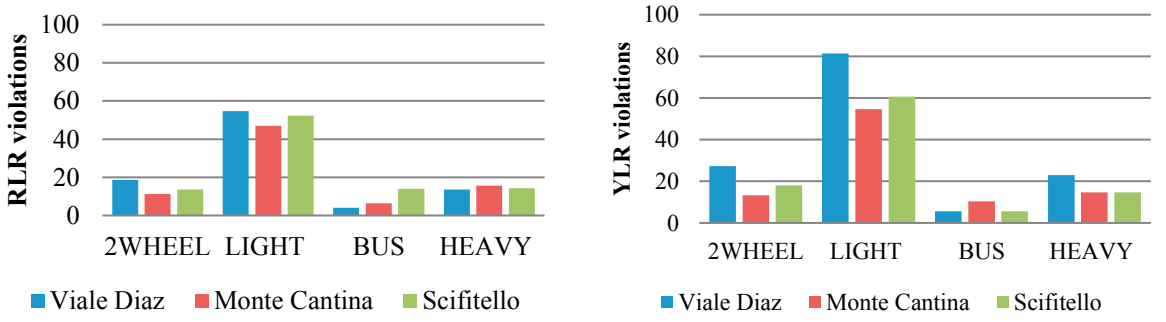

Fig.4. (a) RLR violations per transport mode (b) YLR violations per transport mode

Fig. 5 presents the distribution of violations per type of light vehicles. It should be also noted that the monitoring took place during autumn, a period which is characterized by rain which in turn have made the two-wheeled and heavy-duty vehicles more attentive and diligent. In particular, the graphs below show that cars are the ones with the highest numbers of violations.

Through a comparison with the chi-square method among the variables it was possible to observe that the RLR and the YRL violations can be correlated respectively to the monitoring period (day/night) to the drivers' gender and to the type of vehicle always providing a probability between value observed and expected ($p < 0.05$). From these correlations, it can be noted that males, night and light vehicles increase the probability for more RLR and YLR violations. This value which is close to zero means that the theoretical frequencies and those observed are very close, if not identical. The number of RLR and YRL violations for each intersection was defined through an intensity scale with color from white to burgundy, defining the increasing number of violations. The intersection has been studied over the years considering also possible comparisons of scenarios through the micro-simulation tools of the traffic (Galatioto et al., 2012) and through the fuzzy logic in order to improve the Level of Service (LOS) of the area (Pau et al., 2018). In particular, the Viale Diaz intersection has been characterized by the presence of RLR type violations, especially in the crossing action along the main direction. In particular, the arc A_C (Fig.1) presents the greatest value

of incoming flows along the two directions and the presence of three lanes in arm A (one dedicated to the right turn) and two in C.

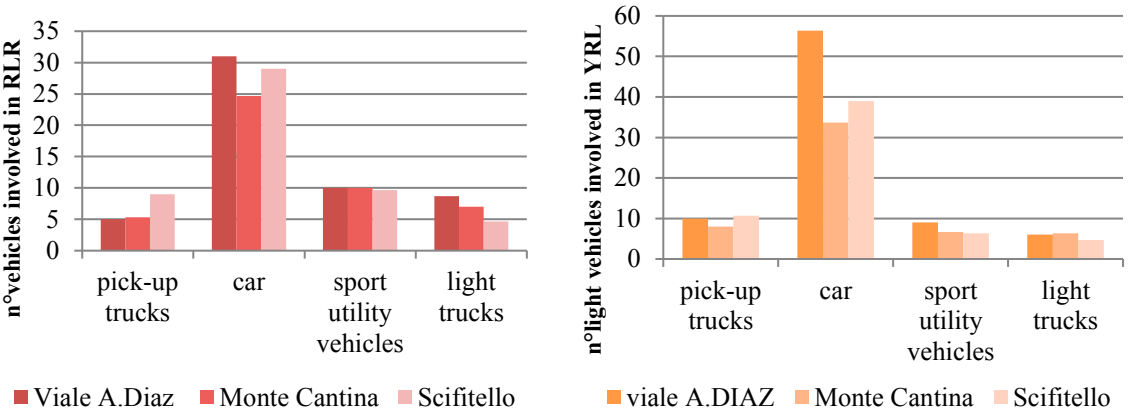

Fig.5. (a) RLR trend related to different Light Vehicle (LV) type (b) YLR trend related to different Light Vehicle (LV) type

4.2. Thessaloniki results

This section presents the descriptive and inferential statistics from Thessaloniki's dataset. Fig. 6 presents the traffic lane which the violation came from and the indication of the traffic light at the time of violation. Fig. 7 presents violations and traffic volume per transport mode.

In Fig. 6 it can be seen that the percentage of violations from the right traffic lane is particularly low (6.84 %) because this specific lane is a bus lane. Finally, in Figure 7 it can be seen that the percentage of RLR/YLR traffic violations per transport mode is almost analogous to the percentage of each transport mode in the traffic volume composition. Table 1 presents the number of traffic light violations per traffic light cycle for every variable of Thessaloniki's set of counts.

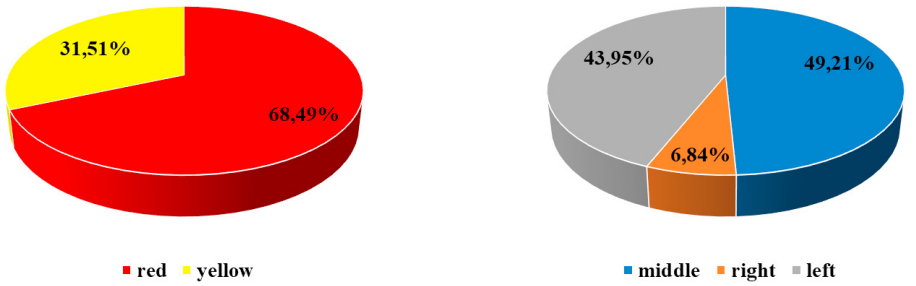

Fig. 6. (a) Traffic lane from which the violation was made (b) Indication of the traffic light at the time of violation

The first correlation refers to the variables "vehicle type" and "traffic lane". The inferential test that was performed was a chi-square test ($p < 0.01$ for the first set of counts and $p < 0.001$ for the second set of counts). The next correlation refers to the variables "violation moment" (the indication of traffic light at the time of violation) and "traffic lane". The inferential test was the Kruskal Wallis test ($p < 0.001$). As a result, there is a strong correlation. The final correlation refers to the variables "violation moment" and "vehicle type". The inferential test that was performed was the Kruskal Wallis test ($p < 0.001$). Therefore, there is a strong correlation.

Table 1. Number of traffic light violations per traffic light cycle of Thessaloniki's counts

Variable	Scale	Violations / traffic light cycle
Lane	left	1.07
	middle	1.19
	right	0.17
Violation moment	yellow	1.67
	red	0.77
Vehicle type	car	1.97
	motorcycle / bicycle	0.42
	truck	0.06
	bus	0

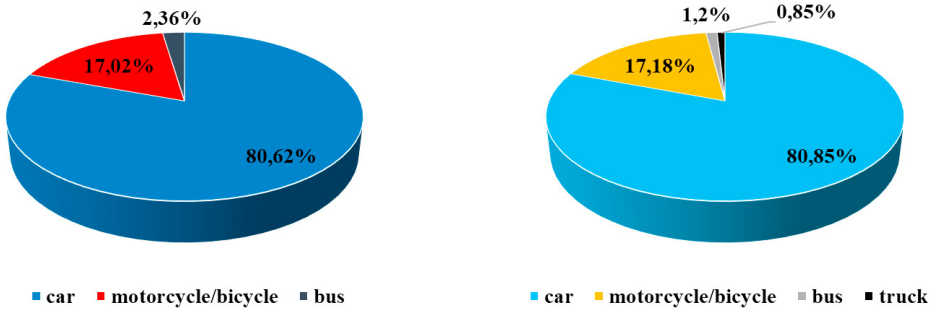

Fig.7. (a) Violations per transport mode (b) Traffic volume per mean of transport

5. Conclusions

The present research shows a comparison of the propensity of RLR and YLR violations at signalized intersections of Enna and Thessaloniki.

From the results obtained of Enna's intersections, considering the same overall traffic cycle of 84sec, it should be noted that RLR/YLR values are not equally distributed. In Viale Diaz and Monte Cantina intersections there is a concentration of RLR and YLR violations along the crossing actions, while in Scifitello intersection RLR violations are mainly recorded in rotary maneuvers on the same arm. It is interesting to note that the percentage of RLR/YLR violations has a peak linked to light vehicles. Cars are the ones that violate the yellow and red traffic light phases more. Furthermore, it is clear that males make more violations compared to females. The geometry of the road allows, in a way, these violations and in particular the downhill gradient as well as the road width. Based on the results of inferential statistics, it seems that there is a strong correlation between the type of vehicle and the traffic lane used for the RLR/YLR violations. Furthermore, there is a correlation between the indication of the traffic light (red-yellow) and the traffic lane.

As far as the Thessaloniki's research is concerned, most RLR/YLR violations took place in the left lane (44%) and the middle lane (49%) while only 7% concerns the right lane, something which was highly expected since the right lane is a bus lane. The indication of the traffic light at the time of violation is 68% YLR and 32% RLR during the survey. It is interesting to notice that the percentage of RLR/YLR traffic violations per transport mode is sort of analogous to the percentage of each transport mode in the traffic volume composition (e.g., 81% cars in traffic composition and 81% RLR/YLR traffic violations made by car). According to the results of the inferential statistics, it seems that there is a strong correlation between the type of vehicle and the traffic lane used as far as RLR/YLR violations are concerned. Also, there is a correlation between the indication of traffic light (red-yellow) and the traffic lane used by each vehicle. Finally, there is a correlation between the indication of traffic light (red-yellow) and the vehicle type.

By performing a qualitative comparison between the results of two surveys, it is noted that the car is the type of vehicle which makes the most RLR and YLR violations. Another fact is that the traffic lane plays an important role to RLR and YLR violations.

The data limitations of both surveys prevent the drawing of general conclusions. However, it is expected that these findings can help researchers in their effort to better understand the RLR/YLR events in the urban environment. The comparison of the findings regarding the years 2015 and 2018 in both cities presupposes the analysis of socioeconomic and traffic data for these two time periods.. In future research it would be interesting to perform a quantitative comparison, analyzing comparable data referred to more extensive period of analysis, in order to make the study even more statistically significant.

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