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An Intertemporal Evaluation of Highway Intersections Red-light Running

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Abstract

During the last 5 years, Greece is in the clamp of a major economic crisis which resulted in an impressive reduction to road traffic volumes, becoming comparable to those many years ago. Taking advantage by that fact, a red-light running study has been repeated covering 13 interurban signalized highway intersections in Greece, comparing results gathered in 1996 to recent ones. The objectives are both to present and explain interrelations between violations and traffic volumes, roadway and operational features of the junctions and to identify any behavioral changes during these 18 years. The main conclusion is that the percentage, as well as the severity of red-signal run have been increased over the years. This will be attributed to a more aggressive behavior as a result of the crises, as well as to the trivial oil and time savings and mainly to the decline of policing.

Keywords: *traffic signals, violations, intersection, traffic safety, red-light running*

1. Introduction

It is well-known among traffic engineers, that driver non-compliance with red traffic lights is a very serious safety issue. Research studies have pointed out that the violation rate of highway traffic signals has been increasing constantly during the recent years. In USA, almost 33% of fatal accidents and 50% of all-type accidents are due to red-light running at intersections [26].

In a signalized intersection the purpose of the amber interval is to inform approaching drivers that they will no longer have priority to cross the intersection. During this amber interval they should either stop or clear the intersection. Crossing the stop line with a red light on is considered a serious traffic violation which might cause the most severe accidents. However, it is common practice for many drivers to cross a highway intersection at the beginning of the red light interval. The principal reasons of this obviously offensive and risky behavior are the avoidance of the discomfort caused by the deceleration due to braking action and by the subsequent loss of time and impetus, in conjunction with the very low probability, as all drivers are convinced, that an accident would occur to them. It is considered that the recent impoverishment of Greeks accentuated a fuel saving hint of this behavior as well.

Accidents caused by red-light running are increasing at more than three times the rate of increase for all other fatal crashes [2, 18, 25]. This is because, on average, that type of accident is particularly severe, especially at interurban intersections. The most dangerous situation arises when an approaching driver realizes that the available green time ahead is

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running out and speeds to catch up, whilst a conflicting approaching driver estimates that the red light he faces is also running out, the green light is imminent and monitors his deceleration to pass the intersection lawfully, but without stopping or even dropping to the uncomfortable first gear in car transmission. This practice, much more common at interurban intersections, because most drivers are familiar with the specific traffic light settings, decisively diminishes the effective intergreen period, necessary to safely clear the junction conflict area and may result to severe lateral-frontal collisions. The specific behavior offers elation to drivers demonstrating experienced driving and zero reaction times. Hence, violating even the first second of the red line for the rushing driver may result in a collision. The less serious rear-frontal collisions may also be the result of the dilemma zone abrupt braking ahead of an oncoming red light, when vehicles headways are short [10, 23].

A relevant intersection red-light running research has been conducted at highway intersections in northern Greece during 1996 [13]. Similar research has been repeated during 2014, at most over the same intersections, in order to compare that aspect of driver behavior after 18 years and to identify whether the grand economic crisis Greeks live, during the last five years, have also influenced their driving behavior. The crisis itself has reduced the 2009 peak traffic volumes by approximately 40%, so that they are closer to those measured during 1996, making the relevant comparison sounder.

Also, a main scope of the study is to identify the interrelations between traffic signal violations and roadway, traffic and operational features of the intersection. As soon as these interconnections are established, highway and traffic engineering recommendations to mitigate the problem and to enhance traffic safety can be proposed. No vigorous accident statistics are available for these intersections, so that no quantitative correlation with accident occurrence can be obtained.

2. Data Collection and Key Parameters Considered

This research study focuses on isolated interurban signalized intersections where only the existence of the signal could intervene with traffic flow conditions. Three criteria have been set to classify an intersection as isolated interurban:

- the traffic free flow mean speed should be ≥ 70 km/h,
- the distance from the next nearest signalized intersection of the examined major highway should be ≥ 1.5 km; (this is to ensure the dispersal of vehicle platoons, since the existence of platoons may affect driving behavior to traffic signals) and
- the surrounding area is, at mostly, without activities.

The interurban intersections of Northern Greece, complying with the above criteria, were 19 in 1996 study [13] and have been reduced to 13 in 2014 study and are listed below:

1. Thessaloniki rind road to Maiandrou street
2. Thessaloniki ring road with PATHE motorway
3. Thessaloniki-Edessa at Kilkis
4. Thessaloniki-Edessa at Sindos
5. Thessaloniki-Ag. Triada at Plagiari
6. Thessaloniki-Kavala at Redina
7. Thessaloniki-Kavala at Stavros
8. Thessaloniki-Kavala at Ofrinio
9. Moudanion-Nikitis at Poligiros
10. Kavala-Xanthi at Kavala new harbor
11. Kavala-Xanthi at Crisoupoli airport
12. Kavala-Xanthi at VIPE Xanthi and
13. Kavala-Drama at Amigdaleonas

For the rest 6 ones, they have either become interchanges (Thessaloniki ring road) or adjacent urban expansion excluded them as interurban by the above criteria.

When a signal changes from green to amber at a highway intersection a decision is demanded by the drivers: to stop or to proceed. The rationale for the amber interval is, in principle, that the drivers should decide to proceed only if they could clear the intersection within the amber period [21]. Obviously, many parameters influence this decision and hence the rate and severity of the violations. These parameters are related to highway and intersection layout, to traffic characteristics and to environmental and operational conditions. All parameters that have been identified and recorded for each intersection and are presented in the following paragraphs.

Data concerning the layout of the selected intersections are presented in Table 1 and have remained constant since 1996. The symbol + stands for 4-legged junctions, whereas T stands for T-shaped junctions. The head of the T always corresponded to the major road. The first number under the heading "No of lanes" refers to the major road and the second to the minor road. A "v" in the next two columns means either the existence of a central reserve or a channelizing island facilitating left turning movements. Unobstructed visibility was judged as adequate "v" according to the standards set by AASHTO ([6], to maintain 1996 criteria) when a driver sees an approaching vehicle on time for safe stopping. It is also a measure for the conspicuity of intersection. Conspicuity greatly affects drivers' evaluation of potential dangers: if the situation seems predictable and no conflict appears, the red signal may be easier ignored.

Table 1. Layout and Operational Features of Selected Intersections

No	Shape	No of lanes	Central reserve	Lanes for left turns	Triangular islands	Blinking amber	Unobstructed visibility
1	+	3/1	v	v	v	X	X
2	+	3/1	v	v	v	v	X
3	T	2/1	v	v	v	X	X
4	+	2/1	v	v	v	X	X
5	T	3/1	v	v	v	X	X
6	T	1/1	X	v	v	v	X
7	T	1/1	X	v	X	v	X
8	+	1/1	X	v	v	v	v
9	T	1/1	X	v	X	v	v
10	+	2/1	v	v	v	v	v
11	+	1/1	v	v	v	v	v
12	T	1/1	X	v	v	v	v
13	T	1/1	X	X	v	v	X

Traffic data collection procedures and sample size were then determined. Operational data were collected for half-hour periods during each of the morning peak, the midday off-peak and the night-time. Thus, a total of 3 half-hour traffic count periods per each intersection have been conducted. In order to avoid Type I and Type II errors, the minimum sample of (all three, for all legs) observations was set to 150 vehicles which, by a standard statistical estimating procedure determines the sample size needed to meet the desirable level of confidence (90% or 95%) and permitted error (5%) as equation (1) indicates [4].

$$n = \left(\frac{t \times s}{\varepsilon} \right)^2 \tag{1}$$

where:

s= Sample standard deviation

t= Student's *t-statistic* for given confidence level and degrees of freedom

The latter data collection period lasted for four months during 2014 fall weekdays. Sample size were the same for both 1996 and 2014. While counting traffic, all approaches were monitoring by observers for red signal violations. Special instructions have been given not to overestimate violations (such types of counting are prone to overcounting). The number of vehicles comply with traffic signals were also counted.

In Table 2, traffic data concerning the selected intersections are presented. Mean speed was measured by radar during the periods the flow was unobstructed by the signal in the vicinity of the intersection. In the secondary road, the free flow speed were lower, on average around 50km/h. Mean speed has been rounded to the nearest 10 km/h. For simplicity and labor-saving reasons traffic was considered to be composed from three types of vehicles: cars, buses and trucks, and motorcycles. This classification has been judged acceptable, since it does not interfere with the scope of the research. Bus-drivers, whose driving behavior might differentiate from that of truck-drivers, consisted a very small sample to be statistically sufficient and stand by itself. The counted traffic has been transformed into Average Annual Daily Traffic (AADT). In Table 2, under the heading "AADT" the first figure represents the traffic volume of the major highway and the second that of the minor road. The same is valid for the column "level of service". The level of service has been estimated for the peak hour of each road of the intersection. During off-peak levels of service were 1-2 classes better.

Table 2. Traffic Data for the Selected Intersections

No	AADT	% buses & trucks	% motorcycles	Level of service (peak hour)	Free flow speeds (km/h)
1	55.000/8.000	12/8	4/6	C/D	90/40
2	70.000/25.000	12/12	3/4	E/E	100/90
3	40.000/10.000	12/15	6/6	D/E	70/60
4	40.000/8.000	12/15	6/7	D/D	80/60
5	60.000/8.000	7/2	6/8	C/C	90/60
6	15.000/4.000	8/5	7/6	B/B	90/50
7	15.000/5.000	8/8	7/10	B/B	80/50
8	20.000/8.000	8/6	6/7	C/B	80/50
9	7.000/2.000	5/2	8/10	B/A	80/50
10	10.000/2.000	7/10	8/4	B/A	80/40
11	8.000/4.000	7/5	8/5	B/B	90/60
12	10.000/2.000	10/15	9/7	C/B	70/40
13	12.000/4.000	10/8	8/6	C/D	70/40

It should be mentioned that during the four month period of 2014 counts there was not even once observed any type of intersection policing, whilst during the first part of the research (1996) there has been noticed policing in three cases.

In Table 3 the signal features of the 13 intersections are presented. All traffic signals have constant cycle varying from 45 to 70 seconds. In only one intersection there are vehicle-actuated signals, which green periods are triggered (but not related) by traffic demand on the minor road. According to the literature [10, 11, 16, 24], if a green extension system is applied when there is traffic demand from the minor road, the exposure of decision making drivers would be radically lower as compared to the situation with a fixed (and short) time green period. As a result the rate of runreds from the minor road would be greatly reduced. In Table 3 the "discomfort parameter" expresses either the waiting time for the specific traffic approach or the percentage of the green time allocated for the approach. If the waiting time is greater than 50 seconds or the available time for the specific movement to the total cycle time is less than 20% the qualitative adjective of "discomfort" has been assigned to the specific approach. This factor is important for the behavior of those drivers familiar with the signalized intersection (which is, generally, the majority of the drivers). Discomfort appears frequently in left turns of the major stream as well as in the minor road approaches.

Table 3. Signal Features of the Selected Intersections

No	Flashing amber ahead	Vehicle - actuated signal	Discomfort parameter
1	-	-	major: left turn
2	v	-	major: left turn
3	v	-	major: left turn
4	v	-	major: left turn
5	v	-	-
6	v	-	minor
7	-	-	minor
8	-	-	major: left turn and minor
9	v	-	major: left turn
10	v	v	-
11	v	-	-
12	v	-	-
13	v	-	major: left turn

In all traffic signals the amber period lasted for 3 to 4 seconds. Thus, the duration of amber period could not be a real variable of the analysis. It should be commented that the amber interval is rather short. Its duration is generally determined according to vehicles speed and is also affected by drivers' reaction time, vehicles' deceleration rate *etc.* [3, 4, 22]. For the measured mean vehicle speeds, the optimum amber interval should change to 4 or even to 5 seconds, especially at intersections No. 6 and 11. This increase will seriously reduce runreds offences [1] although, the opposite view is also expressed [14]. A longer increase is not recommended because the drivers who stop should be immediately rewarded with a red light or they feel they drive overconservatively.

In most intersections there exist a flashing amber situated approximately 100-200 meters ahead. Almost all traffic signals were double: one located at a post and the other at a cantilever arm both at the right side of the road. There were not enough data to investigate the influence of the traffic signal location. Other parameters such as land use variables, time of the day, dry or wet pavement conditions and existence of pedestrian movements have also been noted and has been taken into account in the research, but only qualitatively.

It is known that driver characteristics play a critical role in similar behaviors, but only a rough estimation of drivers' age was possible to be made through the furtive look when moving, which allowed only a gender and a young-middleaged-aged classification. Furthermore, there was no way to estimate drivers' attitude and trip purpose, which greatly influence the studied decision process.

3. Traffic Signal Violation Analysis

Since the objective of this research is to study traffic signal violation, it is important to grade these violations according to their severity. It is obvious that, when a vehicle crosses the stop line after the onset of the red signal indication, this is considered a signal violation. It is also apparent that the rate of violations decreases sharply during the first seconds of the red signal. When a violation happens at the first 3 seconds of the red signal this is termed a "123V". The period of 3 seconds has been selected because it coincides with the typical intergreen period and is about the startup lost time of conflicting movements. Red signal violations occurred during the 4^{th} and 5^{th} seconds of its duration generally involve a certain possibility of traffic collision different either from that at the first three seconds or from that after the 6^{th} second. After the 6^{th} second, the reaction and acceleration time of the stopped vehicles do not affect the accident potential. Thus, it was judged useful to discern these violations (termed as "45V"). All other violations were classified as "6+V". Apart from the severity of the violations the vehicle and maneuver type were also reported.

Identifying the reasoning of traffic signal violations and their consequences, it can be noticed that:

- The main cause of a red signal run is to avoid the discomfort of the braking and stopping actions. This discomfort is greater as vehicle speed is higher (interurban intersections) and as the "discomfort factor" determined at Table 3 becomes more severe. The likelihood that an abrupt braking could lead to rear end collisions, when the following vehicle is also rushing keeping short headways, also leads the drivers to red signal runs. If the visibility is unobstructed, then a driver can monitor its vehicle speed in view of a red signal and approach slowly to the next green period perhaps avoiding the discomfort of stopping or even lowering to the first speed gear. However, as mentioned, this might turned to be a particularly dangerous situation, because it nullifies his reaction and acceleration time and, in case it is combined with a "45V" violation at the cross road, it might lead to a serious side/frontal collisions. Furthermore, the cross-coming driver is most reluctant to a 45V violation if he sees vehicles waiting at the intersecting road stop line (whereas it is much more difficult to spot a vehicle reducing speed a few tens of meters far away the junction so as to cross the junction at the green turn without stopping).
- The influence of the preceding car is also important: once this car stops at the onset of a red signal the decision taken by the following drivers is simpler: to stop or to overpass. If the leading car violates the red signal, this seems to drag (encourage) the following drivers to make a (more serious) violation as well: a massive violation offers better coverage and security. This interrelation of driving behavior is particularly intense in vehicle platoons, which, however, is not a common situation in interurban intersections. To overpass the lawfully stopping vehicle in front, forms a particularly dangerous behavior, which may lead to frontal collisions.
- When the intersection is completely empty there is often the case that drivers stopped at a red signal, start slowly moving their vehicles and when they ensure that there is no oncoming vehicles or policing, they violate the red signal (type: "6+V"), a regular habit of motorcyclists.
- As a separate type of red signal violation might be considered that mostly made by familiar and mostly professional drivers, who, knowing the exact timing of the specific signal, start moving their vehicles exactly at the last seconds of the red period. This type of violation has not been counted separately. As mentioned, this behavior, apart from indicating impatience, boasts for experience and zero reaction time to the fellow drivers and is, for that reason, quite favorite, although particularly risky.

Analysis of the influence of the affecting parameters in conjunction with violation occurrence are then made. Basic statistical tests have been made. Isolated extreme values, which skew the results, have been removed (skewness and kurtosis values greater than 3.0) [17]. An attempt is then made to correlate the results and identify their rationale. It should be mentioned that the attempt to isolate the influence of each parameter and statistically analyze its effect is difficult and not statistically possible. Thus, many conclusions are expressed in a qualitative way. Finally, it was out of the reach of the specific research to relate the type and severity of red-light running with accident occurrence. Few relevant data exist but an attempt is under way to gather more and if the effort becomes fruitful, the results will be soon announced.

4. Results

The presentation of full results for each intersection comprise a great volume of information. The average four leg (+) intersection violation behavior will be presented in details, but commenting would cover all results.

In Table 4 figures for all time periods corresponding to the percentage of each vehicle class making the specific red signal violation to the total traffic class volume which had the opportunity to make the violation during the same period of time (1-2-3, 4-5 and 6+ seconds) are presented. The first figure refers to cars, the second to buses and trucks together and the third to motorcycles. The classification to major and minor road was easy and based on traffic volumes. Figures larger than 15 are rounded to the nearest 5. Typical descriptive statistics concerning the figures have been applied yielding standard deviation and mean values which are the ones presented. Bold numbers highlight a reduction in red-light running and are a minority. All differences are statistically significant at 90% confidence level.

It is very obvious that the results indicate that traffic signal violation at interurban intersections is a major problem, which requires emergency attention. The majority of drivers in Greece consider amber interval as an obvious extension of the green interval which they “should” use to cross the intersection. The impressive 60% of the drivers violate the red signal in the first three seconds of its duration “123V”. Approximately 10% of all drivers (statistics to total number of drivers) violate the red signal in the next two seconds of its duration “45V”. Not taking into account motorcyclists, one out of fifty drivers violate the red signal in the rest of its duration “6+V”.

Table 4. Years 1996 versus 2014 Comparison of Average Proportion (% of the Relevant Stream Traffic Volume) of Red-Running Vehicles at 4-leg Intersections

Approach type	Severity of red signal violation		
	“123V”'	“45V”	“6+V”
	% violations per vehicle class		
Major road, through traffic 2014:	50/45/85	7/**3**/13	2/1/**5**
1996:	45/45/80	3/4/11	1/1/6
Major road, right turn 2014:	**65/60/80**	9/6/**45**	4/1/20
1996:	75/85/90	6/5/55	3/1/15
Major road, left turn 2014:	70/55/90	9/3/12	1/0/3
1996:	65/50/85	2/3/10	0/0/2
Minor road, right turn 2014:	80/**60**/90	20/3/70	5/0/35
1996:	80/70/90	15/2/60	3/0/30
Minor road, left turn 2014:	40/**10/50**	4/0/10	1/0/4
1996:	35/20/55	1/0/5	1/0/2

The above proportions differentiate when expressed for each type of vehicles. Bus and truck drivers, although professionals, violate traffic signals in a similar proportion than car drivers (perhaps they count on the volume of their vehicles as well as on their dominant sight). For motorcycles the proportion dramatically increases: 90% for “123V”, 30% for “45V” and 15% for “6+V”. Unfortunately, among motorcyclists is has become a habit to ignore traffic lights. Motor-riders consider their greater maneuverability as a means to avoid a collision and therefore to overrule traffic signals. According to the literature [7, 12, 23], all the above rates are about 2 times greater than similar obtained in other countries of Europe and even greater than those observed in USA.

The results clearly differentiate for the major and the minor road. In the minor road, where the available green aspect time is definitely smaller, a higher percentage of all vehicle drivers violate the red signal when they are going to turn right. Left turns from the minor roads are much more difficult and exposed, so that red running drivers take greater risks. That violation rate is markedly lower and practically zero outs at “6+V” violation type.

When, due to queues, drivers are waiting for a second green time period, the number of violation increases. In these (not frequent) cases on the one hand the discomfort is greater and on the other hand any violation involves less risk for severe collision due to fact that traffic volumes force lower speeds.

The proportion of red signal violations is definitely higher also during off-peak hours. This is because under these circumstances, drivers check easier the junction and consider the risk of a conflict as been lower. These observations can be correlated with the level of service: “123V” type increases from level C to E. It also increases from level C to A. At level of service A there are 33% more “123V” and 50% more “45V” than at level C. There were not enough data to reliably quote the corresponding figures from C to E. It should be also reported the marked decrease of “45V” from level C to E: at heavy traffic conditions this type of violation looks highly offensive and risky.

Channelizing islands, through reducing the severity of conflict angle, tend to encourage red signal violations at right turns. Generally, right turn is the maneuver concentrating the highest red signal violation rate: almost two times greater than the average, reaching to three times greater at “6+V” type red running. Drivers can check the road during their right turning crawling and (practically equating the red signal to a stop sign) cross the stop line when the conflicting stream is free.

In left turns of the main stream the number of red signal violations is clearly higher than the average. This is mainly due to the shorter green periods allocated to left turns of the main stream. Drivers stick their vehicle to the front one, presuming that the danger is less (and probable is) and the violation lighter.

A flashing amber signal situated ahead of an isolated signalized intersection decreases the number of red signal violations. However, it might arises the case that once the drivers are faced with a near flashing amber and a green signal at the background, instead of stopping, they accelerate so as to cross the junction even in the considered as not-very-risky “123V” period of red signal. It might be better that the flashing amber should not be connected with the advent of the red signal, but simply with the existence of an isolated signalized intersection [14, 27]. Lack of flashing amber increases by 25% red-light running. It should be mentioned that this conclusion is significant at 90% confidence level, whereas it is not at 95% confidence level.

Non familiar drivers of the main road scarcely realize that a signal ahead is vehicle-actuated. (If this was conspicuous, its turn to red would declare the existence of vehicles and discourage violations). They simply spot that the specific signal is usually green. However, it can be identified a lower level of violation (this is also significant at 90% confidence level, whereas it is not at 95% confidence level, *e.g.*, p values lower than 0.05). This behavior might be attributed to the fact that the facing with the red light at this specific intersection draws attention as being an uncommon event. Drivers of the secondary stream have the typical behavior of those having a very constricted time to move.

As far as road gradient is concerned, when it is steep, the number of violations is higher, since it is more difficult either to stop or to restart moving a vehicle. Especially heavy good vehicle drivers are reluctant to stop in cases of steep gradient (as those are classified intersections 10 and 13).

At intersections at suburban areas, the usually heavier traffic and the customization of drivers to interrupted flow, leads to fewer violations.

At T-junctions the direction of the main stream which is adjacent to the minor road records fewer violations than the other direction, probably because the drivers there, being farther from the minor highway, feel the probability of conflict lower. This remark is also significant at 90% confidence level, but it is not at 95% confidence level. This observation is consistent with the markedly lower red-light running probability for the minor road drivers intending to turn left, mentioned above.

At smaller junctions the proportion of red signal violation seems to be higher than the average, especially when there is plenty of visibility. This is because in junctions with extended area (many lanes, islands) it is difficult to check any possible vehicle movement. Besides, more time is required to clear the whole junction. The highly predictable situations in small conspicuous junctions as well as in T-junctions (compared with cross-junctions) give the drivers the reliance that a signal violation is least risky and therefore, it makes up for more offensive driving.

Other interesting (yet qualitative, due to limited data) observations have been made as follows:

- The number of violations decrease markedly with adverse weather conditions. This is the result of more cautious driving under such conditions.
- As the mean vehicle speed becomes higher, the number of red signal violations also increases.
- Constricted visibility (defined where the cross road is not visible at a depth required for safe stopping of the vehicles moving there) decreases 123V by 15% and 45V by 30%.
- Traffic composition has no effect to the number of violations per vehicle class.
- Night-time violations were less compared with daytime ones (night time observations have been made at early dark hours when traffic volumes were still high. The above statement may not be valid for late night hours with low traffic volumes).
- As expected, young males are more prone to serious red-light running than the average driver population.

5. Discussion

A most interesting part of the research lies on the comparison of the intertemporal red-light running behavior. During these 18 years between the first (1996) study [13] and its repetition (2014), Greece passed from a developing optimistic society to an almost bankrupted one with the most expensive (due to heavy taxation: 63%) fuels and the largest in European Union (26%) rate of unemployment. New cars ceased to be purchased, large fuel-consuming cars are selling out and the police has so serious cuts that there are no longer patrol cars available to guard highways. People are deep immersed to their worries, to respect rules and other drivers.

It is considered that all the above negative parameters have the obvious effect of aggravating driver’s behavior. Actually, comparing 1996 and 2014 red-light running behavior (Table 4), only that of professional truck and bus drivers remained virtually the same. Although the economic crises forces them to stand longer on the wheel, to cut expenses, the fear of a catastrophic (for their job alone) accident hold them within the same lawful standards. In all other drivers, offensive driving has markedly increased. Studying Table 4 figures, it can be spotted, that particularly the most offensive "45V" and "6+V" types of red-light violation are those which has mostly increased.

Fuel savings and lack of policing are the obvious explanations of that behavior. Fuel savings for each such running (considering stopping and acceleration to 80km/h average speed) amounts to a few cents of Euro, whilst time savings is about one minute, altogether may sum up to 0,05-0,10€. Although cold calculations yield to that trivial amount of savings, it is considered that drivers themselves may well overestimate the amount. In any case, it by no reason justifies the excessive risk taken for a serious accident.

Finally, the shrinkage of traffic volumes lowered the probability of a conflict. In certain intersections traffic volumes fell below traffic threshold values which justify signaling and this is perceived by drivers as they no more need to wait ahead of a red light for the very-very low crossing traffic of the minor road.

To tackle the red-light running problem in a major economic crises environment, red light cameras (Figure 1) may be an effective way. Generally, enforcement is the best way to get people to comply with any law, and the fear of heavy fining may be highly averting during economic crises.

Cameras are less costly than policing and can fill the void. A study comparing intersections with red light cameras to those without, found the devices reduced the fatal red-light running crash rate by 24% [19, 26].

However, it is important to keep in mind that cameras violate privacy, although there is no sound reason to expect privacy on a public road. Driving is a regulated activity, and people who obtain licenses are agreeing to abide by certain traffic rules. Red light cameras are a mechanism to catch people who break those rules, just like traditional enforcement in every other aspect of life.

Figure 1. Automatic Camera over Intersection to Catch Red-Light Runners

Generally, proper signal timing makes intersections safer. Apart from cameras, restricting speed signs, speed radars, amber light constantly flashing ahead of the intersection, extension of amber signal duration to 4 or 5 seconds or the introduction of an all-red signal phase and vehicle-actuated and demand-related signals for the minor roads would also be effective measures to cope with the risky red-light running major traffic safety intersection problem in Greece.

Further relevant research would be focused on processing data collected during this study together with additional ones, to evaluate whether a model correlating the probability of red light running occurrences to traffic conditions and vehicle type, as well as other geometric and behavioral features, could be obtained.

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