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Effects of drivers' speed during the yellow-light signal and satisfaction of drivers at the intersections with the red-light cameras

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Abstract

The purpose of this article was to investigate driver's speed behaviors during the yellow-light period and how satisfied they were at the intersections under the Red-Light Cameras (RLC) project. The survey data was collected before the project implementation and 3 months after the project began. The data was analyzed by calculating the correlation between the distances from the intersection and the drivers' speeds entering the intersections during the yellow signal. In addition, the satisfaction was evaluated with 400 samples based on the questionnaire conducted when the RLC project was ongoing. The results showed that drivers speeded up significantly during the yellow signal when they were approaching the stop line, both at the intersections under the project and at the other intersection. Besides, it was found that the speed during the yellow light reduced significantly at all distances, i.e, 14-40% (6.5-22 km/hr.), resulting in 20-meter reduction of the maximum length of movement during the yellow signal period, compared to an unchanged distance at the control intersection. The analytical results corresponded to the 56% reduction of red-light runners after RLC project began. As for the drivers' satisfaction towards the RLC project, it was found that the majority (64%) showed positive satisfaction, and that 67% reported that the project resulted in speed reduction. In addition, some variables were found to significantly correlate with the attitudes towards RLC project. The study's findings can be used as references, and the approach can be applied in other locations to prevent traffic collisions at intersections.

Keywords: RLC, Yellow light, Red-light running, Red-light camera, Satisfaction

1. Introduction

Roads are the thoroughfare for vehicles, and facilitate road users from the starting point to their destinations. It is the fundamental rights of people to have access to and use roads, which are particularly important in the development of the quality of life of the people both directly and indirectly. Thus, one of the major government's policies is to develop roads or transportation by roads in all regions of the country. Roads connect different areas in the road network, with a linking point or junction. There are many engineering models for management and control of traffic at junctions, for example, warning of the intersection by a roadside sign, the use of street isles to control movement, the use of traffic lights, or a traffic policeman to control vehicle movements, or the mixture of these. The main objective is to facilitate and provide safety for road users. Selection of the management model and traffic control at an intersection necessitates engineering factors such as the amount of traffic, vehicle speeds, road users' behaviors, risks that may arise, etc., all of which result in the selected pattern being in accordance with the designer's objective. However, accidents at intersections can still occur. The Department of Royal Highway reported that in 2017-2019, from the 17,554 cases of highways accidents that occurred at intersections, 6-7% were due to red-light running and 1.17% were due to traffic lights or traffic signs violations [1]. The traffic lights (red-light signal, yellow-light signal and green-light signal) at an intersection are critical for road users, particularly while preparing to stop, accelerate, or change pace. Drivers normally stop their cars when seeing the red-light signal. If a driver runs a red light, there is a high risk that the driver is involved in an accident, which can be severe and cause death. In addition to that, yellow lights affect the driver's decision as well as red lights. Decision to move past the intersection during the yellow light to pass the intersection may be a wrong decision that leads to red-light running. There is also a high risk of being hit by a vehicle that has been granted the green light signal. Red-light running may happen intentionally and unintentionally [2]. The decision behind this action may be due to many associated factors such as gender, ages, education levels, beliefs, the physical condition of the intersection, speeding, yellow signal, starting and ending time of green signal, traffic volume, traffic enforcement, etc. [3-8]. Red-light running behavior is one among risk

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behaviors and is greatly dangerous to both the driver and other road users. If the accident is a crash on the side by a similar-sized vehicle at a speed of 50 km/hr, the possibility of death of the person in the vehicle being crashed is 10%. The chance of death increases with the speed of the crashing vehicle [9, 10]. However, if one of the parties is a road user in the risk group (the fragile group)-such as a motorcyclist being crashed by a red-light running vehicle, or a bicyclist, or a pedestrian-then the chance of death increases at the same speed. On the other hand, if the driver decides not to stop but moves on at high speed, there is a high possibility of crash by a vehicle that followed (rear-end crash). Rear-end crash is another type of accidents directly related to driving behavior at intersections with traffic lights that occurs frequently. The crash trend on Thailand highways is continuously increasing [11, 12]. Crash type statistics reveal that rear-end collision is the second most common type of collision. However, the highest number of fatalities occur as a result of rear-end collisions [13].

Khon Kaen is a province in the Northeast where socio-economic development has been continuously ongoing, and is expected to step towards being a regional center of industries, communication, transportation, education and health. As a result, Khon Kaen city has developed rapidly until at present, traffic on the main roads has become heavy, and in turn brought about an increasing rate of road accidents. During the years 2017 to 2020, the accidents that occurred at the main intersections of Khon Kaen city caused an average of 18 cases of injuries and an average of 1-2 deaths per year [14].

However, the prevention, control or solving of road and intersection accidents in the urban area is complicated and involves many sectors, or is multidisciplinary. Moreover, there is shortage of responsible personnel, limitations in terms of law and official regulations, and limited budget for expediting measures. Consequently, the measures or means taken during the recent period have not achieved the goals as expected.

With the above reasons, the Khon Kaen Accident Prevention and Mitigation Working Team proposed a project that uses a CCTV camera technology to increase the efficiency of law enforcement, with an aim to reduce the number of traffic crash accidents at intersections by prevention and detection of red-light runners. This project received financial support from the Safer Roads Foundation (SRF), England [15]. The project initially started its full operation on January 9, 2021.

2. Literature reviews

Relevant research studies on red-light running showed many factors that make drivers run red lights, such as at beginning and ending of the red-light signal, where the amount of traffic is little [2, 16] the lighting at the intersection during nighttime, distance with clear visibility, risk to be ticketed by a policeman [17], personal factors including: drunk drivers or drivers with bad-driving history [18], use of high speed to enter the intersection [19], small intersection width [20], short yellow-light time [21], red-light runners being males, young age, not wearing a helmet, driving alone [7, 16, 22], or intention to take risk, conducive situation and weather, such as the car in front driving past the intersection under the yellow light, using high speed when approaching the intersection, driving after drinking alcohol [2].

Many research studies investigated the efficiency of the use of technology, especially an automatic camera to detect red-light runners at many areas. The studies show the reduction of red-light running at 40-49% in one year [2, 18, 21, 23-25]. Blinking lights installed in order to increase the chance of drivers' pausing at the intersection [26], or a red-light running detection system together with warning for high-speed drivers at rural area intersections resulted in the decrease of red-light runners [27] In other studies, it was found that a smart traffic light that changes with the traffic amount can reduce yellow-light running among the drivers with no intention to violate laws [28].

From the past research, it can be seen that the use of technologies to control road users at intersections with traffic lights is efficient in reduction of traffic rule violators and loss from accidents. Nevertheless, context differs from one place to another, for example, traffic laws, strictness in law enforcement, type and size of vehicles, driving behaviors, etc., especially in the high-income countries and medium-income countries like Thailand [29]. This research therefore was aimed at studying the efficiency in expediting RLC measured at the main intersections in a city under the mixed-vehicle condition Studies or research on application of technologies on drivers' behavior control in Thailand are few, especially the ones related to speed use under the red light. Therefore, this study emphasized the evaluation of potentiality and the efficiency of the RLC project implementation for safety of road users. The results would also be a prototype for other urban areas and regions that will implement the project in the future.

3. Methodology

3.1 Study areas

This study evaluated the potentiality and efficiency in implementing RLC measures at the points of installation at intersections in Khon Kaen urban areas, Thailand. The fixed time traffic light system was selected, at 4 intersections of the urban main roads having similar or close physical characteristics. There were 3 intersections under the Red-Light Cameras project (RLC), namely, 1. Bangkok Hospital Intersection, 2. Si Than Junction and 3. Ban Kok Intersection, as shown in Figure 1. The other intersection selected for the study was the Roe-8 Intersection, which was not under the Red-Light Cameras project, but was situated on the same road as the first and second intersections above. The fourth intersection was the control site of this study.

The 3 chosen intersections under the Red-Light Cameras (RLC) project were installed with automatic red-light running detection cameras, and 1-4 sets of 1.2x2.4 m warning signs installed on the left and right sides of the road, as shown in Figure 2. The signs were installed before the intersection (depending on the surrounding condition of each site). No such sign was installed at the Roe-8 Intersection, which was the control site.

3.2 Survey of the physical characteristics, the traffic lights timing, and traffic volume

The width of the intersection was surveyed from one stop line to the other, the yellow-light time, the all-red time, and the traffic volume in the same direction as in the survey for the speeds at all study sites.

Figure 1 Maps of the red-light cameras and signs at 3 intersections

Figure 2 Examples of the installation and the points of the sign installation at the 3 intersections under the red-light camera project

3.3 Survey of driver's speeds entering the intersection during the free-flow period

The speeds of vehicles entering the intersection during the free-flow period in the day time (09:00-11:00 A.M.) were analyzed. The point set for the survey was approximately 250-350 m. from the stop line of each intersection. At this distance, no sign was installed related to the intersection, for example, red-light running warning sign, traffic light warning sign, etc. The speeds were surveyed at the major direction, where the speeds were higher than other directions. This was in order to analyze the maximum moving distance with that speed during the yellow-light signal.

3.4 Survey of speeds of drivers entering the intersection during the yellow-light signal

The speeds of drivers during the yellow-light signal was surveyed by dividing the maximum moving distances using that speed into 4-5 points as shown in Figure 3. The points considered were from the maximum distance of movement using the highest speed during the free-flow period under the yellow light, which was 5 seconds. Next, the surveyed points were stipulated that had equal distance and covered the maximum movement during the yellow light signal.

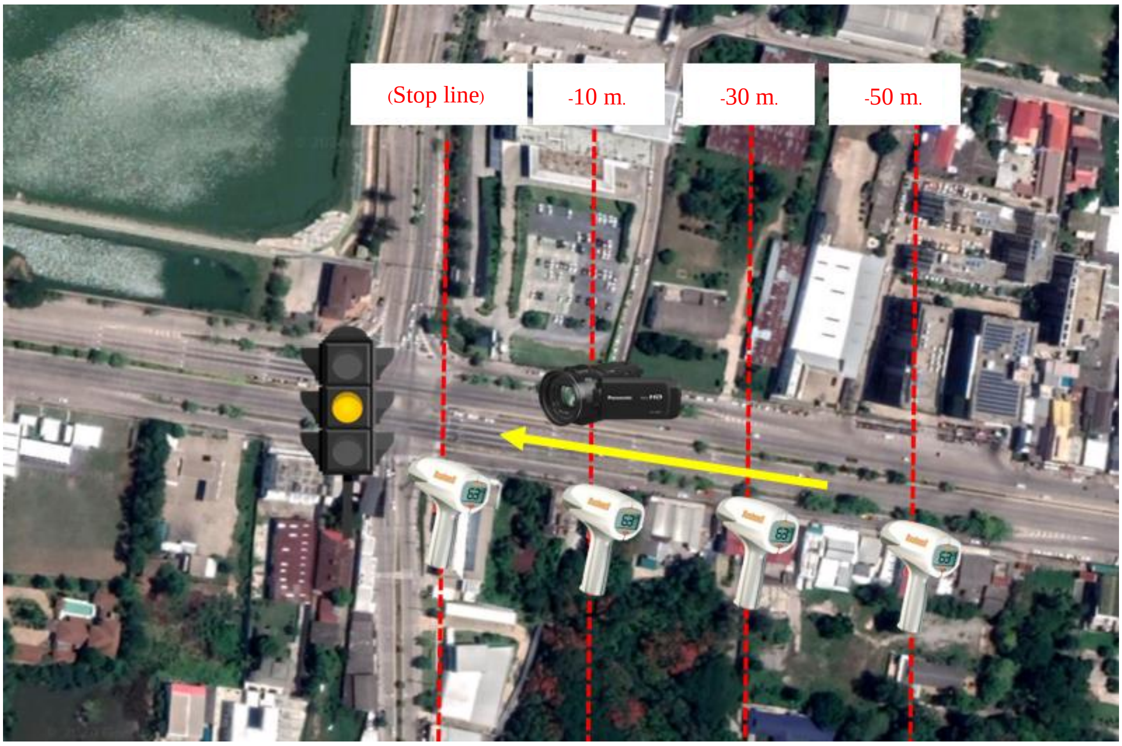


Figure 3 Example of the speed survey points during the yellow-light signal

The speeds at 85 Percentile during the yellow-light signal were calculated to find the maximum distance of moving past the intersection, as shown in Equation 1. The distances calculated were analyzed and compared between the pre-project and project period using the Independence T-Test at the confidence level of 95%. For the minimum yellow-light signal, the calculation was performed by Equation 2.

$$x_0 = v_0\tau - (w + l) \quad (1)$$

Where

x_0 is the maximum moving distance to pass the intersection without speed acceleration (m),
v_0 is the vehicle speed before touching the brake, or the initial speed (m/sec)
τ is the time of yellow-light signal (second)
w is the width of the intersection (meter)
l is the average length of vehicles (4.60m) [30]

$$\tau_{min} = \delta + \frac{v_0}{2\alpha} + \frac{w + l}{v_0} \quad (2)$$

Where

τ_{min} is the minimum yellow-light signal (second)
v_0 is the vehicle speed before touching the brake, or the initial speed (m/sec)
a is the vehicle latency, which is 3.05 m/sec^2 [31]
δ is the time of perception and reaction, which is 1.00 sec [31].

The minimum yellow-light signal is the length of time a driver can stop his/her vehicle safely and comfortably, and can pass the intersection in time without speed acceleration. This time must be less than the sum of the yellow-light timing and all red-light timing.

3.5 Survey of attitudes towards satisfaction during project implementation

The attitudes of drivers related to their satisfaction towards the Red-Light Camera were surveyed from 400 samples obtained from Equation 3 [32]. The questionnaire was used, which was divided into 2 parts: 1) the baseline data, including sex, age, occupation, frequency of intersection passing; 2) valuation of attitudes related to satisfaction when the RLC project was implemented, using the Likert Scale with 5 score levels: 1 means strongly disagree, 2 means disagree, 3 means neutral, 4 means agree, and 5 means strongly agree. There were 4 questions in this part, namely, 1) the visibility of the red-light running warning sign, 2) the red-light running warning sign leads to reduction of speed, 3) the red-light camera decreases the red-light running behavior, 4) feeling safe when driving past the intersection under RLC project.

$$n = \frac{Z^2}{4E^2} \quad (3)$$

Where
n is the size of the sample group
Z is the standard norm of 1.96 at the confidence level of 95%
E is the acceptable deviation of 5% or 0.05.

The descriptive statistics was used for the discussion of the results related to the general data. The correlation between individual variables and the attitude toward the project was analyzed by Chi-Square at the confidence level of 95%.

3.6 Collection data of the number of red-light running vehicles

The number of vehicles running red light was collected from the database of the automatic CCTV camera system during the same period as the survey for the speeds, both before the project and after the project commenced. The descriptive analysis was used for the comparison of the number of red-light runners at each intersection.

4. Results and discussion

4.1 General data of the study sites before and during implementation RLC project

Table 1 demonstrates the general information of the intersections under the Red-Light Camera project and the intersection with no RLC. It was found that drivers' speed during the free-flow period ranged from 70 to 85 km/hr. Traffic volume during the two surveyed periods (before and after project implement) were in the range of 1,090-1,442 vehicles/hr., and approximately 2% different. The intergreen time at all intersections was 7 seconds including the yellow-light (5 seconds) and the all red-light (2 seconds). The calculation for the minimum yellow-light signal (Equation 2) was roughly 7.20-7.35 seconds. This was higher than the current intergreen time. Therefore, the all-red time should be adjusted to be in accordance with the calculated parameter. The calculation of the maximum moving distance during the yellow-light time when the free-flow speeds were used (Equation 1) showed that the minimum distances were: at the intersections of Bangkok Hospital, Si Than, Ban Kok, and Roe. 8, respectively.

Table 1 Demonstrates the general information of the intersections

No.	Intersections	Width of intersection (m.)	Approach speed* (km./hr.)	Traffic volume (Veh./hr.)		Intergreen time (Sec.)		Requirement distance to cross the intersection** (m.)	minimum yellow time (Sec.)
				Before	After	Yellow	All-Red		
1	Bangkok Hospital	54	70	1,109	1,125	5	2	48	7.20
2	Sri-Than	62	83	1,085	1,112	5	2	58	7.32
3	Ban-Kok	43	74	1,171	1,203	5	2	65	7.22
4	Roe-8 (Control site)	35	85	1,417	1,442	5	2	87	7.35

Remark:
* refers to the speed at 85 Percentile in the direction where drivers used the maximum speed,
**refers to the required moving distance for passing the intersection during the yellow light (Maximum distance in the yellow time+Width of Intersection-the average length of vehicles)

4.2 Analysis of speeds during the yellow-light signal, before and during project implementation

Table 2 shows that at 85 Percentile, the speeds of vehicles during the yellow-light signal after RLC project started reduced at 8-16% (mean = 12%). At the intersections under RLC project, the maximum moving distance to pass the intersection was found to reduce about 20 m, as shown in Figure 4. However, this did not have any effect or little effect (mean = 0.7%). For the other intersection outside RLC project, the moving distance during the yellow light was close to the former value. This result indicates that the drivers were concerned about being detected from the RLC during the yellow signal. Drivers' speed was found to decrease during this time more than increased speed for passing through the intersection. In addition, the survey and compilation of the average number of red-light runners (all types of vehicles) during 09:00-11:00 A.M. showed an average of 56% reduction at all RLC intersections, while there was a 5.26% reduction at the non-RLC intersection (insignificant decrease compared to other sites). This finding suggests that RLC intersections are safer than non-RLC intersections.

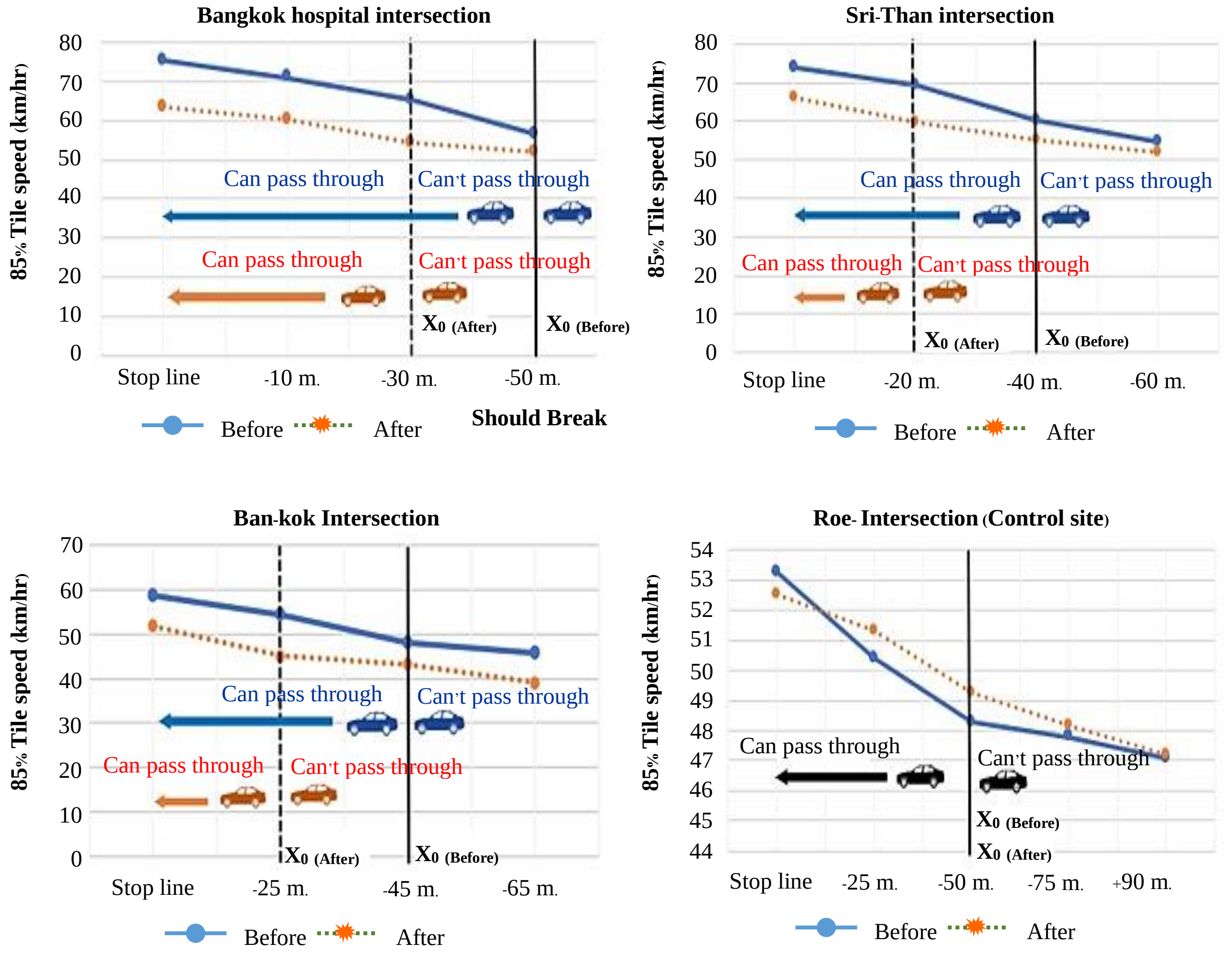
Table 2 Analysis of movement during the yellow-light signal

No.	Intersections	Position survey	85% Tile of speed in yellow time (km./hr.)		Maximum distance in yellow time (m.)		Requirement distance to passed the intersection* (m.)		Average number of red-light running** (Vehicle)	
			Before	After	Before	After	Before	After	Before	After
1	Bangkok Hospital	Stop line	75.3	63.4	104.6	88.1	45.98	29.46	14	6
		- 10 m.	71.1	60.2	98.8	83.6	30.15	15.01		
		- 30 m.	65.4	54.3	90.8	75.4	12.23	-3.18		
		- 50 m.	56.5	52	78.5	72.2	-20.13	-26.38		
2	Sri-Than	Stop line	74.1	66	102.9	91.7	36.3	25.07	15	6
		-20 m.	69.6	59.6	96.7	82.8	10.1	-3.8		
		-40 m.	60.3	55	83.8	76.4	-22.9	-30.21		
		-60 m.	54.85	52.15	76.2	72.4	-50.42	-54.17		

Table 2 (continued) Analysis of movement during the yellow-light signal

No.	Intersections	Position survey	85% Tile of speed in yellow time (km./hr.)		Maximum distance in yellow time (m.)		Requirement distance to passed the intersection* (m.)		Average number of red-light running** (Vehicle)	
			Before	After	Before	After	Before	After	Before	After
3	Ban-Kok	Stop line	58.8	51.85	81.7	72.0	34.07	24.41	10	5
		-25 m.	54.4	45.2	75.6	62.8	2.96	-9.82		
		-45 m.	48.15	43.3	66.9	60.1	-25.73	-32.46		
		-65 m.	45.85	39.15	63.7	54.4	-48.92	-58.23		
4	Roe-8 (Control Site)	Stop line	53.25	52.55	74.0	73.0	39.36	38.39	19	18
		-25 m.	50.4	51.3	70.0	71.3	10.40	11.65		
		-50 m.	48.3	49.25	67.1	68.4	-17.52	-16.20		
		-75 m.	47.8	48.15	66.4	66.9	-43.21	-42.73		
		-90 m.	47.1	47.2	65.4	65.6	-59.18	-59.04		

Remark:
* The positive value means the distance of intersection passing (drivers can pass through the intersection), while the negative value means the required distance in order to pass the intersection (drivers can't pass through the intersection),
** means the average number of vehicles running red light from the database of the automatic CCTV camera system and from the survey during 09:00-11:00 A.M. on working days.



X_0 refers to the position of the vehicle during the yellow-light signal that can pass through the intersection without speed acceleration.

Figure 4 Speeds at 85 percentile of vehicles entering the intersection at different distances during the yellow light signal, before and during RLC project implementation

Table 3 shows the statistical analysis of correlation between the moving distance and the speed during the yellow light, including the difference between the period before RLC project and when RLC project started. The speed in entering the intersection during the yellow-light signal before and after RLC project began correlated significantly and negatively with the distance close to the intersections, under or not under the RLC project. The speed during the yellow light increased if the driver was close to the intersection during the yellow light. Besides, it was found that vehicle speeds during the yellow light after RLC project began significantly reduced approximately 8-39% from the period before RLC. The parameters did not differ at the non-RLC intersection.

Table 3 Statistical analysis to compare movement during the yellow-light signal, before and during project implementation

No.	Intersections	Positions	Number of samples (Veh.)	Spearman's rank[1] Sig. (2-Tailed) Before	Spearman's rank[1] Sig. (2-Tailed) After	T-Test[2] Sig. (2-Tailed)	Mean difference (km./hr.)	Standard error of mean
1	Bangkok Hospital	Stop line	642	-0.735 (0.000)***	-0.413 (0.002)**	0.002**	5.392 (-8%)	2.157
		- 10 m.	630			0.000***	23.451 (-35%)	2.068
		- 30 m.	632			0.000***	22.051 (-39%)	2.544
		- 50 m.	635			0.001**	15.160 (-25%)	2.115
2	Sri-Than	Stop line	622	-0.340 (0.001)**	-0.322 (0.005)**	0.013*	7.698 (-13%)	2.993
		-20 m.	624			0.016*	8.368 (-16%)	2.329
		-40 m.	632			0.000***	14.323 (-26%)	2.563
		-60 m.	645			0.000***	15.543 (-26%)	1.543
3	Ban-Kok	Stop line	656	-0.406 (0.000)***	-0386 (0.001)**	0.001**	6.551 (-14%)	1.801
		-25 m.	631			0.000***	14.261 (-33%)	1.131
		-45 m.	641			0.000***	8.517 (-22%)	1.251
		-65 m.	623			0.001**	6.769 (-18%)	1.864
4	Roe-8 (Control Site)	Stop line	621	-0398 (0.000)***	-0.318 0.004)**	0.350	-1.825 (+5%)	1.928
		-25 m.	611			0.814	1.390 (-1%)	1.642
		-50 m.	603			0.929	1.155 (-0.5%)	1.736
		-75 m.	620			0.716	0.880 (-2%)	2.399
		-90 m.	614			0.423	0.237 (-0.5%)	2.125

Remark:
[1] means the correlation between the variables of the points where the survey of speeds and the speeds in entering the intersection during the yellow-light signal was conducted using the Spearman's rank correlation coefficient,
[2] means the testing of the difference of the means (driver's speed between before and during RLC project implementation) using the Independence T-Test, * Significance at 5% level, ** Significance at 1% level and *** Significance at 0.1% level.

4.3 General data of questionnaire informants

The results of the survey conducted on 400 drivers showed that 208 informants (52%) were males and 192 informants (48 %) were females. The average age was 34 years, 25% being younger than 22 years (school and university students), 24% being at the age range of 23-30 years, 26% at the range of 31-40 years, and 25% were over 41 years. As for the occupation, 25% were school and university students, 32% were government officials, 37% were employees of government or private organizations, and 36% had other occupations. The frequencies of driving past the RLC intersections were: 6-7 days/week (26%), 5 days/week (31%), 2-4 days/week (33%), and 1 day/week (10%).

4.4 Results of the survey of satisfaction towards RLC project

Table 4 illustrates the satisfaction survey results. Most of the informants (64%) were positively satisfied with RLC project. The most satisfactory aspect was that the RLC project led to reduction of the speeds (X_2) of 67% of the informants, followed by 65% being satisfied with the clear warning signs (X_1), while 60% felt safe when passing the intersections under RLC project (X_4), and the project reduced their red-light running action (X_3). However, some informants had negative attitude (7% in item X_3). This finding suggests that relevant personnel should increase knowledge and carry out public relations about RLC project.

Table 4 Data from the survey of satisfaction towards the RLC project

No.	Dependent variable	Satisfaction (%) Strongly disagree	Disagree	Neutral	Agree	Strongly agree
1	The warning signs are clearly visible. (X_1)	1	6	29	48	17
2	RLC project causes reduction of the speed to enter the intersection. (X_2)	1	5	28	44	23
3	RLC project made the number of red-light running reduced. (X_3)	7	7	27	36	24
4	I feel safer when passing through the RLC intersection. (X_4)	0	7	29	41	24

4.5 Analysis of statistical correlation between personal variables and satisfaction towards RLC project

Table 5 shows that sex correlated with the satisfaction with the warning signs. Women were significantly more satisfied than men in this regard. Sex also correlated significantly with the satisfaction in terms of the feeling of safety when passing the intersection, with men being more satisfied than women. However, sex did not correlate with the satisfaction with their speed reduction and red-light running behavior. Age and occupation were found to correlate significantly with all aspects of satisfaction. The youngest age group, lower than 22 years (students), was least satisfied with the visibility of signs. The RLC project significantly resulted in their speed reduction and higher feeling of safety when passing the intersections, but it did not correlate with the reduction of red-light running in all variables. As for the frequencies of use of the intersections under the RLC project, it was found that the group passing the intersection one day/week significantly correlated with the satisfaction in terms of speed reduction.

Table 5 General data of questionnaire informants

No.	Independence variable	Chi-Square (Sig.)			
		X_1	X_2	X_3	X_4
1	Gender Male Female	18.754 (0.012)* Female > Male	6.418 (0.217)	2.047 (0.727)	13.733 (0.037) * Male > Female
2	Age Below 22 year old Between 23-30 year old Between 31-40 year old Above 41 year old	24.895 (0.015)* Agree Min. = Below 22 year old	25.009 (0.015)* Agree Min. = Below 22 year old	10.746 (0.140)	37.520 (0.000) *** Agree Min. = Below 22 year old
3	Career Student Government / Private officer Owner business / Other	25.468 (0.001)** Agree Min. = Student	23.294 (0.003)** Agree Min. = Student	6.081 (0.638)	22.672 (0.004) ** Agree Min. = Student
4	Frequency to passed the RLC 6-7 days per week 5 days per week 2-4 days per week 1 day per week	12.455 (0.410)	21.755 (0.040) * Agree Min. = 1 day / week	9.182 (0.687)	7.538 (0.820)

Remark: * Significance at 5% level, ** Significance at 1% level and *** Significance at 0.1% level

5. Conclusions

This article aimed at investigating how driver's speed behavior during the yellow-light period and how satisfied they were at the control intersection using Red-Light Cameras (RLC). It was found that if the driver was close to the intersection during the yellow light, the speed increased, the vehicle speeds at the intersections under RLC project significantly reduced at an average of 27%. This led to a 56% reduction of the number of red-light runners at the intersections under RLC project, which were in the range of 40-69 %, similar to the studies in other areas both in the country and abroad [2, 18, 21-25, 33] This demonstrated the importance of the measure that has impact on the control of speeds of road users, which are positive on the reduction of red-light running [2, 19] or the reduction of the incidence of accidents and the severity at the controlled areas [34-37].

The evaluation of attitudes towards the satisfaction with the RLC project showed that most of the informants (67%) were satisfied with the project, similar to the number of red-light runners and road traffic accident data, which were in the range of 0.25-0.50 persons/month (before RLC were in the range of 0.75-0.90 persons/month) at the intersections under RLC project [14].

The personal factors including age, sex, occupations and frequencies of passing the intersections under RLC project correlated significantly: women were more satisfied with the warning signs of RLC project than men. For the age groups, the group lower than 22 years of age or student group were satisfied with the visibility of the RLC warning signs, for they led to reduction of speeds. The feeling of safety of the youngest age group was reported less than the other age groups and the other occupation groups. For the frequency of passing the intersections under RLC project, it was found that the group passing the intersections once a week was the least satisfied with the reduction of speed. Therefore, the organization working on public relation should inform the people about the project, especially the student group or the youngest age group. The safety from the project implementation should be publicized especially among the women group, and the warning signs among the men group. Visibility of the warning signs should be increased. Public relation should be carried out by means of different media about RLC project implementation so that those not passing the intersections regularly also know about the project.

In order to increase the efficiency in the control of red-light running behavior, or the risk behaviors when using an intersection, research studies both in the country and abroad have proposed various engineering measures, for example, the use of technology to detect vehicles moving towards an intersection [26, 38], installation of traffic lights that vary with the amount of traffic [39-41], blinking green-light signal before the yellow light with a warning sign: “Prepare to stop at the blinking light” [42], limitation of vehicle speeds in order to control the speed in entering an intersection [43, 44], The use of technology to detect red-light running with a warning sign for the detection [45, 46], etc., all of which can be used together to increase the project implementation efficiency.

According to the policy implications from this study, the all-red time should be set at 2.5 second, the installation speed limit sign or warning speed sign of 50 km/hr. before vehicles enter the intersection, the blinking green-light signal set before the yellow light and a warning sign: “Prepare to stop at the yellow light” should be for roughly 50 m. before the stop line. The setting and installation would help reduce drivers’ decision-making time and increase safety at the intersections. Besides, departments engaged in the RLC project should carry out more public relation or educate people about the importance of slowing down at intersections for road user safety. Adolescents under 22 years old as well as outside users and those who use the intersection infrequently should be emphasized in this regard.

The results of the study can be used for citing the engineering efficiency and the attitudes towards the implementation of the automatic red-light camera project at the beginning in order to extend the outcomes and make adjustment to increase the implementation efficiency. Nevertheless, evaluation should be carried out continuously on other aspects as well, such as accidents at intersections, injuries, death, economic evaluation, etc., both for medium-and long-term purposes. The project should also be evaluated by taking into account the results or recommendations to learn about the advantages and disadvantages. As such, more benefits will arise from the implementation of the project.

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