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<th>Title</th>
<th>An overview of red-light surveillance cameras in Singapore (Main article)</th>
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<tr>
<td>Author(s)</td>
<td>Lum, Kit Meng; Wong, Yiik Diew</td>
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An Overview of Red-Light Surveillance Cameras in Singapore

TRAFFIC COLLISIONS AT SIGNALIZED INTERSECTIONS are, in most cases, a direct consequence of drivers disobeying the red signal. Statistics from the Traffic Police Department, Singapore, showed a total of 5,240 reported cases of fatal and injury road accidents in Singapore in 1995, of which 1,797 cases (34 percent) occurred at road intersections. Of these intersection accidents, 268 cases (15 percent) were ascribed principally to drivers disobeying the traffic signals. A study by Retting et al., of a recent sample of 4,526 police crash reports from four urban areas in the United States showed that 56 percent of the crashes occurred at intersections, of which 8 percent (212 cases) were due primarily to running the red signal. Thus, managing red-light violations is one of the effective measures to reduce accidents at signalized intersections.

DRIVERS’ DECISION MAKING AT ONSET OF AMBER

Drivers approaching a signalized intersection during the onset of amber must decide whether to drive through and clear the intersection or to stop. Inappropriate actions taken by drivers may result in either right-angled collisions from the conflicting flows, or rear-end collisions between the lead stopping vehicle and the following vehicle(s). Red-runners, referring to those vehicle drivers entering the intersection after the signal indications have turned red, contribute significantly to the occurrence of right-angled collisions.

There are several types of red-running offenders. Bagley categorized the red-running offenders into three groups, namely, (a) those who are caught in the dilemma zone, (b) those who are held up by slower traffic ahead or waivered due to indecision and (c) those who are able to stop comfortably but choose to deliberately run the red. The risk of accidents arising from red-running of the first two types, as studied by Mahafel and Zaidel, can be minimized effectively by improvements such as extending the amber period or increasing the visibility of signal light. However, the third type poses a serious danger to other vehicles and can only be controlled effectively by surveillance and enforcement techniques.

EFFECT OF CLEARANCE INTERVAL ON RED-RUNNING VIOLATIONS

The actions taken by drivers at signalized intersections during the onset of amber are not well understood. Harders reported that an increase from three to four seconds in the amber interval showed a reduction in red-running violations from 4.8 percent to 1.8 percent of all vehicle passages after the onset of amber. However, for a duration of amber less than three seconds, the number of red-running violations increased significantly. Hence, one may argue that increasing the amber interval seems to be a logical way to tackle red-running offenses, but this solution would be at the expense of a reduction in intersection capacity. It may also result in the usage of variable amber duration at intersections along the road network that may be undesirable in terms of driver expectation and traffic safety. It is generally agreed that a three-second amber interval can be provided to allow an adequate clearance interval for speeds up to 50 kilometers/hour (km/h) (30 miles per hour mph).

RED-LIGHT SURVEILLANCE CAMERAS AS COUNTERMEASURES

The problem of red-light violations and traffic collisions at intersections
needs to be tackled by both engineering and nonengineering measures. Improvements at signalized intersections on skid resistance, roadway lighting and signal visibility are typical engineering measures, but they alone cannot deal adequately with the complexity of intersection safety problems. In view of this, a feasible complementary measure is to put in place an unmanned traffic surveillance system that could be perceived by drivers as a "threat" if they attempt to violate the traffic signal. The rationale behind such an approach is that if the level of violation can be managed through automated enforcement, then the rate of accident occurrence could be reduced. One such automatic enforcement system is the red-light surveillance camera system that is in operation in countries such as Singapore, Australia, New Zealand, the United Kingdom and Malaysia.

**OWNER-ONUS LEGISLATION**

The red-light camera system serves as a visible enforcement tool that provides a deterrent effect on red-light violation. When the camera system was first introduced in Australia and the United Kingdom, prosecution procedures involved a lengthy process of identifying and establishing liability of the offender. Legislation has since been enacted whereby the onus of liability for the offense lies with the vehicle owner, resulting in a reduction of personnel involved in the prosecution process. This reduction in personnel allows for more intensive deployment and, therefore, more efficient use of the cameras for enforcement purposes. The camera automates the enforcement procedure and, hence, enhances the deterrence against violation of traffic signal regulations.

**PAST STUDIES ON RED-RUNNING VIOLATIONS**

Thompson et al.\[^{10}\] investigated the effect of red-light surveillance cameras at two sites in Nottingham, United Kingdom, by comparing the violation rates before and after camera installation. A substantial reduction was observed immediately after the cameras were activated. The violation rates at three months after the introduction of the cameras were similar to the before rates; however, there were reductions at both sites in the number of violations occurring at 0.8 seconds or more after the onset of red.

A before-and-after study\[^{11}\] was conducted to investigate the change in red-running rates following the first installation of red-light cameras in Singapore. The study covered 26 sites comprising 11 camera intersections with the remaining five noncamera intersections as comparison sites. The results of the study indicated that violation rates at camera intersections fell sharply (an average of 40 percent drop) shortly after the introduction of the red-light cameras, at both camera and noncamera approaches. The findings may not be indicative of a long-term trend in red-light violations as the study was conducted over a relatively short duration of about three months. Moreover, the influence of novelty effect may not have worn off substantially as the after-study field observations were carried out only one month after camera installation.

**RED-LIGHT CAMERA PROGRAM IN SINGAPORE**

In Singapore, traffic light surveillance camera systems were installed at a number of intersections over a five-year period starting in August 1986. The basic system consisted of a 35-mm camera together with a monitor display unit in a housing positioned on a pole that allowed easy mounting and dismounting of the camera system. Linked to a traffic control system, the camera system became active during the red phase of the signal cycle. To support the taking of photographs in poor lighting conditions, a flash unit was mounted on a pole erected a few meters ahead of the camera unit. Each camera was loaded with a roll of film that could take up to 800 black-and-white pictures. Vehicles crossing the stop-line during the red phase were detected by inductance loop sensors buried in the pavement just after the stop-line of an approach. On detection, the camera was activated to take two sequential photographs one second apart. The presence of a red-light camera was made known to drivers by a traffic sign "Red Light Camera" at some distance upstream of each series of camera intersections.

The operation of the red-light cameras is under the jurisdiction of the Traffic Police Department which is also responsible for follow-up procedures to prosecute red-light violators. As a standard practice, typically within a fortnight after a violation, a "Notice of Traffic Offense" is sent to the registered owner of the violating vehicle stating the type, date and time of offense under the owner-onus rule. The penalty incurred for a red-light offense as documented in the Traffic Act\[^{12}\] is a fine of $5150 (US$1 = $1.43) for light vehicle or $8180 for heavy vehicle and six demerit points. Under Singapore traffic regulations, a driver who accumulates a total of 24 points within 24 months is liable for license suspension.

**EVALUATIVE STUDIES ON THE IMPACTS OF RED-LIGHT CAMERAS**

Presently, about one in every five signalized traffic intersections is covered by one to three surveillance camera systems. Given that the scale of operation of red-light cameras in Singapore is relatively large, it is appropriate and worthwhile to carry out an evaluation study of the long-term effects of red-light cameras on traffic safety at signalized intersections. The impact of red-light cameras on accident reductions is first evaluated. This is followed by an evaluation of red-light violation rates based on data captured by the surveillance camera and by video-filming at a number of camera and noncamera intersections along an arterial road.

**Intersection Accidents**

To evaluate the effectiveness of the red-light cameras on accident reductions, a before-and-after study was carried out on a sample of 125 camera intersections. The intersections were restricted to three-legged ("T" or "Y") or four-legged (cross) intersections. Camera intersections that had undergone major geometric changes were excluded. Accident counts (fatal and injury types) from 1985 to 1993 were identified for these intersections, and
before-and-after accident rates were computed and compared. The findings indicate that the accident counts, as shown in Figure 1, were at a high point in 1986 (also the year when the first cameras were introduced), followed by consistent improvements thereafter (apart from a large drop in 1988). The reduction in accident rates at camera intersections clearly provides supportive evidence on the effectiveness of the camera program. However, one should also caution that the red-light cameras may not be the sole factor contributing to reduction in intersection accidents.

To determine whether the accident reduction was large enough to be principally ascribed to the installation of red-light cameras, a before-and-after analysis was carried out on two equivalent samples, comprising 42 treatment (installed with red-light cameras) intersections and 42 comparison intersections. The results indicate a 25.8 percent reduction in accidents for the treatment intersections, and a corresponding 18.8 percent reduction for the comparison intersections. Thus, there was a net reduction of 8.6 percent at camera intersections. The observed chi-square values, in the range of 0.02 to 0.86, were not significant when compared to the critical one-tail chi-square value at 5 percent significance level. One may argue that the lack of statistical significance can be partly ascribed to the possibility of an area-wide component in the effect of the red-light camera. For example, with widespread surveillance (about one in every five intersections in Singapore), drivers will maintain a generally higher level of alertness in the driving task, leading to increased vigilance, which is desirable from a safety point of view.

**Red-Light Violation Characteristics Captured by Surveillance Cameras**

Essential details captured by red-light cameras include vehicle type, offense time, day and date, location, and time-after-red. Various analyses were performed to characterize red-running violations but only two aspects of red-running violations are highlighted.

- The proportion of violations of various vehicle types as a percentage of the total number of violations are shown in Table 1. Car and station wagon vehicle types were ranked at the top, while motorcycle and scooter vehicle types were ranked on the other end of the scale at 64.7 percent and 1.2 percent, respectively. An index of violation, defined as the ratio of proportion of violations (percent) to vehicle type population (percent), was computed to relate involvement of violations with population of each vehicle type. An index with a value greater than unity means a relatively high involvement and vice versa. Motor-taxis, buses, and minibuses were found to have high indices, while that of the motorcycles and scooters remained the lowest; and

- Violation rates were found to be higher at three-legged than at four-legged intersections; the average rates were 0.25 and 0.19 violations per camera per hour, respectively. The difference is statistically significant at the 5.4 percent level.

**Violation Characteristics by Video-Filming**

The preceding analyses dealt with red-running violation characteristics only at camera approach of signalized intersections installed with red-light cameras. It was not able to make a comparative study with red-running violations at noncamera intersections, or even with the noncamera approach of a camera intersection. Further field study of violation behavior at camera and noncamera
intersections is, therefore, desirable to provide additional insight into the effectiveness of the surveillance cameras in curbing red-running violations.

A field study was carried out at seven "T" intersections that consisted of no-, one-, and two-camera housings along a 70 km/h (43.5 mph) speed limit arterial road. These intersections, situated near each other along a stretch of arterial road (Bukit Batok Road), were chosen on the basis of their similar geometric layout and signal phasing and timing (all intersections have an amber interval of three seconds) so as to minimize their influence on red-running violations. Moreover, driver mix and inter-site traffic were consistent along these intersections.

Two hours (4 p.m. to 5 p.m. and 5:30 p.m. to 6:30 p.m.) of video-camera filming, with cameras placed at vantage points not conspicuous to the driver, were carried out to collect traffic volumes of straight-through movements traveling in both directions along Bukit Batok Road. Violations also were recorded by field observers positioned at strategic locations within the vicinity of the stop-line during the same period.

The straight-through movement violation rates, normalized with respect to traffic volumes, for major approaches of the no-, one- and two-camera intersections are shown in Table 2. The findings clearly indicate that the overall violation rate of 0.0088 (or 88 vehicles per 10,000 vehicles) for no-camera intersections is the highest as compared to one-camera (0.0049) and two-camera (0.0020) intersections. Within a camera intersection, violation rates at the non-camera approach are also much higher than at the camera approach. This clearly demonstrates that the presence of the red-light camera plays a very crucial role in curbing red-runners. One can also notice that the violation rates for approach 1 (with right turning, or left turning in the context of the United States road system, onto a minor road) are always higher than approach 2 (with left turning onto a minor road) for all intersections irrespective of whether these intersections are installed with cameras.

However, one should also realize that there are still a small number of violators who simply have no regard for the red-light cameras. These are beyond the control of the red-light camera system. Only the motorists themselves, through the passage of time, are able to overcome these problems.

ACKNOWLEDGMENTS

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### Table 2. Straight-through movement violation rates at seven "T" intersections.

<table>
<thead>
<tr>
<th>Intersection study site at</th>
<th>Number of Cameras</th>
<th>Major Approach</th>
<th>Total Traffic Volume</th>
<th>Total Violations</th>
<th>Violation Rate (10^-4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bukit Batok West Ave / (J1)</td>
<td>0</td>
<td></td>
<td>4604</td>
<td>41</td>
<td>0.93</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td></td>
<td>2341</td>
<td>12</td>
<td>0.51</td>
</tr>
<tr>
<td>Bukit Batok West Ave / (J2)</td>
<td>0</td>
<td></td>
<td>4473</td>
<td>44</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td></td>
<td>2192</td>
<td>19</td>
<td>0.87</td>
</tr>
<tr>
<td>Bukit Batok West Ave / (J3)</td>
<td>0</td>
<td></td>
<td>2564</td>
<td>24</td>
<td>0.94</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td></td>
<td>2123</td>
<td>18</td>
<td>0.85</td>
</tr>
<tr>
<td>Bukit Batok West Ave / (J4)</td>
<td>1</td>
<td></td>
<td>4417</td>
<td>37</td>
<td>0.85</td>
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<tr>
<td></td>
<td>2</td>
<td></td>
<td>2187</td>
<td>3</td>
<td>0.14</td>
</tr>
<tr>
<td>Tock Whye Avenue / (J5)</td>
<td>1</td>
<td></td>
<td>2722</td>
<td>18</td>
<td>0.65</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td></td>
<td>3046</td>
<td>6</td>
<td>0.16</td>
</tr>
<tr>
<td>Choa Chu Kang Road / (J6)</td>
<td>2</td>
<td></td>
<td>1868</td>
<td>7</td>
<td>0.38</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td></td>
<td>3575</td>
<td>4</td>
<td>0.11</td>
</tr>
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</table>

Overall: no camera = 18047, 158 = 0.88; one camera = 13133, 64 = 0.49; two cameras = 5423, 11 = 0.20

1. Only two major approaches to the "T" intersection are considered: 1 for the approach onto right turning for left-hand drive (driving onto minor road), and 2 for the other approaches with left turning onto minor road.
2. Camera approach capturing violations along the approach indicated.
3. Violation rate is observed by detecting red violations with no traffic volume.
4. Summation of traffic volume and violations for all approaches approaches with non, one, and two-camera intersections.
References

Kit Meng Lum is a Senior Lecturer in the Centre for Transportation Studies and School of Civil and Structural Engineering, Nanyang Technological University. His current research interests include traffic characteristics and interactions at signalized intersections installed with red-light surveillance camera systems. He is currently a Member of ITE and also a Member of the Professional Engineers Board, Singapore.

Yik Diew Wong is a Lecturer in the Centre for Transportation Studies and School of Civil and Structural Engineering, Nanyang Technological University. He graduated with B.Eng. (civil engineering) and Ph.D. degrees from the University of Canterbury, New Zealand. His current research interests are in driver and traveler behavior, and road safety engineering and practice.