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RED LIGHT RUNNING BEHAVIOUR AT RED LIGHT CAMERA AND CONTROL INTERSECTIONS

Report prepared for VicRoads by
Monash University Accident Research Centre

by

Sally Kent

Bruce Corben

Brian Fildes

David Dyte

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Red Light Running Behaviour at Red Light Camera and Control Intersections

Author(s):

Sally Kent, Bruce Corben, Brian Fildes & David Dyte

Sponsoring Organisation:

VicRoads, Road Safety Department
60 Denmark Street, Kew, 3101, Victoria, Australia

Performing Organisation:

Monash University Accident Research Centre
Wellington Rd, Clayton, 3168, Victoria, Australia

Abstract:

One of the key enforcement initiatives intended to reduce the number and severity of intersection crashes is Red Light Cameras. There are currently about 120 Red Light Camera intersections covering metropolitan Melbourne and Geelong. The objective of this study was to determine the nature and extent of red light running behaviour at a sample of camera and comparable non-camera sites around Melbourne. Signal compliance was measured as a function of speed zone, road cross section, lane type, time of day and day of week. Three intersections were investigated. For each intersection, measurements of red light running behaviour were obtained by video-taping traffic at three selected approaches, namely the camera approach, the opposite (non-camera) approach at the same intersection (i.e., subject to the red light camera ahead sign but with no camera) and also a matched approach with no signs or camera. Red light running was a relatively rare occurrence (123 encroachments out of 38,000 observed vehicle movements - 0.32%); Further, 93% of the encroachments occurred during the all-red period of the signal cycle when the probability of conflicting traffic is lowest. Red light running rates were significantly higher for right-turn movements compared to through movements. Red light running rates were also higher for right-turn movements in 60 km/h speed zones, on undivided roads than in 80 km/h speed zones on divided roads. The difference between right-turn and through movement red light running rates was most pronounced in the evening peak period. Notably, there were no differences in the observed rates of red light running between camera and non-camera approaches. Results are discussed in terms of their implications for further research and for the operation of the Red Light Camera Program in Victoria.

Key Words:

RED LIGHT RUNNING, RED LIGHT CAMERAS, TRAFFIC FLOW, CRASH RISK, SCRAM TECHNOLOGY, CRASH OCCURRENCE

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Monash University Accident Research Centre,

Wellington Road, Clayton, Victoria, 3168, Australia.

Telephone: +61 3 9905 4371, Fax: +61 3 9905 4363

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EXECUTIVE SUMMARY

Red light cameras have been in operation in Victoria since 1983 and currently cover about 120 signalised intersections in metropolitan Melbourne and Geelong. Cameras were originally introduced to reduce the incidence and severity of intersection crashes, particularly cross-traffic crashes.

While there have been some evaluations of the effectiveness of the Red Light Camera Program in reducing intersection crashes, there has never been a detailed study in Victoria of the nature and extent of red light running behaviour.

Thus, the prime objectives of this study were:

1. To examine red light running behaviour at a sample of Red Light Camera (RLC) sites in Metropolitan Melbourne and behavioural differences between RLC and Non-RLC sites (including non-camera approaches of RLC sites);

2. To investigate the effects of road cross section, speed zone, traffic volume, lane type and day of week on red light running behaviour;

3. To examine the relationship between red light running behaviour and crash occurrence at RLC sites in the light of the findings of a recent investigation of the effects of red light cameras on crash occurrence and types (Andreassen, 1995);

4. To make recommendations on future directions for the Red Light Camera Program in the light of the findings of the current study.

The study set out to examine red light running behaviour using the SCRAM computer-based network which controls traffic at most of Melbourne's signalised intersections. It was hoped that red light running behaviour could be efficiently measured via the SCRAM technology which relied on "trailing edge triggering" as vehicles cleared the magnetic loops prior to the intersection stop line. Extensive pilot testing using the SCRAM technology indicated that, in its current form, it was inadequate for the task for the following reasons:

1. There was under-counting of total hourly traffic volumes caused by vehicles queuing on the red phase with reduced headways (the detector loops were insensitive to short gaps between vehicles);

2. Over-counting of red light runners occurred in instances where vehicles stopped well over the stop line but did not proceed through the intersection;

3. Technical difficulties were experienced resulting in the loss of encroachment data.

After discussions with VicRoads and the Victoria Police, a more reliable method was developed based on video recording traffic from an unmarked private vehicle. This procedure proved to be successful although it required considerably more staff time, thereby limiting the design of the study from that originally proposed.

Observations of red light running behaviour were taken at **three** carefully selected red light camera approaches and **six** matched non-camera control approaches around Melbourne. Red light running behaviour was measured as a function of speed zone, road cross section (divided or undivided), time of day, day of week and vehicle type.

The results of the study, in relation to the four main objectives were as follows:

Objective 1 - Extent of Red Light Running

Red light encroachments were relatively rare events and, for the most part, those observed were not all that dangerous. However, there was a relatively small number (8 in over 38,000 vehicle movements) that were dangerous manoeuvres during the full-red interval. If this rate is extrapolated to all traffic signal approaches in Victoria, it represents more than 500,000 dangerous encroachments per year. Though not able to be rigorously investigated in this study, there was also a suggestion in the data that trucks may be over-represented in red light running during the all-red interval. The results suggested that a simple, inexpensive countermeasure to reduce crashes resulting from red light running may be to increase the all-red periods at signalised intersections by one or two seconds, although the behavioural consequences of this need careful consideration.

Objective 2 - Road and Environment Effects

The speed limit and cross-section of an approach appeared to influence red light encroachments only for right-turners. Arterial roads with 60 km/h limits and undivided roads had higher rates of illegal right-turn encroachments than did 80 km/h and divided roads.

Red light running rates were generally higher in right-turn than in through lanes, but were particularly so during the evening peak period. Further, there were fewer right-turn encroachments at the site where **all** approaches had fully-controlled right-turn phases.

Interestingly, there were no statistically reliable differences in red light encroachments observed between camera and non-camera approaches. It is unlikely that this could be attributed to traffic flow differences or other environmental influences as these were relatively constant across test and control approaches for any given site. The results suggest some investigation of the current mode of operation of the red light camera program may be warranted.

Differences between week days and weekend days could not be analysed thoroughly because football traffic had an extreme influence on the weekend data, preventing a proper analysis of the red light running behaviour of drivers on weekends. This finding may be highlighting a substantial safety problem associated with football traffic (or sporting event traffic generally) and warrants further investigation.

Objective 3 - Red Light Running & Crashes

Andreassen (1995) found that the installation of RLC's at 41 sites studied did not result in any reduction in accidents at those sites. Further, he found no significant differences between crashes at RLC sites compared with signalised intersections in Melbourne generally. Thus, there was no need to do an extensive analysis of the correlation between red light running behaviour observed in this study and crashes. Nevertheless, a simple correlation analysis was undertaken for red light running data in the current study and revealed no significant relationship between the frequency of crashes at RLC and non-RLC sites and differences in red light running behaviour.

Objective 4 - Extension of the RLC Program

While the need for more RLC installations was not justified by this, or the recent accident study of Andreassen (1995), nevertheless there are grounds for improving the operation of existing RLC locations. Highest priority should be given to increasing the perceived risk of detection at these sites. This could be done by overcoming existing technical difficulties at some sites, by increasing the level of activity and by supportive publicity. Subsequent testing might then indicate whether there is a need for more RLC installations.

Recommendations

The three basic recommendations from the findings of this study were that:

1. *An action program be undertaken to improve the effectiveness of existing Red Light Camera operations in Melbourne as outlined above;*

2. *Further research be undertaken to test red light running behaviour more extensively than was possible in this study. A focus on red light running behaviour associated with weekend sporting events and/or heavy vehicles may be especially worthwhile;*

3. *Consideration be given to increasing the duration of all-red periods by one or two seconds, as a simple, inexpensive countermeasure for crashes caused by red light running, taking into account the traffic capacity and behavioural consequences of such a change.*

CHAPTER 1 INTRODUCTION

1.1 Background

Red Light Cameras (RLC's) were first introduced in Victoria during the early 1980's in an attempt to reduce red light running behaviour and subsequently intersection crashes. In particular, cross-traffic crashes, normally a very severe type of crash because of side impact configurations, were expected to reduce with these measures.

After an initial three month trial at one site in 1981, camera equipment was progressively installed and was operational at 46 sites in Metropolitan Melbourne by November 1984. The number of RLC sites in Melbourne has since increased to a current level of approximately 120 The RLC program in Victoria is administered jointly by the Victoria Police (Traffic Camera Office) and VicRoads.

An early evaluation of the RLC program by South, Harrison, Portans and King (1988) examined accident statistics at the initial group of RLC sites over the period 1979-1986 (i.e., 5 years pre- and two years post-RLC). The authors reported a statistically significant reduction of 32% in right-angle crashes and in the number of crash casualties.

A subsequent study of the benefits of RLC's at the same group of sites has recently been finalised by the Australian Road Research Board (Andreassen, 1995). This study concluded that there has been no significant post-RLC reduction in accidents at these sites, but rather an increase in rear-end crashes and crashes involving vehicles from adjacent directions.

It was timely, therefore, to assess the benefits of RLC's in terms of behavioural change. This report outlines a study designed to examine red light running behaviour differences at RLC and other control sites.

1.2 Objectives

The objectives of this study were:

1. To determine the nature and extent of red light running behaviour at a sample of RLC and non-RLC sites in Metropolitan Melbourne;

2. To determine if there is a difference in red light running behaviour between RLC and non-RLC sites (including non-camera arms of RLC sites) and to examine the effects of road cross section, speed zone, traffic volume, lane type and day of week on this behaviour;

3. To examine the relationship between red light running behaviour and crash occurrence at RLC sites, assuming that a difference in crash occurrence is found by the ARRB study;

4. To advise on the potential for the extension of the RLC program to other intersections.

CHAPTER 2 PILOT STUDY USING SCRAM ELECTRONIC TECHNOLOGY

2.1 Data Collection Method

A pilot study was initially carried out in consultation with VicRoads Traffic Control Department to attempt to collect red light encroachment data using the SCRAM network and technology. SCRAM (Signal Co-ordination of Regional Areas in Melbourne) is the Melbourne application of SCATS (Sydney Co-ordinated Adaptive Traffic System). The Melbourne SCRAM system covers approximately 85% of metropolitan signalised intersections ensuring that practically all intersections selected would be available for data collection by this method. The method offered high potential for efficient, large scale data collection on red light running for a large sample of sites and conditions.

Using the SCRAM system, the levels of red light running by drivers in different traffic situations would be measured by collecting data on the numbers of vehicles crossing the traffic signal stop line during specified periods in the traffic signal cycle. The SCRAM system was modified and programmed for this task under the coordination of Ray Sprague from VicRoads' Traffic Signal Operations Department. Encroachments were defined as any instance of a vehicle crossing the stop line and proceeding through the intersection after the green phase of the signal cycle. While it is recognised that yellow encroachments are legal, their distribution over time nevertheless indicates a propensity to encroach during the illegal red signal phases, particularly if they are large in number and occur late in the yellow period. Yellow encroachments also represent a crash risk in the case of long vehicles (e.g., semi-trailers) which take longer to clear an intersection.

Encroachment data would be based on "trailing edge" triggering after commencement of the yellow and red periods. *"Trailing edge"* triggering refers to sensing when the vehicle has cleared the magnetic loop in the road. As the normal loop position is 1½ metres back from the stop line and most cars are 4 to 5 metres in length, it was assumed that a vehicle has entered the intersection once the loop has been triggered. While a small percentage of vehicles might stop over the stop line without proceeding, it was expected that the vast majority would continue through.

2.2 Design

The experimental design for collection of the red light running data using the SCRAM system incorporated three different samples of sites: *Test sites* (i.e. red light camera approaches at red light camera intersections); *Control 1 sites* (i.e. non-red light camera approaches at red light camera intersections); and *Control 2 sites* (i.e. matched approaches at non-camera intersections). This would allow a comparison of the effects of camera hardware (*Test*), red light camera ahead signs only (*Control 1*) and no camera or signs (*Control 2*), on the rate of red light running.

The design also incorporated two levels of *road cross section* (Divided and Undivided), three levels of *speed zone* (60, 70 & 80 km/h), and two levels of *traffic congestion* (High and Low), since it was hypothesised that these variables would have a significant influence on the probability of red light running. The design included two replications of each combination of these variables, making a total of 72 approaches (see Table 2.1).

Table 2.1 Experimental Design for Red Light Running Observations

Site Characteristic	RLC	No. of Approaches Control 1	Control 2
1. Speed zone	x 3	x 3	x 3
2. Road Cross Section	x 2	x 2	x 2
3. Congestion/Saturation	x 2	x 2	x 2
4. Replications	x 2	x 2	x 2
TOTAL	24 approaches	24 approaches	24 approaches

For each approach, additional variables investigated were *time of day* (Morning Peak, Off-Peak, Afternoon Peak, Night), *lane type* (Through and Right-Turn) and *day of week* (Weekday or Weekend Day). The day of week variable was included to allow a comparison between compliance during routine commuting times (Weekday) versus recreation times (Weekend) which was also a surrogate for low and high alcohol times.

2.3 Site Selection

Site selection was based on a current list of red light camera sites supplied by VicRoads. Further lists categorising these sites according to speed zone and traffic congestion and identifying the approach arm on which the red light camera was located were also obtained from VicRoads.

The site selection process revealed that a perfect hierarchical design (as described in Table 1) was not possible as the road cross section and speed zone variables were closely dependent (there were practically no instances of undivided intersections with 70 or 80 km/h speed limits). In order to compensate for this shortfall, the design was modified to include three, rather than two, replications of each combination of variables (road cross section x speed zone x congestion), which still resulted in a total of 72 approaches.

Based on the above design specifications, over 100 individual approaches were selected and visited by MUARC staff to verify suitability for inclusion in the study. A detailed list of the 72 approaches and their design characteristics is provided in Appendix 1.

2.4 Pilot Testing

As the SCRAM technology has not previously been used in this type of application, pilot testing was necessary in order to validate the method. Electronic data collected by SCRAM were compared with manual counts collected by MUARC observers at the site. Further validation was provided by Traffic Camera Office photographic records of red light infringements collected during corresponding time periods. The pilot testing was conducted in successive stages, as each stage highlighted new problems requiring further investigation.

2.5 Stage 1 Testing

2.5.1 Method

On Monday 16 and Tuesday 17 January 1995, SCRAM data on vehicles triggering the stop line loops were collected during different time intervals at four red light camera intersections. Data were collected for up to five hours for two lanes (i.e. two detectors) on each of the camera approaches. Concurrently, manual counting of corresponding vehicle movements was undertaken for at least two hours on site by a MUARC observer to validate the SCRAM data collection method.

The four intersections studied in the stage 1 testing program were:

1. Springvale Road/Wellington Road, Mulgrave
2. High Street Road/Springvale Road, Glen Waverley
3. High Street Road/Huntingdale Road, Mount Waverley
4. Balwyn Road/Whitehorse Road, Balwyn

No SCRAM data could be collected at Springvale Road/Wellington Road due to a signal system malfunction at the time. In addition, meaningful counts of encroaching vehicles at the Balwyn and Whitehorse Road intersection were prevented by the existence of a bonus left turn phase (i.e., a phase operating simultaneously with the right-turn phase(s) on the adjacent approach(es)). However, total vehicle counts for two lanes at this intersection were available for comparison with those for High Street Road/Springvale Road and High Street Road/Huntingdale Road.

2.5.2 Results - Encroachments

The results for the number of vehicles triggering the stop line loops during the yellow, all-red and red periods are summarised in Table 2.2 below. Overall there was a high level of consistency between the SCRAM and the manual (MUARC) counts. Of the 134 cycles for which traffic counts were collected by the two sources, 125 cycles showed results where the manual counts were either identical or differed only minimally from the SCRAM counts.

In each of the nine cycles (i.e., 7%) where there were inconsistent results the difference never exceeded one vehicle. In some of these cases, the one-vehicle difference seemed to be due to trucks or other traffic obscuring the observer's view of the signals and/or traffic at the stop line, to lane straddling, or to motor cycles not being detected as they pass between stop line loops. In others, the differences may have been due to the complexity of the simultaneous manual counting and signal monitoring tasks (i.e.,. the difficulty in accurately assigning a vehicle to the correct time category, when the vehicle crosses the stop line near to the instant when the signals change from one phase to another).

These differences were considered to fall within the level of accuracy of the method used. Notably, lane discipline as observed by MUARC, was generally high, thereby reducing the likelihood of lane straddling as a source of error in the SCRAM counts.

Table 2.2 Comparison of SCRAM and Manual Counts of Red Light Running

Detector Number	Number of Cycles Observed and Measured	Number of Cycles with Consistent Results	Number of Cycles with Inconsistent Results	Level of Consistency (%)
1. High Street Road/Springvale Road, Glen Waverley				
Detector 7	25	23	2	92
Detector 8	24	21	3	88
2. High Street Road/Huntingdale Road, Mount Waverley				
Detector 7	37	35	2	95
Detector 8	48	46	2	96
Total	**134**	**125**	**9**	**93**

2.5.3 Results - Total Vehicle Counts

As an additional comparison between the SCRAM and manual measurement techniques, total hourly traffic volumes were counted. These volumes were recorded by SCRAM in 15 minute intervals, commencing at 00:00 (midnight). Therefore it was not possible to maintain a precise time relationship with the manual counting in each traffic signal cycle. Total vehicle counts were obtained for six detectors, two at High Street Road/Springvale Road, two at High Street Road/ Huntingdale Road, and two at Balwyn Road/Whitehorse Road. The results are summarised in Table 2.3.

There was reasonably good agreement between the MUARC and SCRAM data on three of the six detectors for which SCRAM data were collected (High Street Road/Springvale Road - Detectors 7 & 8; High Street Road/Huntingdale Road - Detector 7). The difference on these detectors was only of the order of 0-5%. These differences were considered to fall within the expected level of accuracy of the method used. However, for the other three detectors (High Street Road/Huntingdale Road - Detector 8; Balwyn Road/Whitehorse Road - Detectors 5 & 6) the MUARC counts were 9 to 17% higher than the SCRAM counts. This difference was more than expected (allowing for the previously mentioned inaccuracies of the manual counting method) and suggested that the SCRAM technology may under-count vehicles.

Table 2.3 Comparison of SCRAM and Manual Counts of Total Hourly Traffic Volumes

Location	MUARC	SCRAM	Difference	% Difference*
1. High Street Road/Springvale Road, Glen Waverley				
Detector 7	466	465	1	0%
Detector 8	539	550	-11	-2%
2. High Street Road/Huntingdale Road, Mount Waverley				
Detector 7	310	295	15	5%
Detector 8	287	257	30	10%
3. Balwyn Road/Whitehorse Road, Balwyn				
Detector 5	302	275	27	9%
Detector 6	206	170	36	17%

* *The difference divided by the total MUARC count*

2.5.4 Discussion - Stage 1 Results

The results of the first phase of the pilot study indicated a reasonable level of consistency between SCRAM and manual methods in counting vehicles crossing the stop line during the yellow, all-red and red periods of each cycle. However, there were a number of inconsistencies between the two methods, suggesting that SCRAM may be under-counting.

After discussions with VicRoads' Traffic Signal Operations Department it appeared that under-counting could occur on approaches where vehicles queue in a given lane before the green phase. The smaller headways during queuing lead to two vehicles simultaneously covering the detector loop, with only the trailing edge of the second vehicle being counted. This tendency towards under-counting required further examination to confirm the suspected reasons, and to assure appropriate levels of accuracy in the main study. Finally, sites with a bonus left turn phase introduce the potential for counting error and, therefore, dedicated left or shared left/through lanes with such a phase were not included in the main study.

2.6 Stage 2 Testing

2.6.1 Method

Traffic volumes at one of the original pilot sites, High Street Road/Huntingdale Road, were re-counted on Tuesday 7 February between the hours of 9.30-11.00 am.. As an additional source of validation, traffic movements were also video recorded and later analysed to check the accuracy of both the MUARC manual counts and the SCRAM counts further. The manual and SCRAM counts were compared in 15-minute intervals over the total 1.5 hour period.

Four 15-minute time periods were compared and results are shown in Table 2.4. As there were no differences found between the manual counts and video counts, only data collected using the former method were subsequently analysed.

2.6.2 Results

These results concur with those of the original pilot testing at this site, indicating average under-counting by SCRAM of about 12%. Once again, this difference was larger than expected, even after taking into account difficulties in obtaining a precise time match between manual and SCRAM counts in each time interval and the complexity of manual monitoring.

Table 2.4 Second Comparison of SCRAM and Manual Counts of Total Hourly Traffic Volumes at High Street Road/Huntingdale Road

	MUARC	SCRAM	Difference	% Difference*
Time interval 1	127	106	21	16%
Time interval 2	139	126	13	9%
Time interval 3	105	92	13	12%
Time interval 4	120	107	13	11%
Total	**489**	**431**	**58**	**12%**

* *The difference between SCRAM and MUARC counts divided by the total MUARC count.*

Further investigation of apparent under-counting by SCRAM was conducted during an additional visit to the High Street Road/Huntingdale Road site. On this occasion vehicle counts were taken by two observers - one using the manual monitoring method, the other monitoring the detector activation displays on the traffic signal controller at the site. This revealed that the under-counting problem related to only the first two vehicles travelling through the intersection at the beginning of the green phase (the detector consistently failed to count the first queued vehicle at the beginning of the green phase, as the front of the second vehicle was already over the loop before the rear of the first vehicle had cleared it).

These measurements also showed that vehicles stopping on the red signal beyond the stop line activated the loop; thus, they would be included by SCRAM in the number of vehicles crossing the stop line in the all-red or red period, even though they did not actually proceed through the intersection. Such occurrences were defined as 'false red light running'.

2.6.3 Discussion - Stage 2 Results

In summary, SCRAM under-counted traffic movements but over-counted encroachments , and it was not possible to correct for this as it was not consistent across sites. After further consultation with VicRoads it was decided to quantify the problem of 'false red light running' by further pilot testing at a sample of sites.

2.7 Stage 3 Testing

2.7.1 Method

In order to investigate the extent of 'false red light running' and its potential for introducing error in to the measurements of red light running in the main study, further counts were undertaken at a sample of red light camera *Test* approaches from those selected for the main study. Manual counts of *false* and *full* (i.e., actual) red light running were taken using two observers at each site; one observer monitored the intersection and the phasing of the signals while the second observer monitored the SCRAM detector activation displays in the controller. These manual counts were then compared with SCRAM counts measuring the *total* (i.e., *false* plus *full*) number of vehicles crossing the stop line during the all-red and red periods of the signal cycle.

The sites sampled in this stage were:

1. Springvale Road/High Street Road, Glen Waverley;
2. Toorak Road/Burke Road, Camberwell;
3. Nepean Highway/Highett Road, Highett.

Manual data were collected at each site, during two separate one-hour periods representing the morning and evening peak periods (see Table 2.5). Data were collected on through lanes of the camera approaches. SCRAM counts were taken continuously over periods of up to 72 hours, which incorporated the manual counting periods.

The Victoria Police Traffic Camera Office assisted in this stage by installing cameras in the housing erected at two of the pilot sites (Springvale Road/High Street Road and Nepean Highway/Highett Road) thereby providing further data for validation of red-light-camera infringements during the relevant measurement periods. This film was installed as a test film and any infringements recorded were not prosecuted, thus enabling MUARC staff to view the film without breaching the confidentiality of drivers involved. Film was not installed at Toorak Road/Burke Road due to problems with camera hardware.

2.7.2 Results

The results from the various methods of measuring red light running behaviour are shown in Table 2.5. Comparisons between the various methods of measuring red light running proved difficult for two reasons:

1. Manual observations from the traffic controller could not always be verified by the SCRAM counts because of operational difficulties with the SCRAM system or because of difficulties in extracting precise information from the viewing program (DSG-View);

2. Further validation of manually collected data with Traffic Camera Office data was on occasions prevented by camera malfunction.

Comparing controller with observer counts indicated that almost half of recorded instances of red light running at the three pilot sites were actually false red light running (where a vehicle stopped over the stop line on either the all-red or full-red periods of the signal cycle but did not continue through the intersection). Assuming that controller counts should equate to SCRAM counts (where available and able to be accurately measured), this result suggests that the SCRAM method of measuring red light running has the potential to over-count by almost 100%. Additionally, viewing the available SCRAM data from this pilot phase revealed several other inconsistencies which further cast doubt on the reliability of the method.

Table 2.5. Comparison of SCRAM, Manual and Traffic Camera Office Measurements of Red Light Running

Site	No. of Red Light Runners				
	SCRAM	MUARC			TCO
		Controller (a)	*Observer (b)*	*Partial (a-b)*	
1. Springvale Rd/High St Rd					
27/2/95 ~10.35 - 11.35	N/A	4	3	1	N/A*
27/2/95 ~16 .40 - 17.45	N/A	0	0	0	N/A*
2. Toorak Rd/Burke Rd					
1/3/95 ~11.13 - 12.15	N/A	3	1	2	N/A
1/3/95 ~17.00 - 18.00	2	2	0	2	N/A
3. Nepean Hwy/Highett Rd					
8/3/95 ~16.30 - 17.30	3	7	3	4	2
9/3/95 ~08.20 - 09.30	N/A	3	3	0	0
Total	-	**19**	**10** (53%)	**9** (47%)	-

Notes: N/A = Not available
N/A = Not available due to camera malfunction*

2.7.3 Discussion - Stage 3 Results

The results of Stage 3 of the pilot study indicated that actual occurrences of full red light running in either the all-red or red periods were rare, and that SCRAM could not accurately or reliably measure instances of full red light running. Furthermore, the unpredictable nature of the occurrence of errors would prevent the development of effective correction factors.

2.8 Discussion Of Pilot Study Results

The three successive stages of the pilot study revealed specific problems with the SCRAM technology which were of concern and cast serious doubt on its accuracy and reliability for measuring the probability of red light running at given intersections: These are listed below:

1. There was the potential for under-counting of total hourly traffic volumes caused by two vehicles queuing on the red phase with reduced headways, thereby covering the detector loop at the same time and activating it only once;

2. There was the potential for over-counting the number of full red light runners in instances where vehicles stop well over the stop line on the all-red or red periods, thereby activating the loop, even though they do not proceed through the intersection. No ready or simple

means of correcting for this type of error could be determined, and the level of error was considered too high to be tolerated in this study;

3. There was the occasional tendency for SCRAM to 'drop out' or experience technical difficulties during a measurement period, resulting in the loss of essential data and the likelihood of unacceptable extensions to the data collection timetable.

Discussions between VicRoads and MUARC staff indicated that additional modifications or enhancements to SCRAM to eliminate the potential for counting error would be too costly in terms of time and resources. Further, calculating the error factor for a representative sample of approaches (specified by the study design) would be an extremely time consuming and costly process, and ultimately not very accurate. Thus, in the light of the above, it was mutually agreed that the SCRAM technology should not be pursued as the measurement tool and that an alternative method for collecting red light running data should be investigated.

CHAPTER 3 VIDEO OBSERVATION STUDY

3.1 Design

The inability of the SCRAM technique to provide suitable data on red light runners meant that an alternative approach had to be adopted. Direct observation of red light runners at suitable intersections was an obvious candidate, although this method suffers if observers are not totally vigilant and often the mere presence of the observers can influence behaviour at these sites. A variant involving unobtrusive videoing of behaviour and then scoring these videos was chosen for the task to overcome these possible behavioural biases.

A modified study design was also necessary to complete the project with the remaining resources, while still addressing the prime objectives. The design was modified to include two rather than three speed zones (60 km/h and 80 km/h) providing a simple low and high speed comparison. This would maximise the chance of detecting speed-related differences, should they exist. The divided/undivided comparison was also maintained, giving three types of sites (undivided-60 km/h, divided-60 km/h and divided-80 km/h). The "divided" condition was defined as having either a continuous median or central approach island at the intersection. As there were no replications, generalising from the results of this limited sample may prove unreliable. For each site configuration three approaches were measured as in the original design, namely:

1. *Test* approach (RLC)
2. *Control 1* approach (opposite the *Test* approach - Sign only)
3. *Control 2* approach (No RLC or sign)

These characteristics yielded a total of 9 separate approaches to be studied. Further, it was decided to address the effect of intersection congestion/saturation by a time-of-day sampling strategy, rather than by an overall rating of congestion at each site. Measurements were taken over four x 3-hour time periods reflecting different levels of traffic congestion, namely morning peak (7.30-10.30 a.m.), midday off-peak (11.30 a.m.-2.30 p.m.), afternoon peak (3.30-6.30 p.m.) and evening off-peak (8.00-11.00 p.m.).

Measurements were taken on one weekday and weekend day per approach to examine differences in red light running behaviour by time of the week. Weekday recordings were collected on either Mondays, Tuesdays or Wednesdays as these days were considered to be typical weekdays. Weekend recordings were taken over the same time periods on Saturdays in order to include the high alcohol hours normal on Saturday evenings. Through lanes and right-turn lanes were still sampled in the modified design. For the purposes of this study, shared through-right lanes were classified as right-turn lanes.

The modified experimental design is set out in Appendix 2.

3.2 Site Selection

Six intersections (9 approaches) were chosen from the list of 48 intersections (72 approaches) selected in accordance with the original study design (see Appendix 1). The six intersections were selected to match the modified design described above with due consideration of the following issues:

1. No road construction or other changes pending;
2. Good access for the vehicle housing video equipment;
3. Contour of *Test* site flat or has only minor gradients;
4. Red light camera loops functional;
5. Crash histories;
6. Number of prosecutable red light offences (TCO data) on the *Test* approach.

Potential sites were visited to verify their suitability on the access and contour criteria (see Appendix 3 for site visit legend). A detailed list of the final nine approaches and their design characteristics is provided in Appendix 4.

3.3 Data Collection Method

Data on red light running and total hourly traffic volumes were collected by discrete video recording at selected sites and times, and the behaviour was then manually scored.

3.3.1 Equipment

An unmarked car belonging to MUARC was specially fitted with the following equipment to allow unobtrusive videotaping of traffic at the chosen sites:

- two video cameras
- two 'magic arm' devices for mounting the cameras inside the vehicle
- a VCR for recording directly onto VHS videotapes
- a television monitor (8 ") for displaying the recorded images
- an Image Splitter to simultaneously display the images from both cameras
- a DC/AC Inverter for powering the equipment off the car battery

The car was positioned to minimise the likelihood of it influencing driver behaviour. The equipment was set up so that one camera was directed at the stop line of the selected approach, while the other camera (with a zoom lens attachment) was directed at the traffic signal controlling that approach. The use of the 'magic arm' devices allowed maximum flexibility in the mounting of the cameras inside the vehicle to achieve the best possible views. The image from the first camera (stop line) constituted the main view, while the image from the second camera (traffic signal) was superimposed onto the top right-hand corner of the main image via the image splitter. A timer in the first camera provided a permanent time recording (in hours, minutes and seconds) on the main image. The camera time was routinely synchronised with Telecom recorded time using a mobile telephone present in the vehicle.

3.3.2 Procedure

An observer was present in the vehicle for the entire 3-hour videotaping session to monitor the functioning of the equipment and the images being recorded. Two observers shared the videotaping sessions on any one day so that each observer monitored two of the four sessions.

The observers were instructed to cancel sessions in the event of wet weather, as it was expected that drivers' behaviour and general compliance with traffic signals would be different on wet versus dry roads. These sessions were re-scheduled for the next appropriate dry day.

3.4 Data Extraction

A team of four specially trained observers manually extracted the data from the videotapes and entered it directly onto computer spreadsheets ready for data analysis.

3.4.1 Equipment

The videotapes were played back using VCR machines with a jog-shuttle facility, allowing the tape to be advanced or reversed on a frame-by-frame basis. This facility gave the observers greater efficiency and flexibility in locating particular events precisely in time. It also enabled the observers to convert a frame count into 1/100ths of a second (based on the number of frames per second) allowing the data to be analysed and presented in one-second intervals. Data were extracted on a cycle by cycle basis for right-turn and through lanes separately. For each cycle and each lane type, the following information was recorded onto a computer spreadsheet for later analysis:

- the number of the cycle;
- the time at which the green phase of the cycle began;
- the number of vehicles travelling through during the green phase;
- the time at which the green turned to yellow;
- the time at which the yellow turned to all-red (this was programmed directly into the spreadsheet using formulae based on the constant yellow and all-red times set out in the VicRoads time setting sheets for each intersection);
- the time at which the all-red terminated (this was also programmed into the spreadsheet as above);
- the time(s) at which any vehicles entered the intersection (i.e., front wheels crossed the stop line) after the commencement of the yellow, all-red or red periods;
- the type of vehicle encroaching during one of the above periods was coded as: 1=passenger vehicle; 2=truck (rigid and articulated); 3=bus; 4=motorcycles; and 5=bicycles.

Formulae were programmed to convert the vehicle times into a 'type of runner' category (i.e., yellow, all-red or red). A sample spreadsheet is provided in Appendix 5. After collecting the data it was discovered that there was considerable variation in traffic congestion/saturation within each 3 hour session. Thus it was decided initially to extract only 1½ hours of data from each 3 hour session. The 1½ hour sessions were chosen to reflect the most homogeneous traffic congestion conditions within the 3 hour period, namely:

- 7.30-9.00 a.m. (morning peak)
- 11.30-1.00 p.m. (midday off-peak)
- 5.00-6.30 p.m. (afternoon peak)
- 9.30-11.00 p.m. (evening off-peak)

The chances of detecting either a time-of-day or traffic congestion effect would thus be maximised by the more homogeneous, yet distinctly different, periods.

The data extracted from the videotapes covered 38,469 vehicle movements on weekdays and a further 30,360 vehicle movements on the weekend days.

3.5 Data Analysis

An Ordinal Logistic model was used to analyse the results within the BMDP statistical software package (Moran, Engelman, Fitzgerald & Lynch, 1993). The model calculates the likelihood of a particular outcome while controlling for various factors and combinations of factors (such as the likelihood of encroaching during particular phases in the cycle under different conditions of speed zone, lane type, time of day, etc). The factors entered into the model for both the weekday and weekend datasets were:

- site (undivided 60 km/h, divided 60 km/h, divided 80 km/h,)
- approach (*Test*-camera, *Control 1*-signed, *Control 2*-unsigned)
- time of day (am peak, midday off-peak, pm peak, evening off-peak)
- lane (through, right-turn)

The outcomes investigated were the number of vehicle movements or encroachments during various phases of the traffic cycle, namely green, yellow, all-red and red. Within the model, green and yellow (i.e., legal) movements were grouped while all-red and red movements were retained as separate entities. The model calculates significance values for each of the factors (main effects) and for combinations of any two factors (first-order interactions) based on a Chi-squared (χ^2) distribution which compares observed and expected outcomes. Higher order interactions were not investigated because of uncertainty in interpreting results.

It was intended to combine weekday and weekend data in the analysis and include "day of week" as a factor. However, this could not be done as the initial analysis revealed some extreme observations of weekend red light running behaviour which overwhelmed the analysis. An irregularity in the weekend data occurred at the Springvale Road *C2* approach where there was an unusually high number of right-turn red encroachments in the late afternoon. Closer investigation revealed that these results could be related to football traffic due to the proximity of this approach to Waverley Park. This extreme observation suggested that a similar effect on the weekend data was also probable at the Geelong Road approaches due to their proximity to Western Oval, although these effects were not as obvious as at the Springvale Road site. Thus, weekday and weekend data sets had to be analysed separately.

3.6 Weekday Results

Table 3.1 shows the overall incidence of encroachments during the yellow, all-red and red periods across the nine approaches investigated. By comparison with total vehicle movements, the rate of encroachments in the all-red or red periods seems very small. However, the total number of red light runners (123) over the total recorded period of 54 hours (6 hours x 9 approaches) represents a rate of a little over two encroachments per hour at the sites investigated and these represent a significant crash risk. There were more yellow encroachments (approx. 38 per hour), however relative to total vehicle movements they were low in number, and, in terms of crash risk, clearly less dangerous.

Table 3.1 Overall Number and Rate of Vehicle Movements in Various Phases of the Signal Cycle

Legal				Illegal				Total
Green	*(%)*	Yellow	*(%)*	All-Red	*(%)*	Red	*(%)*	
36275	*(94.30)*	2071	*(5.38)*	115	*(0.30)*	8	*(0.02)*	**38469**

Percentages represent the observed rate of encroachments per traffic flow (i.e, total vehicle movements) for various phases of the signal cycle.

3.6.1 Effects of the Independent Variables

The only factors which were found to have a significant effect on the probability of red light running were **site** ($\chi^2(2) = 52.45, p=0.0000$) and **lane type** ($\chi^2\ (1) = 14.77, p=0.0001$). **Lane type** also interacted significantly with **site** ($\chi^2(2) = 14.27, p=0.0008$), and **time of day** ($\chi^2(3) = 8.32,\ p=0.0398$). **Approach type** (reflecting camera presence or not) did not significantly effect the probability of red light running ($\chi^2\ (2) = 0.56, p=0.7560$), nor did **time of day** on its own ($\chi^2(3) = 2.27, p=0.5177$). These results are discussed in more detail below.

3.6.2 Site

Pairwise comparisons were performed within the site variable in order to examine the effects of speed zone and road cross section independently.

Speed Zone: Table 3.2 shows the number and rate of vehicle movements for the two different speed zone sites (both divided). The rate of illegal encroachments (i.e., all-red and red) was higher at the Geelong Road (60 km/h) site compared with the Springvale Road (80 km/h) site, suggesting that the probability or red light running may be greater in low, rather than high speed zones. This effect was statistically significant ($\chi^2(1) = 15.84, p=0.0001$).

The potential influence on red light running behaviour of speed zone can be examined further by separately considering the red light running rates for through and right-turning drivers. The data in Table 3.5, suggest that red light running rates for drivers of through vehicles are essentially the same for 60 km/h as for 80 km/h speed zones. However, red light running rates for right-turners vary from 0.26 for the Springvale Road approaches (80 km/h, divided), to 1.03 and 2.02 for the Geelong Road and Centre Road approaches (both 60 km/h, divided and undivided, respectively). Possible interpretations of these results are discussed in Section 4.3.

Table 3.2 Number and Rate of Vehicle Movements by Speed Zone

	Legal				Illegal				Total
	Green	*(%)*	Yellow	*(%)*	All-Red	*(%)*	Red	*(%)*	
60 km/h-Div	7406	*(94.84)*	366	*(4.67)*	34	*(0.44)*	3	*(0.04)*	**7809**
80 km/h-Div	19387	*(95.00)*	992	*(4.86)*	27	*(0.13)*	1	*(0.00)*	**20407**

Road Cross Section: Table 3.3 shows numbers and rates of vehicle movements for divided and undivided sites (both 60 km/h). Illegal encroachments were statistically higher at the undivided (Centre Road) site than the divided (Geelong Road) site ($\chi^2(1) = 8.94,\ p=0.003$).

Table 3.3 Number and Rate of Vehicle Movements by Road Cross Section

	Legal				Illegal				Total
	Green	(%)	Yellow	(%)	All-Red	(%)	Red	(%)	
Div-60 km/h	7406	*(94.84)*	366	*(4.67)*	34	*(0.44)*	3	*(0.04)*	**7809**
Undiv-60 km/h	9482	*(92.48)*	713	*(6.95)*	54	*(0.53)*	4	*(0.04)*	**10253**

3.6.3 Lane Type

Vehicle movements by lane type are shown in Table 3.4, where all-red and red encroachments were significantly higher in right-turn lanes than through lanes ($\chi^2(1)$ *=14.77, p=0.0001)*. Yellow encroachments, however, were higher in through lanes than right-turn lanes.

Table 3.4 Number and Rate of Vehicle Movements by Lane Type

	Legal				Illegal				Total
	Green	(%)	Yellow	(%)	All-Red	(%)	Red	(%)	
Right-turn	9186	*(94.16)*	480	*(4.92)*	83	*(0.85)*	7	*(0.07)*	**9756**
Through	27089	*(94.34)*	1591	*(5.54)*	32	*(0.11)*	1	*(0.00)*	**28713**

Table 3.5 shows that the lane type differences were not consistent across the 3 sites, as reflected by the interaction between lane and site ($\chi^2(2)$ *=14.27, p=0.0008*). The probability of running a red light in right-turn lanes was highest at the Centre Road site and lowest at the Springvale Road site. This difference may be related to the differences in right-turning facilities at the sites studied.

Table 3.5 Number and Rate of Vehicle Movements by Site and Lane Type

	Legal				Illegal				Total
	Green	(%)	Yellow	(%)	All-Red	(%)	Red	(%)	
Springvale Rd (80 km/h divided)									
Right-turn	4198	*(97.70)*	88	*(2.05)*	11	*(0.26)*	0	*(0.00)*	**4297**
Through	15189	*(94.28)*	904	*(5.61)*	16	*(0.10)*	1	*(0.01)*	**16110**
Geelong Rd (60 km/h divided)									
Right-turn	2942	*(94.02)*	155	*(4.95)*	29	*(0.93)*	3	*(0.10)*	**3129**
Through	4464	*(95.38)*	211	*(4.51)*	5	*(0.11)*	0	*(0.00)*	**4680**
Centre Rd (60 km/h undivided)									
Right-turn	2046	*(87.81)*	237	*(10.17)*	43	*(1.85)*	4	*(0.17)*	**2330**
Through	7436	*(93.85)*	476	*(6.01)*	11	*(0.14)*	0	*(0.00)*	**7923**

It is worth noting that signal compliance in right-turn lanes was highest at the Springvale Road site where all approaches had fully controlled, three-aspect right-turn phases (i.e., green, yellow and red arrows), and was lower at the Geelong and Centre Road sites where the various approaches were either full control, partial control two-aspect (i.e., green and yellow, but no red arrow) or uncontrolled (i.e., no arrows). Further, the Centre Road *Control 2* approach had a right-turn phase with three possible sub-phases, depending on time of day and traffic flow. Collectively, these results suggest that the particular signal phasing operation at a given intersection under varying conditions of time and traffic congestion may influence the propensity to run red lights, and requires further investigation.

Table 3.6 indicates that while the rate of illegal right-turn encroachments is highest in the morning off-peak period, the difference between illegal right-turn and through encroachments is most pronounced during the daytime off-peak period (not statistically significant) and evening peak period (statistically significant).

Table 3.6 Number and Rate of Vehicle Movements by Time of Day and Lane Type

	Legal				Illegal				Total
	Green	(%)	Yellow	(%)	All-Red	(%)	Red	(%)	
7.30-9.00 am									
Right-turn	2970	*(94.47)*	149	*(4.74)*	23	*(0.73)*	2	*(0.06)*	**3144**
Through	7885	*(93.13)*	566	*(6.68)*	16	*(0.19)*	0	*(0.00)*	**8467**
11.30-1.00 pm									
Right-turn	2175	*(93.43)*	127	*(5.46)*	25	*(1.07)*	1	*(0.04)*	**2328**
Through	6984	*(95.46)*	326	*(4.46)*	6	*(0.08)*	0	*(0.00)*	**7316**
5.00-6.30 pm									
Right-turn	3215	*(94.36)*	159	*(4.67)*	29	*(0.85)*	4	*(0.12)*	**3407**
Through	9686	*(94.86)*	519	*(5.08)*	6	*(0.06)*	0	*(0.00)*	**10211**
9.30-11.00 pm									
Right-turn	826	*(94.18)*	45	*(5.13)*	6	*(0.68)*	0	*(0.00)*	**877**
Through	2534	*(93.20)*	180	*(6.62)*	4	*(0.15)*	1	*(0.04)*	**2719**

3.6.4 Approach Type

As the results in Table 3.7 indicate, there were no differences found between approach types across the three sites (χ^2 *(2) =0.56, p=0.7560*), suggesting that camera presence (or the presence of "red light camera ahead" signs) had no significant effect on red light running behaviour. In fact, the above results suggest that other site factors such as signal phasing, which are correlated with road cross section and lane type, may have a stronger effect on the likelihood of red light running than the presence or absence of cameras per se. Given the importance of this aspect of the results and the minimal number of sites, this warrants more extensive testing.

Table 3.7 Number and Rate of Vehicle Movements by Approach Type

	Legal				Illegal				Total
	Green	(%)	Yellow	(%)	All-Red	(%)	Red	(%)	
Test *(Camera)*	11990	*(94.41)*	654	*(5.15)*	51	*(0.40)*	5	*(0.04)*	**12700**
Control 1 *(Signed)*	10627	*(94.66)*	564	*(5.02)*	34	*(0.30)*	1	*(0.01)*	**11226**
Control 2 *(Unsigned)*	13658	*(93.91)*	853	*(5.87)*	30	*(0.21)*	2	*(0.01)*	**14543**

3.6.5 Time of Day

Time of day, on its own, had no significant effect on the rate of illegal encroachments on weekdays, as shown in Table 3.8 ($\chi^2(3) = 2.27, p = 0.5177$). This suggests that alcohol had little effect on the incidence of running red lights on weekdays at these sites. This compares with the findings of a study by Corben (1982) in which it was concluded that, relative to all crash types, alcohol was over-represented in both rear-end and single-vehicle/loss-of-control crashes occurring at signalised intersections.

Table 3.8 Number and Rate of Vehicle Movements by Time of Day

	Legal				Illegal				Total
	Green	(%)	Yellow	(%)	All-Red	(%)	Red	(%)	
7.30-9.00 am	10855	*(93.49)*	715	*(6.16)*	39	*(0.34)*	2	*(0.02)*	**11611**
11.30-1.00 pm	9159	*(94.97)*	453	*(4.70)*	31	*(0.32)*	1	*(0.01)*	**9644**
5.00-6.30 pm	12901	*(94.73)*	678	*(4.98)*	35	*(0.26)*	4	*(0.03)*	**13618**
9.30-11.00 pm	3360	*(93.44)*	225	*(6.26)*	10	*(0.28)*	1	*(0.03)*	**3596**

3.6.6 Vehicle Type

Table 3.9 shows the distribution of types of vehicles that ran red lights during the weekday observation periods. It should be stressed, though, that these figures do not represent rates per vehicle type, as the exposure of different vehicle types at the sites measured was not extracted from the recorded data. Thus, while 88% of all-red encroachments and 100% of full-red encroachments were by passenger cars this probably reflects greater exposure of this vehicle type.

It is worth noting, though, that 7% of yellow encroachments and 11% of all-red encroachments were by rigid or articulated trucks. Analysis of traffic count data for seven of the nine approaches studied here (traffic count data were not available for either Geelong Street approach) shows that commercial vehicles make up 6.9% of all traffic, averaged over morning and evening peak periods. This suggests that trucks may be over-represented in red light running, as over 11% of vehicles running all-red intervals were found to be trucks. There is no suggestion in the data of trucks being over-represented in yellow running. Red, and to a lesser extent yellow, encroachments represent relatively risky behaviour since these types of vehicles take longer to clear the intersection given their length and decreased manoeuvrability.

Table 3.9 Percentage of Encroachments by Vehicle Type for Weekdays

	All Approaches		
	Yellow (*n=2071*)	All-Red (*n=115*)	Red (*n=8*)
Cars	92.2%	87.8%	100%
Trucks	6.9%	11.3%	0%
Buses	0.7%	0.9%	0%
Motorcycles	0.2%	0%	0%
Bicycles	0.05%	0%	0%
Total	100%	100%	100%

3.6.7 Weekday Site Analysis

The study was also interested in examining red light running behaviour by time in the cycle, that is, whether all running was immediately after the signal turned to red or at some later time during the red phase. Obviously, the later into the red cycle, the more risky is the manoeuvre and the higher the likelihood of a collision. As intersection approaches usually had different phasing arrangements, and, in some cases, different yellow, all-red and red intervals, it was not possible to collapse the data across approaches. These analyses are therefore presented on an approach by approach basis. Moreover, they provide clear indications of the nature and extent of red light running, as required by Objective 1 of this study. Only selected comparisons, where the results are of particular interest, are presented.

It should be noted that in the case of both the Geelong Road *Test* approach and the Centre Road *C2* approach, signal phasing arrangements are such that skipped phases (reflecting a traffic responsive mode of operation), can lead to yellow and all-red periods of different durations.

Figure 3.1 below shows the nature and extent of red light running for right-turners at each of the three *Test* approaches during weekdays, summed across the four observation periods. In general, it can be seen that the rate of encroachments reduces progressively after the termination of the green signal, with red light running occurring entirely within the all-red period or within one to two seconds of the introduction of the conflicting green movement (i.e., full-red period for the *Test* approach).

As reported in section 3.6.3, the rate of red light running differed in statistical terms between each *Test* approach. Red light running was least at Springvale Road and highest at Centre Road. All *Test* approaches had fully controlled right-turn phases. The total number of observed full-red light runners is, however, too small to draw any conclusions concerning right-turning conditions, such as type of right-turn control, turn lane provision, etc.

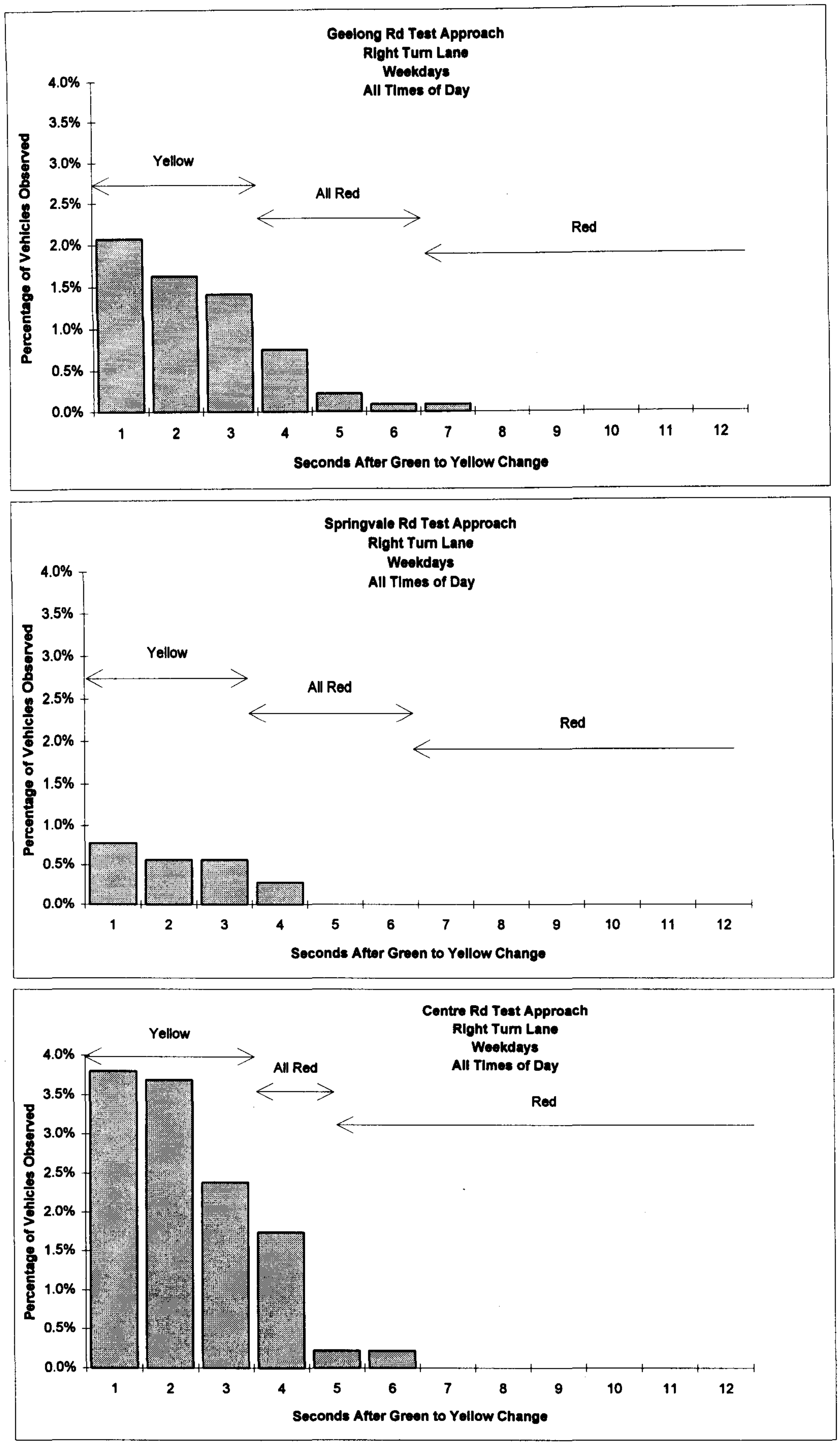

Figure 3.1 *Site results for the 3 Test sites (right-turn lanes) summed across the 4 time periods for the weekday observations.*

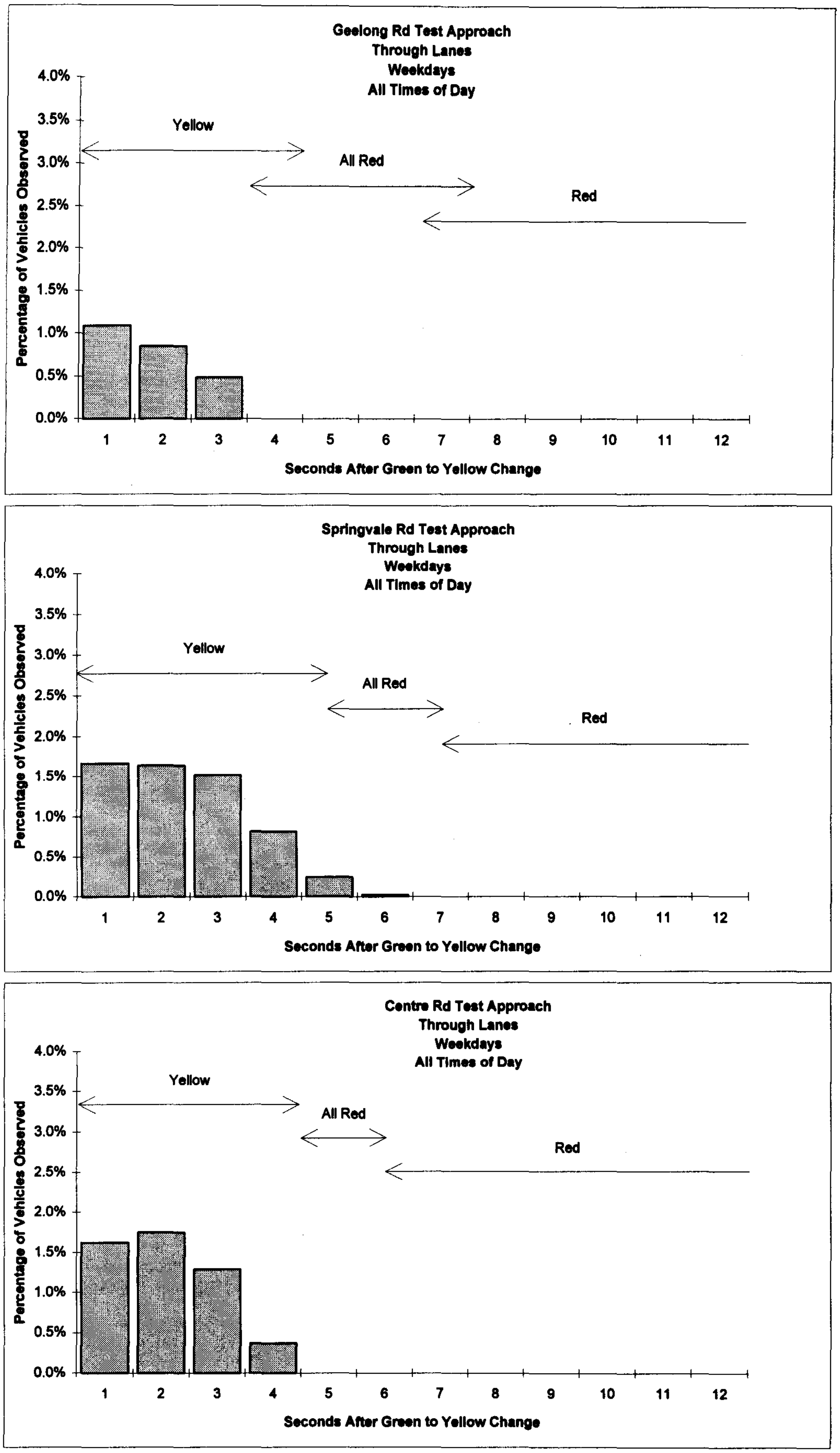

***Figure 3.2** Site results for the 3 Test sites (through lanes) summed across the 4 time periods for the weekday observations.*

In Figure 3.2, the equivalent information for the through lanes on *Test* approaches is shown. As with the right-turners, the encroachment rate generally declines with each second following the termination of the green signal. Overall, there were relatively few instances of red light running, with all encroachments occurring during the less dangerous all-red period.

The nature and extent of red light running behaviour for right-turners at the Centre Road group of *Test, C1* and *C2* approaches, across the four time periods of the weekday, are shown in Figure 3.3. The same basic trend of a progressively declining rate of encroachments after the termination of the green signal can be seen. Once again, while the majority of red light running occurs during the less dangerous all-red period, there were four drivers who ran signals during the full-red period, that is, after the introduction of the conflicting green movement. These latter encroachments, with the potential to result in crashes, occurred within one to two seconds after the introduction of the conflicting movements. The results presented here for the Centre Road group of approaches are indicative of the general lack of a significant difference in the rate of red light running between *Test, C1* and *C2* approach types at all sites studied.

Summary: These results provide clear indications of the nature and extent of red light running at the intersections studied, namely that most red light running occurred within the all-red interval with only a small proportion (7%) occurring during the full-red period. Further, most red light running during the full-red period was in the first few seconds after the termination of the all-red period and involved right-turners more often than through vehicles. Other findings reported earlier indicate factors which appear to affect encroachment rates.

While it is apparent that practically all of the red light running occurred within the first 2 or 3 seconds of the red phase (i.e., usually during the all-red period) and this is undesirable in road safety terms, nevertheless it is not as dangerous as encroachments during the full-red period when there is more likely to be conflicting traffic.

Full-red light running appears to be primarily associated with right-turn movements (seven of the eight cases (88%) involved right-turners) and occurred most often during the evening peak period (four cases-50%).

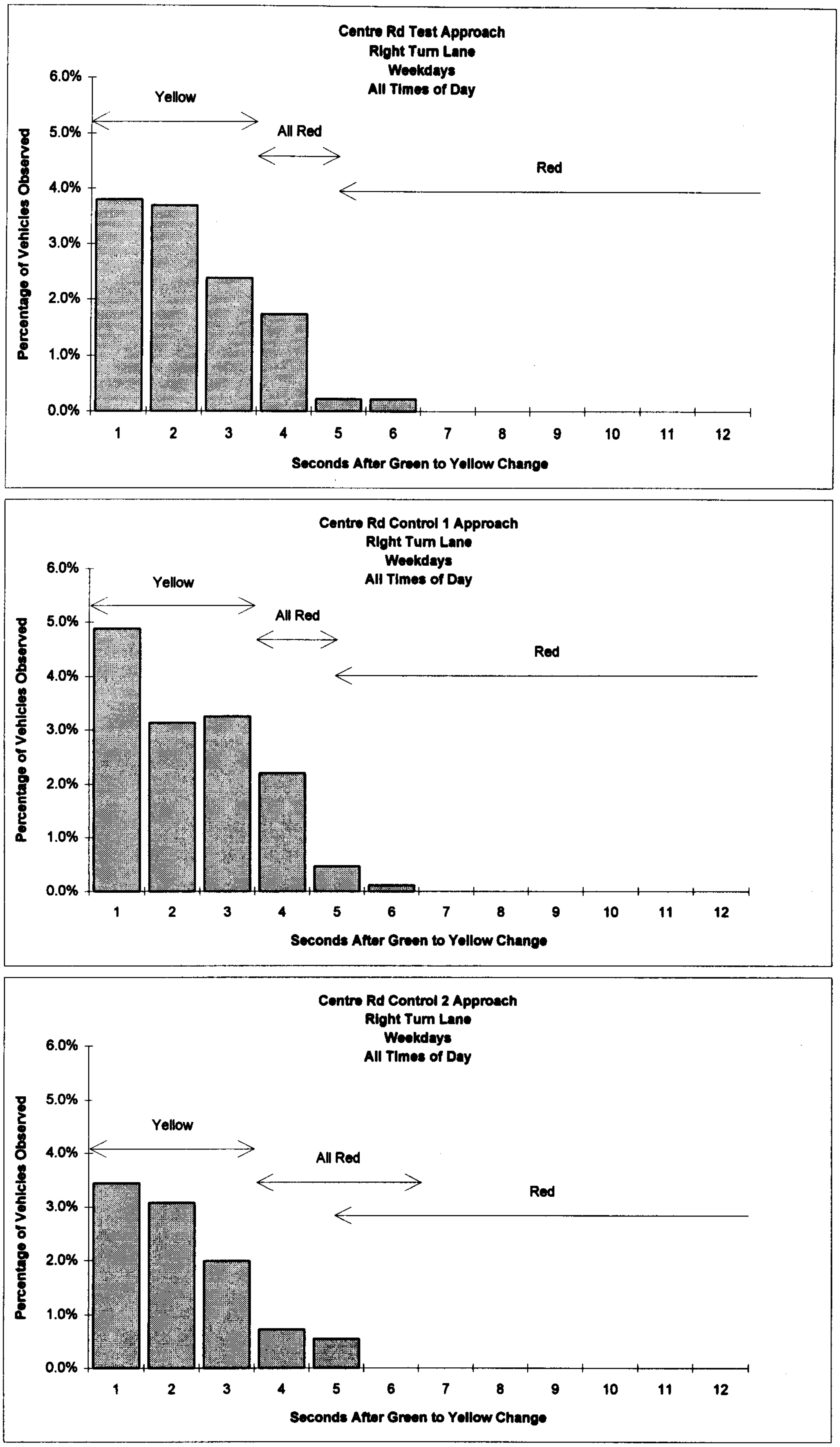

***Figure 3.3** Site results for the Centre Road Test site and its two control sites for right-turn lane summed across the 4 time periods for weekday observations*

3.6.8 Summary of Full-Red light Running

In excess of 38,000 vehicles were observed during the weekday data collection phase of this study. Of these, only eight drivers were found to have run a full-red signal, that is, during the especially dangerous interval after the end of the all-red period. The time distribution of these eight vehicles, after the end of the all-red period, is shown in Figure 3.4, for all approaches, both lanes and for all times observed on weekdays.

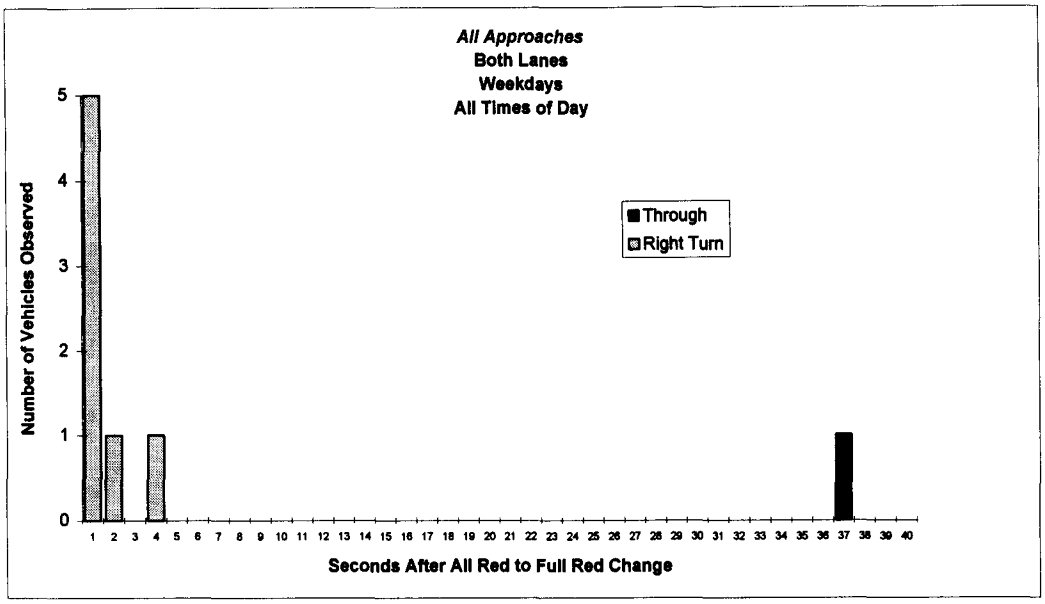

Figure 3.4 *Full-red runners summed across all approaches, both lane types and 4 time periods for weekday observations*

All but one of the eight vehicles ran the full-red phase within four seconds of its introduction. The remaining vehicle did so in the 37th second which actually corresponded to "jumping" a green signal by less than one second. Given the tendency for the observed full-red runners to be clustered within the first second, the potential to reduce the number of full-red runners by increasing the all-red period by one to two seconds presents itself as a serious countermeasure option. If driver response to the onset of a longer all-red signal does not induce increased running of the all-red interval, then almost all of the full-red runners would become less dangerous all-red runners if the all-red period were one second longer.

3.6.9 Relationship with Crashes

As Andreassen (1995) found no significant differences between crashes at RLC sites compared with those at signalised intersections generally, there was no need to formally test for a correlation between red light running behaviour and crashes. Furthermore, the current study found that there were no statistically reliable differences in the rates of red light running between *Test, C1* and *C2* approaches.

Any meaningful comparison of crashes and red light running is confounded by the fact that, during the period of crash occurrence being examined (1990 to 1994), there were substantial operational changes at the Springvale Road *C2* approach, in the form of the installation of fully controlled right-turn phases. This type of control has a dramatic effect on the way in which right-turns are made and is highly effective in reducing the incidence of right-through crashes (approximately 90-95% average reductions). As this study found that the rate of red light running was significantly higher for right-turners compared with through vehicles, it is not valid to include these "pre-right-turn phase" crashes for comparison.

Table 3.10 sets out the reported crash data (all severities) for the various approaches studied, together with the corresponding number of observed instances of red light running. The crash data in the table only covers the specific approaches investigated in the current study and combines only rear-end, right-through and cross-traffic type crashes, as these have been found in other studies to be affected by red light running behaviour.

For many crashes it has not been possible to assign the possible red light running behaviour leading to the crash to a specific approach because of the nature of the vehicle movements involved. For example, for DCA 121 (right-through), it is unclear as to whether the through vehicle or the right-turner may have run the red signal. Consequently, it has been necessary to sum crashes on *Test* and *C1* approaches, rather than assign them to one or the other approach. In order to compare crash frequencies with red light running frequencies, red light running frequencies have been similarly combined.

Table 3.10 Comparison of Number of Reported Weekday Crashes (all severities) and Number of Weekday Red Light Runners

Variable	Springvale Rd		Geelong Rd		Centre Rd	
	Test and C1	*C2*	*Test and C1*	*C2*	*Test and C1*	*C2*
1. No. of crashes potentially related to red light running (1990 to 1994)	6	14	4	4	6	4
2. No. of crashes potentially related to red light running, after adjustment for intersection treatments (1992 to 1994)	2	2	0	3	4	2
3. Total no. of weekday red light runners observed during study period	16	12	29	8	46	12
4. No. of weekday full-red light runners observed during study period	0	1	2	1	4	0

After adjusting for the effects of known intersection treatments mentioned above, the period of crash occurrence reduces to 1992 to 1994, with the consequent change in crash frequencies shown in the Table 3.10.

Figure 3.5 compares the numbers of crashes with the corresponding numbers of red light runners of both types (i.e. the sum of all-red and full-red). Figure 3.6 compares the numbers of crashes and the corresponding numbers of full-red light runners.

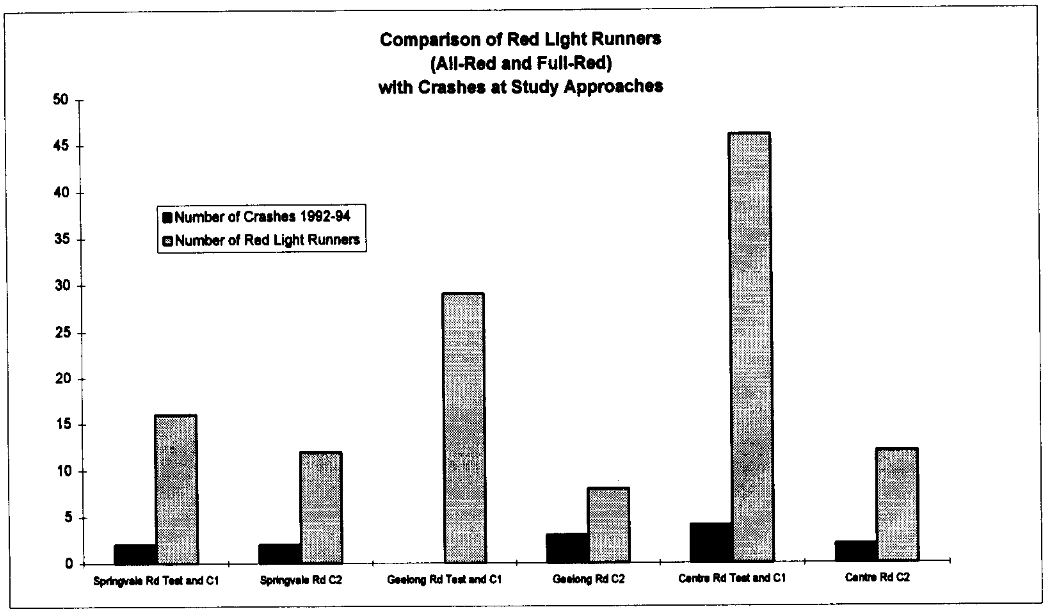

Figure 3.5 *Comparison of the numbers of weekday crashes (1992 to 1994) and weekday red light runners (all-red and full-red) for each site*

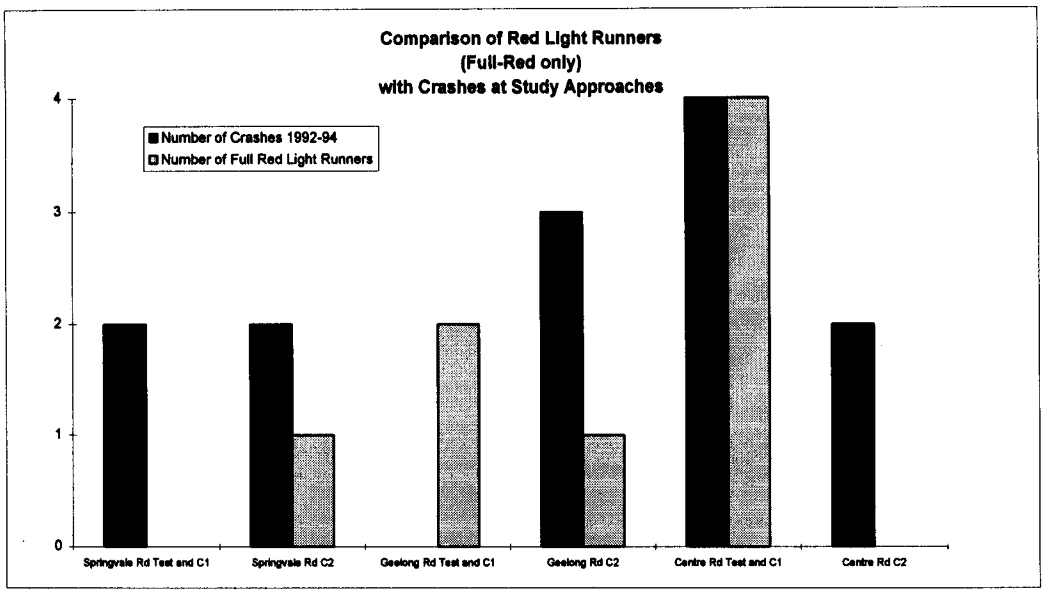

Figure 3.6 *Comparison of the numbers of weekday crashes (1992 to 1994) and weekday full-red light runners for each site*

Statistical correlations between the number of crashes and number of red light runners (total and full-red only) were carried out, with non-significant correlations being found for both the total number of red light runners ($r = 0.22$) and the number of full-red light runners ($r = 0.37$). Clearly, there was no meaningful relationship between these data, though it must be noted that the crash frequencies were very low and are therefore unlikely to show a reliable relationship. Interestingly, though, the correlation between full-red light running and crash frequencies was stronger than the correlation between total red light running and crash frequencies.

3.7 Weekend Results

As noted earlier, the weekend results were rather spasmodic, seemingly due to an exceptionally high level of red light running on one approach around the conclusion of Saturday afternoon football which had a marked effect on the results. This effect is clearly demonstrated in Table 3.11 below. The rate of right-turn encroachments (particularly all-red) is overwhelmingly higher on the weekend day than during the same period on the weekday. The observed rate of all-red running (8.45) on this approach is nearly 50% higher than the highest period of all-red running observed on any approach at any time in the weekday data (4.96). Further, the weekend results for this Springvale Road *C2* approach also indicated large volumes of traffic in the through lanes similar to the evening peak levels observed at that approach during the week (2243 cf 2336). This was unrepresentative of other approaches where the traffic volumes on the weekend days were generally lower than for the corresponding periods during the week. The Springvale Road result further suggested that the weekend data might also have been affected at other sites near football grounds, such as the Geelong Road approaches, although this effect was not immediately discernible from the data.

Table 3.11 Number and Rate of Right-turn Vehicle Movements at Springvale Road /Ferntree Gully Road*

	Legal				Illegal				Total
	Green	*(%)*	Yellow	*(%)*	All-Red	*(%)*	Red	*(%)*	
Weekday *(5.00-6.30 pm)*	493	*(97.82)*	10	*(1.98)*	1	*(0.11)*	0	*(0.00)*	**504**
Weekend day *(5.00-6.30 pm)*	225	*(63.38)*	99	*(27.88)*	30	*(8.45)*	1	*(0.28)*	**355**

* *This was the control 2 (unsigned) approach*

For the above reasons it was not appropriate to apply the same statistical comparisons between sites on the weekend data as that applied to the weekday data, as the effect of sporting events near some sites would produce non-typical results.

3.7.1 Vehicle Type

Table 3.12 shows there were no observed differences between vehicle types in the proportions of observed red light running on weekend days. The predominant category was once again passenger cars. The main difference from the weekday data is fewer yellow and all-red encroachments by trucks relative to passenger cars, a result probably stemming from the lower exposure of trucks on weekend days.

3.7.2 Weekend Site Analysis

The differences in red light running during the Saturday afternoon post-football period at the Springvale Road *C2* site are further illustrated in Figure 3.7. This shows a substantial increase in both yellow and red light running behaviour for right-turn traffic at this location during the weekend observation period, even though the total volume of right-turn traffic was only 70% of that of the weekday traffic. These results indicate that special attention may need to be given to red light running in the late afternoon and/or early evening hours on Saturdays. An analysis of these times may be warranted as a first step.

Table 3.12 Percentage of Encroachments by Vehicle Type for Weekends

	All Approaches		
	Yellow *(n=1717)*	All-Red *(n=108)*	Red *(n=7)*
Cars	96.9%	96.3%	100%
Trucks	2.4%	0.9%	0%
Buses	0.4%	0.9%	0%
Motorcycles	0.2%	0.9%	0%
Bicycles	0%	0.9%	0%
Total	100%	100%	100%

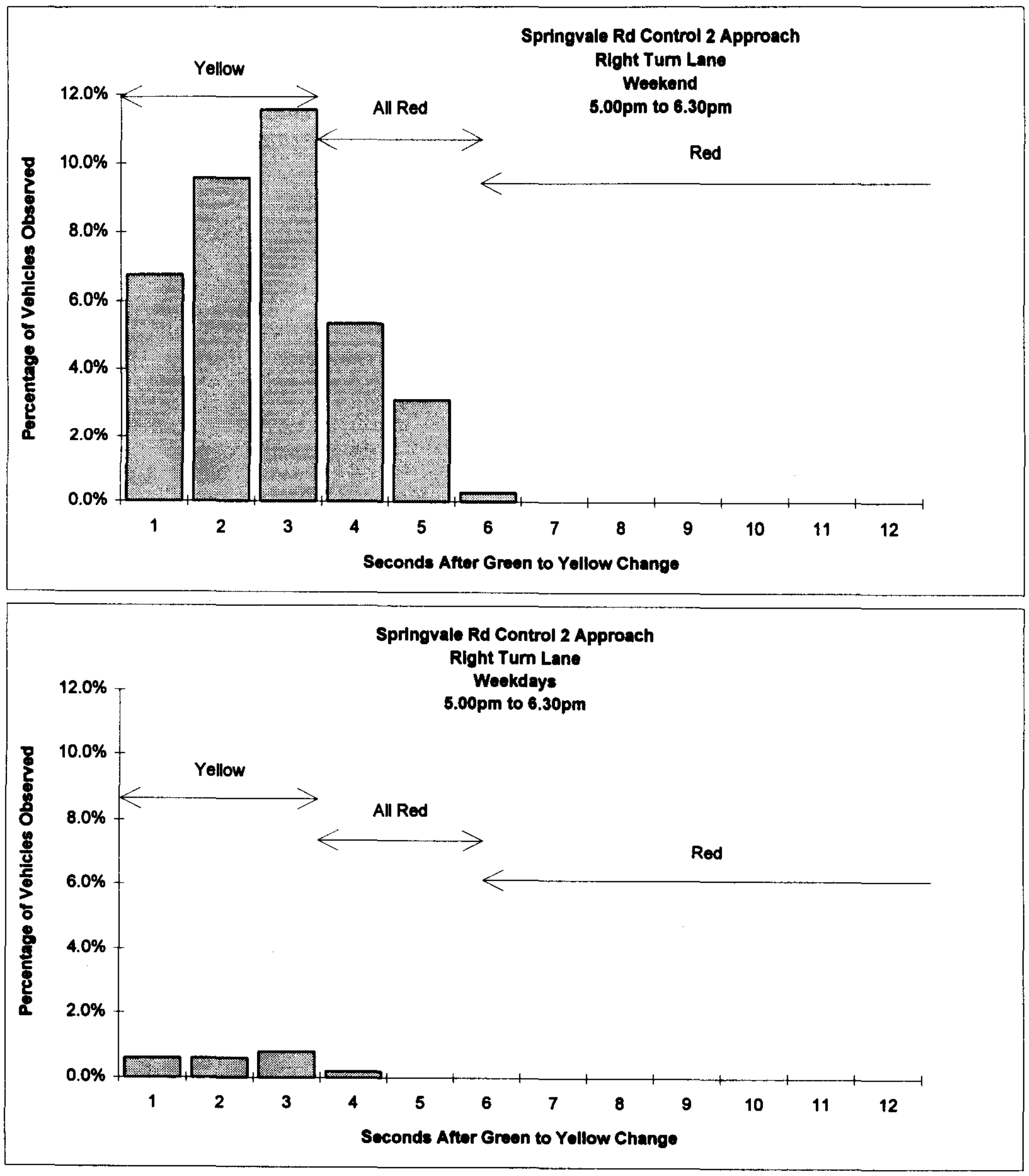

***Figure 3.7** Differences in right-turn red light running behaviour at the Springvale Road C2 site between 5.00 p.m. and 6.30 p.m. on weekend and weekdays.*

CHAPTER 4 DISCUSSION AND RECOMMENDATIONS

A number of interesting aspects to the results were found which require discussion, especially in relation to the four objectives of the study. Some preliminary comments, however, are warranted on the data collection issues raised by this program of research.

4.1 Methodological Issues

The study set out to examine red light running behaviour at a number of red light camera and control sites using the existing SCRAM electronic network used for controlling traffic at most of Melbourne's signalised intersections. This method, which relied on "trailing edge triggering" as vehicles cleared the magnetic loops prior to the intersection stop line, offered promise for collecting and analysing vast amounts of red light running data at a substantial number of sites, thereby allowing a comprehensive analysis of red light running behaviour. Unfortunately, the SCRAM technology, in its current form, proved to be inadequate for this task for a number of reasons.

First, there was the problem of under-counting of total hourly traffic volumes caused by two vehicles queuing on the red phase with reduced headways (the detector loop was insensitive to short gaps between vehicles). Second, there was over-counting in the number of *full-red* light runners in instances where vehicles stopped well over the stop line but did not proceed through the intersection. Finally, there was the occasional tendency for SCRAM to 'drop out' or experience technical difficulties during a measurement period, resulting in the loss of essential data and the likelihood of unacceptable extensions to the data collection timetable.

After extensive pilot testing and discussions between staff of VicRoads, Victoria Police and MUARC, it was decided <u>not</u> to proceed with this method of data collection and to develop a more reliable observational technique. A video recording procedure from an unmarked private vehicle was developed and red light running was recorded successfully at a reduced number of sites to that initially proposed. This reduction in site numbers was necessary because of limitations in available resources and the fact that this method of data recording involved considerably more staff time than the SCRAM method originally envisaged.

The video recording procedure proved to be satisfactory and allowed a number of additional characteristics of red light running behaviour to be scored, such as type of vehicle involved. However, the process was more time consuming and hence only one combination of each site variable could be examined in this study. More will be said of this later on.

With further technical development, it may be possible to adapt the SCRAM network to the task required here, even though this is not SCRAM's primary purpose. Additional loops ahead of the stop line may reduce the recording of false red light running (i.e., a vehicle stopping over the stop line without proceeding through the intersection). Network communication and/or hardware improvements may also overcome the problem of the system dropping out on occasions. Under-counting as a result of vehicles with short headways, however, could require substantial system redevelopment. These modifications are all likely to be relatively expensive options and may not be warranted on purely research grounds.

4.2 Extent Of Red Light Running Behaviour

Red light running behaviour was found to be a relatively rare occurrence, given the number of vehicles observed at the study locations. From the weekday data there was a total of 123 red light runners over 54 hours of recording (2.3 vehicle encroachments per hour) for a total traffic flow of over 38,000 vehicles. This represents an average rate of 0.32 encroachments per 100 vehicles on any given approach, although not all these vehicles would have had an opportunity to run a red light. These results are a reflection of the nature of the road crash problem, in that failures in the system in the form of critical incidents or crashes are a relatively rare event for each vehicle/driver, but when multiplied by the millions of vehicles on our roads, represent a large total problem. Furthermore, the study has found that on Saturday afternoons at one site, the encroachment rate to be as high as 8.4%.

Opportunity to run red lights is a function of what time during the signal cycle the vehicle approaches the intersection and whether the road is clear ahead of the vehicle. Obviously, those who approached and proceeded through the green light phase did not have an opportunity to encroach. In addition, those who arrived after the light had turned red and with a stationary vehicle in the same lane directly ahead of them (especially when the adjacent lanes were also full) had no opportunity to encroach either.

While not within the scope or defined objectives of this study, it would be useful in any further investigation of red light running behaviour to measure encroachment rate per opportunity to encroach for the range of various road and site factors examined here. This more in-depth analysis may well reveal a different pattern of effects to those observed in the current study.

Most (93%) of the 123 weekday red light encroachments occurred within the *all-red* periods of the signal cycle which is of some reassurance given that traffic in the conflicting direction would have been stationary. The eight full-red encroachments observed, however, were dangerous events, particularly since these occurred predominantly during the evening peak period when the conflicting traffic flow and the risk of a collision were highest.

A preliminary comparison of traffic volumes indicates that trucks may well be over-represented in running the all-red period, though a more rigorous analysis is required to improve the reliability of this tentative finding. It is, however, consistent with the conclusions of a recent study of crashes involving heavy vehicles in urban areas sponsored by the Federal Office of Road Safety (Sweatman, Ogden, Haworth, Corben, Rechnitzer & Diamantopoulou, 1995).

As discussed in Section 3.6.8, a potential countermeasure for red light running might be to increase the duration of the all-red interval at traffic signals. Based on the distribution of times of red light running and, if driver response to the onset of a longer all-red signal does not induce increased running of the all-red interval, then the data gathered in this study suggest that almost all of the full-red runners would become less dangerous all-red runners if the all-red period were one second longer. While such a measure will result in small reductions in the amount of time available for green phases, the overall effect may be highly beneficial to safety at signalised intersections, without interfering unduly with intersection capacity. This warrants closer consideration.

4.3 Factors Which Influenced Red Light Running

Road factors predominantly seemed to influence red light running behaviour in this study. Of particular interest was the higher red light running rate in 60 km/h than 80 km/h speed zones on divided roads. Closer examination of the data shows that this finding did not apply to through vehicles, which were found to show no such differences, but was confined to right-turners only.

There are a number of possible interpretations for this finding. Traffic signals in higher speed zones typically have longer yellow intervals which may reduce the chances of red light running (yellow intervals are normally based on the 85th percentile speeds of traffic travelling along that particular route). Alternatively, it could suggest that right-turning motorists are more impatient at lower speed limits and more inclined to run the red.

A further consideration is the standard of right-turn facilities existing at each of the sites. For example, the Springvale Road site (80 km/h), which had the lowest rate of red light running for right-turners (0.26%), had protected, double right-turn lanes with full control of these turns. However, the Centre Road site (60 km/h), which had the highest red light running rate for right-turners (2.02%), was characterised by only one indented right-turn lane on each approach, protected only by painted islands and controlled by a mix of partially and fully controlled right-turn phases. Different right-turn phase durations also lead to typically different delays for right-turners. Overall, these circumstances suggest that the design of right-turn facilities, and the relative delays and levels of protection offered by these facilities have a potentially important influence on the red light running behaviour of right turners.

This finding needs to be examined further, using for example the records of red light cameras for both approach types, and with a larger number of approaches, as the current result is based on the limited comparisons possible in this study.

Road cross-section also had a significant influence on these data where undivided roads had higher rates of encroachment for right-turners than divided roads. The 24% higher traffic volume on the undivided approaches might well explain this, as often motorists are encouraged to run red lights for fear of being struck in the rear if they stop in busy traffic. It is not possible to test this finding further for undivided approaches with higher speed limits, as Victoria's speed zoning policy generally does not permit speed zones of greater than 60 km/h on undivided roads in urban areas.

Lane type was also found to have a significant effect on the rate of red light running, with right-turn lanes exhibiting a consistently higher red light running rate than through lanes. This finding may be a reflection of the relative delays experienced by right-turning drivers compared to drivers of through vehicles and/or the relative difficulties of the movements involved. While this difference was accentuated in evening peak periods, perhaps due to the possible increase in delays for right-turners during this period, the actual rates of red light running among right-turners were highest during the daytime off-peak period. It should be noted that red light running rates for right-turners were lowest at the Springvale Road site, which had fully controlled right-turn phases on each approach and provided right-turners with the highest level of protection from being struck in the rear by other vehicles.

It is important to note that while every reasonable effort was made to match these approaches as closely as possible, in terms of the many characteristics of their operation, unwanted variation in a number of potentially significant factors could not be completely eliminated without excluding all candidate approaches. For example, there remained differences in the performance of traffic signal co-ordination along each approach, the type of phasing and timings (especially for right-turn movements), lane configurations and the nature of the surrounding land use and demography. The study approach could only attempt to minimise such potential influences.

4.4 Red Light Camera Effects

An interesting aspect of these results from a safety point of view was the apparent lack of an effect for the red light camera at reducing potentially dangerous red light running behaviour below the levels of control approaches. This result may be a reflection of the fact that cameras have been installed on the approaches which had the highest incidence of red light running. It is understood that, wherever possible, the approaches on which the cameras were installed were selected on the basis of their histories of crashes related to red light running.

While not a statistically reliable effect, the data revealed a trend toward more red light running at the red light camera approaches than either of the two controls (same intersection with no camera or a non-camera intersection). This result was not a function of differences in traffic volume as they were relatively constant at all three locations during the weekday observations. Moreover, as the *Control 2* approach was usually on the same road and only one or two intersections away from the *Test* approach, it is unlikely that there were other extraneous environmental influences.

The length of time that these installations have been in place, or the perception that they are not in use may also contribute to the apparent absence of a difference in red light running behaviour at camera approaches. Indeed, during the course of the study, a number of camera installations were found to be non-functional for various technical or other reasons. Perhaps the current practice of rotating only a limited number of cameras around the network might also need to be revisited in the light of these results.

In any event, efforts to extend the current red light camera program should first concentrate on increasing motorists' ***perceptions of risk*** of detection at these locations, if these cameras are to be more successful at mediating red light running. There is considerable support for this on the basis of conventional enforcement theory alone. Highest priorities would seem to be first in overcoming the technical difficulties currently experienced in a number of existing locations. Attention could then be given to increasing the level of activity of red light cameras and the prosecution rate per encroachment photographed. The level of penalties is a further issue which could be addressed. Publicity supporting this program is also warranted in association with these improvements. Recent experience with speed cameras has demonstrated conclusively that high levels of activity/exposure, prosecutions and publicity can have a marked positive effect on changing behaviour.

In the event that a program was undertaken to improve the effectiveness of RLC enforcement operations, then further evaluation research might show the efficacy of extending the number of Red Light Camera installations in this State.

4.5 Time Of Day Effects

Time of day (peak versus off-peak and day versus night) was expected to have a marked influence on the number of red light encroachments. However, there was no statistical difference observed for this variable except as an interaction with lane type. This might suggest that time of day, and consequently traffic volume, are not critical factors for this behaviour, although this finding is counter-intuitive. Further testing at more sites would be required in order to test the statistical reliability of this null effect.

4.6 Weekend And Weekday Influences

The results of the weekday analysis were systematically examined using an ordinal logistic modelling technique which was able to control for variations in the number of vehicles, cycle times, etc., while comparing the effects of the variables of interest and their interactions. As there were no apparent extraneous influences at work at these sites and times, it was possible to interpret the findings in a meaningful way.

The weekend results, however, were subject to higher variations in the levels of traffic volume and encroachments, due to some extreme influences such as weekend football and, perhaps, shopping traffic flows. While it is important to report these influences for possible future action, nevertheless, they had a marked and overwhelming influence on the analysis. Repeating data collection at the approaches near football grounds at more representative weekend times (i.e., when there are no football matches at those locations), and/or obtaining extra site data at additional locations would also be desirable given these results.

4.7 Red Light Running and Crash Occurrence

Objective 3 of the study sought to examine the relationship between red light running behaviour and crash occurrence (as reported in the ARRB study), assuming that red light cameras were found to reduce crash occurrence. As indicated in Section 1.1, no reduction in crash occurrence was found in the ARRB study (Andreassen, 1995) and therefore there was no need to formally test for a correlation between red light running behaviour and crashes.

Nevertheless, the crash data for the sites studied were examined and statistical correlations between the number of crashes and number of red light runners (total and full-red-only) were carried out. Correlation coefficients were found to be non-significant, however, the correlation between full-red light running and crash frequencies was marginally stronger than the correlation between total red light running and crash frequencies.

It is worth noting that this study found an average of 2.3 encroachments per hour at the nine approaches studied. Even assuming a more conservative estimate of, say, 1 encroachment per hour at other signalised intersections as more representative of other signalised intersections, in recognition of the possible over-representation of red light running at the sites studied here, this represents a large number of encroachments in a year. On the basis of approximately 2,000 signalised intersections, comprising perhaps 7,000 approaches, it can be estimated that there would be approximately 780 encroachments per hour throughout Victoria. Even if only 7% of these encroachments are dangerous in terms of potential to cause crashes (i.e, approximately 7% of encroachments occur after the end of the all-red period), this equates to approximately 55 dangerous encroachments per hour throughout Victoria. Across an entire year, this corresponds to about 500,000 dangerous encroachments. This estimate is substantially higher if pedestrian operated signals are also considered.

While in this study the observed rate per volume of traffic was relatively low, the above estimate illustrates the extent of the potential statewide crash problem if this level of red light running behaviour continues. Further, the number of casualty crashes at signalised intersections in Victoria is of the order of 1,500 per year, indicating that the risk of a casualty crash due to red light running is relatively low at approximately 0.003. Driver perception of crash risk from this form of behaviour may, understandably, be low indicating that initiatives to heighten risk perception would be potentially beneficial.

4.8 Limitations Of The Study

As noted elsewhere in this report, the study of red light running behaviour undertaken here evolved considerably during the course of the research. It was initially intended to collect and analyse an extensive volume of data using the SCRAM electronic network which would have permitted a thorough and meaningful analysis of red light running behaviour at red light camera and control intersections. After thorough assessment of SCRAM's capabilities in this type of application, it was found that a more accurate and reliable method of data collection was required for this study. In its place, an observational technique was developed involving video-recording of traffic movements and subsequent translation of these records into encroachment data.

While the study was ultimately successful in developing a useful technique for recording red light encroachments, the new method (which was more labour intensive) could only be applied to a limited sample of sites within the constraints of the original project budget. Additional resources would help overcome these limitations and enable the study objectives to be more fully addressed. Without further examination, the findings from this study should only be viewed as tentative.

4.9 Study Conclusions

The study into red light running behaviour at three red light camera and control sites revealed a number of interesting and practical findings.

4.9.1 Data Collection

First, the SCRAM electronic network in its present form is not suitable for collecting data on red light encroachments for the reasons outlined above. Observational techniques were a more preferred means of collecting red light running behaviour data at this time. This is not to say that the SCRAM network could not be made more suitable with some additional technical development work, although this is not really necessary for its primary function of traffic control.

4.9.2 Objective 1 - Extent of Red Light Running Behaviour

Red light encroachments were relatively rare events and, for the most part, those observed were not all that dangerous. However, there was a relatively small number (8 in 38,000 vehicle movements) that were dangerous manoeuvres during the full-red interval and need to be targeted in future efforts to reduce this behaviour and, therefore, crash potential. Furthermore, if this rate is extrapolated to all traffic signal approaches in Victoria, it represents more than 500,000 dangerous encroachments per year. Though not able to be rigorously investigated in this study, there was a suggestion in the data that trucks may be over-represented in red light running during the all-red interval.

A simple, inexpensive and potentially effective countermeasure for crashes resulting from red light running involves relatively small increases (1-2 seconds) to all-red periods at signalised intersections.

4.9.3 Objective 2 - Road and Environment Effects

Within the constraints of the limited amount of data available, some potential road and environment effects were apparent during these observation periods:

- The speed limit and cross-section of an approach appeared to influence red light encroachments. Arterial roads with 60 km/h limits and undivided roads had higher rates of illegal encroachments by right-turners than did 80 km/h and divided roads.
- Higher rates of red light running were found for right-turn lanes than through lanes. This difference was found to fluctuate according to time of day and was not consistent across all sites.
- There were no differences in red light encroachments observed between RLC and non-RLC approaches. Moreover, there were no differences in rates of illegal encroachments by time of day during these observation periods.
- Weekend data could not be analysed thoroughly because of the extreme influence of weekend football traffic. These data may be highlighting a substantial safety problem associated with football traffic (or sporting event traffic generally) and may warrant further investigation.

Given the limited amount of data collected here, a more extensive program of research is warranted to examine these preliminary results more thoroughly.

4.9.4 Objective 3 - Red Light Running & Crashes

Andreassen (1995) found that the installation of RLC's at 41 sites studied did not result in any reduction in accidents at those sites. Further, he found no significant differences between crashes at RLC sites compared with signalised intersections in Melbourne generally. Thus there was no need to formally test for a correlation between red light running behaviour and crashes. Nevertheless, a simple correlation analysis was undertaken for red light running data in the current study and revealed no significant relationship between the frequency of crashes at RLC and non-RLC sites and differences in red light running behaviour.

4.9.5 Objective 4 - Extension of the RLC Program

While the need for more RLC installations was not justified by this, or the recent accident study of Andreassen (1995), nevertheless there are grounds for improving the operation of existing RLC locations. Highest priority should be given to increasing the perceived risk of detection at these sites. This could be done by overcoming existing technical difficulties at some sites, by increasing the level of activity and by supportive publicity. Subsequent testing might then indicate whether there is a need for more RLC installations.

4.10 Recommendations

Three recommendations seem warranted from the research conducted here into red light encroachments at RLC and non-RLC intersections.

1. *An action program be undertaken to improve the effectiveness of existing Red Light Camera operations in Melbourne as outlined above;*

2. *Further research be undertaken to test red light running behaviour more extensively than was possible in this study. A focus on red light running behaviour associated with weekend sporting events and/or heavy vehicles may be especially worthwhile;*

3. *Consideration be given to increasing the duration of all-red periods by one or two seconds, as a simple, inexpensive countermeasure for crashes caused by red light running, taking into account the traffic capacity and behavioural consequences of such a change.*

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APPENDICES

APPENDIX 1 - 72 Approaches for Collection of "Red Light Running " Data Using SCRAM

Road Cross-section	Speed Zone (km/h)	Congestion	Location	Melway Ref	Suburb	Road	Dir
Divided	60	H	Geelong St/Geelong Rd	41-K5	Footscray West	Geelong St	SE
			Geelong St/Geelong Rd	41-K5	Footscray West	Geelong St	NW
			Napier St/Whitehall St	42-D6	Footscray	Napier St	E
			Warrigal Rd/Centre Dandenong Rd	87-C2	Cheltenham	Warrigal Rd	N
		9 apps.	Warrigal Rd/Centre Dandenong Rd	87-C2	Cheltenham	Warrigal Rd	S
			Warrigal Rd/High Street Rd	60-H11	Ashwood	Warrigal Rd	S
			Williamstown Rd/Francis St	41-J10	Yarraville	Williamstown Rd	N
			Williamstown Rd/Francis St	41-J10	Yarraville	Williamstown Rd	S
	18 apps.		Whitehall St/Napier St	42-D6	Footscray	Whitehall St	N
		L	Grattan St/Swanston St	43-H4	Carlton	Grattan St	W
			Grattan St/Swanston St	43-H4	Carlton	Grattan St	E
			Queensbury St/Swanston St	43-H5	Carlton	Queensbury St	W
			King St/Hawke St	43-D6	West Melbourne	King St	E
		9 apps.	King St/Hawke St	43-D6	West Melbourne	King St	W
			King St/Dudley St	43-E7	West Melbourne	King St	E
			Mt Dandenong Rd/Dorset Rd	51-B4	Croydon	Mt Dandenong Rd	E
			Mt Dandenong Rd/Dorset Rd	51-B4	Croydon	Mt Dandenong Rd	W
			Mt Dandenong Rd/Colchester Rd	51-F4	Croydon	Mt Dandenong Rd	E
	70	H	Bell St/St. Georges Rd	30-E1	Preston	Bell St	W
			Bell St/St. Georges Rd	30-E1	Preston	Bell St	E
			Bell St/Chifley Dve	31-C2	Preston	Bell St	W
			Dandenong Rd/Chapel St	58-D8	Windsor	Dandenong Rd	W
		9 apps.	Dandenong Rd/Chapel St	58-D8	Windsor	Dandenong Rd	E
			Dandenong Rd/Hotham St	58-F8	St Kilda East	Dandenong Rd	E
			Springvale Rd/High Street Rd	71-D1	Glen Waverley	Springvale Rd	N
			Springvale Rd/High Street Rd	71-D1	Glen Waverley	Springvale Rd	S
54 apps.	18 apps.		Springvale Rd/Waverley Rd	71-C4	Glen Waverley	Springvale Rd	N
		L	Canterbury Rd/Bayswater Rd	64-G1	Bayswater	Canterbury Rd	W
			Canterbury Rd/Bayswater Rd	64-G1	Bayswater	Canterbury Rd	E
			Canterbury Rd/Wantirna Rd	63-G1	Ringwood	Canterbury Rd	W
			Geelong Rd/Droop St	42-C3	Footscray	Geelong Rd	W
		9 apps.	Geelong Rd/ Droop St	42-C3	Footscray	Geelong Rd	E
			Western Hwy/Station St	25-E8	Deer Park	Western Hwy	E
			North Rd/Clayton Rd	70-C11	Clayton	North Rd	W
			North Rd/Clayton Rd	70-C11	Clayton	North Rd	E
			North Rd/Milgate/Fenton Rds	70-A11	Oakleigh Sth	North Rd	W
	80	H	Burwood Hwy/Blackburn Rd	61-K7	Burwood East	Burwood Hwy	E
			Burwood Hwy/Blackburn Rd	61-K7	Burwood East	Burwood Hwy	W
			Burwood Hwy/Scoresby Rd	73-D11	Knoxfield	Burwood Hwy	E
			Maroondah Hwy/Springvale Rd	48-F9	Nunawading	Maroondah Hwy	E
		9 apps.	Maroondah Hwy/Springvale Rd	48-F9	Nunawading	Maroondah Hwy	W
			Burwood Hwy/Springvale Rd	62-E7	Burwood East	Burwood Hwy	E
			Springvale Road/Wellington Road	80-B1	Mulgrave	Springvale Rd	S
			Springvale Road/Wellington Road	80-B1	Mulgrave	Springvale Rd	N
	18 apps.		Springvale Rd/Ferntree Gully Rd	71-A9	Mulgrave	Springvale Rd	S
		L	Canterbury Rd/Dorset Rd	51-A11	Bayswater Nth	Canterbury Rd	E
			Canterbury Rd/Dorset Rd	51-A11	Bayswater Nth	Canterbury Rd	W
			Canterbury Rd/Colchester Rd	51-E10	Bayswater Nth	Canterbury Rd	E
			Nepean Hwy/Highett/Rowans Rds	77-F9	Highett	Nepean Hwy	NW
		9 apps.	Nepean Hwy/Highett/Rowans Rds	77-F9	Highett	Nepean Hwy	SE
			Nepean Hwy/Park/Centre Dandenong Rds	86-F1	Mentone	Nepean Hwy	SE
			Nepean Hwy/White St/Como Pde	87-E10	Mordialloc	Nepean Hwy	N
			Nepean Hwy/White St/Como Pde	87-E10	Mordialloc	Nepean Hwy	S
			Nepean Hwy/ParkerRd/Imes St	87-D8	Parkdale	Nepean Hwy	N
Undivided	60	H	Ballarat Rd/Churchill Ave	27-F11	Braybrook	Ballarat Rd	NW
			Ballarat Rd/Churchill Ave	27-F11	Braybrook	Ballarat Rd	SE
			Ballarat Rd/Rosamund/Summerhill Rds	41-K1	Footscray	Ballarat Rd	SE
			Centre Rd/Warrigal Rd	78-E2	Oakleigh South	Centre Rd	W
		9 apps.	Centre Rd/Warrigal Rd	78-E2	Oakleigh South	Centre Rd	E
			Centre Rd/Huntingdale/Clarinda Rds	78-J3	Oakleigh South	Centre Rd	E
			Toorak Rd/Burke Rd	59-H5	Camberwell	Toorak Rd	E
			Toorak Rd/Burke Rd	59-H5	Camberwell	Toorak Rd	W
18 apps.	18 apps.		Toorak Rd/Tooronga Rd	59-F6	Kooyong	Toorak Rd	W
		L	Gower St/Plenty Rd	18-H12	Preston	Gower St	W
			Gower St/Plenty Rd	18-H12	Preston	Gower St	E
			Gower St/High St	18-G12	Preston	Gower St	W
			High Street Rd/Huntingdale Rd	61-A11	Mt Waverley	High St Rd	E
		9 apps.	High Street Rd/Huntingdale Rd	61-A11	Mt Waverley	High St Rd	W
			Waverley Rd/Stephensons Rd	70-E11	Mt Waverley	Waverley Rd	E
			Murray Rd/Elizabeth St	18-A11	Coburg	Murray Rd	E
			Murray Rd/Elizabeth St	18-A11	Coburg	Murray Rd	W
			Gaffney St/Cumberland St	17-B9	Pascoe Vale	Gaffney St	E

Test approach (dark shading) | Control 1 approach (unshaded) | Control 2 approach (light shading)

APPENDIX 2
New Experimental Design for Collection of Red Light Running Data

Road Cross-section	Speed Zone (km/h)	Approach	Day Of Week	Time of Day	Lane Type	
					Through	Right
Divided	60	Test	Week Day	7.30 - 10.30 am		
				11.30 - 2.30 pm		
				3.30 - 6.30 pm		
				8.00 - 11.00 pm		
			Weekend Day	7.30 - 10.30 am		
				11.30 - 2.30 pm		
				3.30 - 6.30 pm		
				8.00 - 11.00 pm		
		Control 1	Week Day	7.30 - 10.30 am		
				11.30 - 2.30 pm		
				3.30 - 6.30 pm		
				8.00 - 11.00 pm		
			Weekend Day	7.30 - 10.30 am		
				11.30 - 2.30 pm		
				3.30 - 6.30 pm		
				8.00 - 11.00 pm		
		Control 2	Week Day	7.30 - 10.30 am		
				11.30 - 2.30 pm		
				3.30 - 6.30 pm		
				8.00 - 11.00 pm		
			Weekend Day	7.30 - 10.30 am		
				11.30 - 2.30 pm		
				3.30 - 6.30 pm		
				8.00 - 11.00 pm		
Divided	80	Test	Week Day	7.30 - 10.30 am		
				11.30 - 2.30 pm		
				3.30 - 6.30 pm		
				8.00 - 11.00 pm		
			Weekend Day	7.30 - 10.30 am		
				11.30 - 2.30 pm		
				3.30 - 6.30 pm		
				8.00 - 11.00 pm		
		Control 1	Week Day	7.30 - 10.30 am		
				11.30 - 2.30 pm		
				3.30 - 6.30 pm		
				8.00 - 11.00 pm		
			Weekend Day	7.30 - 9.00 am		
				11.30 - 1.00 pm		
				5.00 - 6.30 pm		
				9.30 - 11.00 pm		
		Control 2	Week Day	7.30 - 9.00 am		
				11.30 - 1.00 pm		
				5.00 - 6.30 pm		
				9.30 - 11.00 pm		
			Weekend Day	7.30 - 10.30 am		
				11.30 - 2.30 pm		
				3.30 - 6.30 pm		
				8.00 - 11.00 pm		
Undivided	60	Test	Week Day	7.30 - 10.30 am		
				11.30 - 2.30 pm		
				3.30 - 6.30 pm		
				8.00 - 11.00 pm		
			Weekend Day	7.30 - 10.30 am		
				11.30 - 2.30 pm		
				3.30 - 6.30 pm		
				8.00 - 11.00 pm		
		Control 1	Week Day	7.30 - 10.30 am		
				11.30 - 2.30 pm		
				3.30 - 6.30 pm		
				8.00 - 11.00 pm		
			Weekend Day	7.30 - 10.30 am		
				11.30 - 2.30 pm		
				3.30 - 6.30 pm		
				8.00 - 11.00 pm		
		Control 2	Week Day	7.30 - 10.30 am		
				11.30 - 2.30 pm		
				3.30 - 6.30 pm		
				8.00 - 11.00 pm		
			Weekend Day	7.30 - 9.00 am		
				11.30 - 1.00 pm		
				5.00 - 6.30 pm		
				9.30 - 11.00 pm		

APPENDIX 3

SITE VISIT - LEGEND

DEFINITIONS

Access

Veh Acc =	Vehicle Access
Cam Pos =	Camera Position
Veh Seen =	Vehicle Seen (i.e. Can vehicle with camera equipment be seen? / Is it conspicuous?)
Vehicle Obst =	Vehicle Obstruction (i.e. Is the vehicle with camera obtructing any traffic, pedestrians, or causing interuptions to the area or creating a safety hazard?

Alignment

V( ) =	Vertical Alignment
H( ) =	Horizontal Alignment

App Slope =	Approach Slope
Dep Slope =	Departure Slope

Vertical Alignment Assessment

- 3	- 2	- 1	0	1	2	3
High	Medium	Slight	Flat	Slight	Medium	High

Negative values =	Sloping downwards in direction of travel
Positive values =	Sloping upwards in direction of travel

Horizontal Alignment Assessment

H(S) =	Straight Horizontal Alignment
H(SLB) =	Slight left bend in direction of travel
H(SRB) =	Slight right bend in direction of travel
H(ShLB) =	Sharp left bend in direction of travel
H(ShRB) =	Sharp right bend in direction of travel

APPENDIX 4

Final 9 Approaches for Collection of Red Light Running Data

Road Cross-section	Speed Zone (km/h)	Location	Melway Ref	Suburb	Road	Dir
Divided	60 *3 apps*	Geelong Rd/Geelong St	41-K5	Footscray West	Geelong St	SE
		Geelong Rd/Geelong St	41-K5	Footscray West	Geelong St	NW
		Napier St/Whitehall St	42-D6	Footscray	Napier St	E
	80 *3 apps*	Springvale Road/Wellington Road	80-B1	Mulgrave	Springvale Rd	S
		Springvale Road/Wellington Road	80-B1	Mulgrave	Springvale Rd	N
		Springvale Rd/Ferntree Gully Rd	71-A9	Mulgrave	Springvale Rd	S
Undivided	60 *3 apps*	Centre Rd/Warrigal Rd	78-E2	Oakleigh South	Centre Rd	W
		Centre Rd/Warrigal Rd	78-E2	Oakleigh South	Centre Rd	E
		Centre Rd/Huntingdale/Clarinda Rds	78-J3	Oakleigh South	Centre Rd	E

Dark	*Test Approach*
White	*Control 1 Approach*
Light grey	*Control 2 Approach*

APPENDIX 5

Sample Spreadsheet for Recording of Red Light Running Data

	Display	Right Turn	Through	Simult.
Site: *Geelong St/Geelong Rd*				
Approach: *Geelong St (S)*	**Yellow*	0:00:03.00	0:00:04.00	0:00:03.00
Approach Type: *Test*	***All Red*	0:00:03.00	0:00:03.00	0:00:03.00
Day: *Weekday*				
Date: *Mon 29/5/95*				

	RIGHT TURN LANES								THROUGH LANES								
Cycle No.	GA-Begin	GA-Count	GA-YA	*YA-AR	**AR-R	Veh Type	Veh Time	Type Run	G-Begin	G-Count	G-Y	*Y-AR	**AR-R	Veh Type	Veh Time	Type Run	Comments
1	7:28:18.00	13	7:28:30.72	7:28:33.72	7:28:36.72	1	7:28:31.72	Y	7:28:18.00	7	7:28:44.92	7:28:48.92	7:28:51.92				
			7:28:30.72	7:28:33.72	7:28:36.72	1	7:28:33.12	Y									
2	7:29:36.00	11	7:29:49.80	7:29:52.80	7:29:55.80	1	7:29:50.16	Y	7:29:36.00	4	7:30:05.00	7:30:09.00	7:30:12.00				
			7:29:49.80	7:29:52.80	7:29:55.80	1	7:29:51.08	Y									
			7:29:49.80	7:29:52.80	7:29:55.80	1	7:29:51.48	Y									
3	7:30:57.00	12	7:31:10.84	7:31:13.84	7:31:16.84				7:30:57.00	1	7:31:24.84	7:31:28.84	7:31:31.84				
4	7:32:16.20	9	7:32:30.24	7:32:33.24	7:32:36.24	1	7:32:30.60	Y	7:32:16.20	2	7:32:44.00	7:32:48.00	7:32:51.00				
5	7:33:38.00	4	7:33:45.36	7:33:48.36	7:33:51.36				7:33:38.00	3	7:34:01.16	7:34:05.16	7:34:08.16				
6	7:35:04.40	11	7:35:20.80	7:35:23.80	7:35:26.80	1	7:35:21.16	Y	7:35:04.40	5	7:35:38.76	7:35:42.76	7:35:45.76	1	7:35:39.96	Y	
			7:35:20.80	7:35:23.80	7:35:26.80	1	7:35:22.80	Y									
			7:35:20.80	7:35:23.80	7:35:26.80	1	7:35:24.80	AR									
7	7:36:59.28	17	7:37:18.88	7:37:21.88	7:37:24.88	1	7:37:19.20	Y	7:36:59.28	6	7:37:32.12	7:37:36.12	7:37:39.12				
			7:37:18.88	7:37:21.88	7:37:24.88	1	7:37:20.56	Y									
8	7:39:02.36	19	7:39:22.88	7:39:25.88	7:39:28.88				7:39:02.36	7	7:39:56.00	7:40:00.00	7:40:03.00				
9	7:40:47.00	13	7:41:07.88	7:41:10.88	7:41:13.88	1	7:41:08.16	Y	7:40:47.00	6	7:41:24.48	7:41:28.48	7:41:31.48				
			7:41:07.88	7:41:10.88	7:41:13.88	2	7:41:09.72	Y				0:00:04.00	0:00:07.00				
10	7:42:36.00	6	7:42:46.72	7:42:49.72	7:42:52.72				7:42:36.00	3	7:43:05.80	7:43:09.80	7:43:12.80				
11	7:44:29.32	14	7:44:50.92	7:44:53.92	7:44:56.92	1	7:44:50.80	Y	7:44:29.32	6	7:45:10.72	7:45:14.72	7:45:17.72				
			7:44:50.92	7:44:53.92	7:44:56.92	1	7:44:52.20	Y									
12	7:46:17.28	6	7:46:31.88	7:46:34.88	7:46:37.88	1	7:46:32.48	Y	7:46:17.28	6	7:46:52.32	7:46:56.32	7:46:59.32				
13	7:48:04.28	9	7:48:25.92	7:48:28.92	7:48:31.92				7:48:04.28	5	7:48:40.28	7:48:44.28	7:48:47.28				
14	7:49:53.48	11	7:50:08.72	7:50:11.72	7:50:14.72				7:49:53.48	4	7:50:42.92	7:50:46.92	7:50:49.92				
15	7:51:45.40	15	7:52:05.28	7:52:08.28	7:52:11.28				7:51:45.40	1	7:52:24.80	7:52:28.80	7:52:31.80				
16	7:53:43.32	9	7:53:57.12	7:54:00.12	7:54:03.12	2	7:53:58.12	Y	7:53:43.32	6	7:54:21.84	7:54:25.84	7:54:28.84				
			7:53:57.12	7:54:00.12	7:54:03.12	1	7:53:59.04	Y									
17	7:55:39.24	23	7:56:01.72	7:56:04.72	7:56:07.72	2	7:56:01.60	Y	7:55:39.24	6	7:56:34.92	7:56:38.92	7:56:41.92	1	7:56:36.68	Y	
			7:56:01.72	7:56:04.72	7:56:07.72	1	7:56:03.72	Y									
18	7:57:35.40	18	7:57:56.48	7:57:59.48	7:58:02.48				7:57:35.40	2	7:58:10.64	7:58:14.64	7:58:17.64				
19	7:59:24.28	15	7:59:46.08	7:59:49.08	7:59:52.08	1	7:59:45.92	Y	7:59:24.28	13	8:00:20.00	8:00:24.00	8:00:27.00				
			7:59:46.08	7:59:49.08	7:59:52.08	1	7:59:47.36	Y									
20	8:01:17.40	18	8:01:38.80	8:01:41.80	8:01:44.80	1	8:01:39.64	Y	8:01:17.40	15	8:02:11.00	8:02:15.00	8:02:18.00				
			8:01:38.80	8:01:41.80	8:01:44.80	1	8:01:41.60	Y									
			8:01:38.80	8:01:41.80	8:01:44.80	1	8:01:41.68	Y									
			8:01:38.80	8:01:41.80	8:01:44.80	2	8:01:44.00	AR									
21	8:03:10.32	17	8:03:32.00	8:03:35.00	8:03:38.00	1	8:03:34.16	Y	8:03:10.32	8	8:04:06.00	8:04:10.00	8:04:13.00				
			8:03:32.00	8:03:35.00	8:03:38.00	1	8:03:32.00	Y									
22	8:05:03.40	16	8:05:24.68	8:05:27.68	8:05:30.68	1	8:05:27.60	Y	8:05:03.40	5	8:05:39.12	8:05:43.12	8:05:46.12				
23	8:06:56.40	24	8:07:17.92	8:07:20.92	8:07:23.92	1	8:07:19.00	Y	8:06:56.40	11	8:07:32.48	8:07:36.48	8:07:39.48				
24	8:08:50.28	22	8:09:12.80	8:09:15.80	8:09:18.80	1	8:09:14.04	Y	8:08:50.28	9	8:09:45.88	8:09:49.88	8:09:52.88				
			8:09:12.80	8:09:15.80	8:09:18.80	1	8:09:14.08	Y									
			8:09:12.80	8:09:15.80	8:09:18.80	1	8:09:15.08	Y									
			8:09:12.80	8:09:15.80	8:09:18.80	1	8:09:16.48	AR									
25	8:10:50.40	15	8:11:13.84	8:11:16.84	8:11:19.84				8:10:50.40	1	8:11:47.00	8:11:51.00	8:11:54.00				