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A long term study of Red Light Cameras and Accidents

A report initiated and part funded by

vic roads

Australian
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Contents

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Contents

APPENDIX

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SUMMARY

This study has examined the long term effect on accident-types of redlight cameras (RLC) at 41 signalised intersections in Melbourne. The RLC were installed in 1984, and reported accidents for the period 1979 to 1989 were used in the detailed analysis.

The analysis was addressed in several ways. The first was a grouped analysis taking the predominant accident-types for all the RLC sites taken together and comparing the changes over time with the changes in the same accident-types in Metro Melbourne, in the rest of the State, and at signalised intersections in Melbourne. The second was to separately examine each accident-type for the 41 sites and look for changes over the whole period. The third was to classify the accidents at individual RLC sites according to whether it involved the approach on which the camera was installed. The fourth was to consider the frequency of each accident-type before the RLC installation and stratify the frequencies to ascertain if there was any difference in effect by initial frequency. The fifth was by considering both the camera approach and initial frequency. The sixth was to compare the changes at the RLC sites with changes in accidents at signalised intersections.

The original choice of the RLC sites must be questioned. Three-quarters of the sites had initial annual frequencies of two or less reported "adjacent approaches" accidents. Low frequency sites are not good candidates for testing the effectiveness of accident countermeasures.

The results of this study suggest that the installation of the RLC at these sites did not provide any reduction in accidents, rather there has been increases in rear end and adjacent approaches accidents on a before and after basis and also by comparison with the changes in accidents at intersection signals.

There has been no demonstrated value of the RLC as an effective countermeasure.

1. INTRODUCTION

This study was undertaken, at the request of the Road Safety Department, VicRoads, to ascertain the long term effects of Red Light Cameras (RLC) on accidents at RLC sites which had been involved in an earlier study. Part of the cost of this study was funded by VicRoads and the balance was provided from ARRB project RS 680, Countermeasure Evaluation.

The previous study involved a group of RLC installed in Melbourne in 1984 and was reported by South et al. (1988). While that study examined accident statistics from 1979 to 1986, there were only approximately two after years. The question of what has happened at these previously studied sites after more time elapsed provided the rationale for this study.

2. THE PREVIOUS STUDY IN VICTORIA

The study by South et al. (1988) stated that a list of signalised intersections was ranked according to "the number of right-angle and right-angle casualty accidents" for the five year period 1977 to 1981. (It is presumed that "right-against" should have been the second type). The two accident-types were used in the belief that RLC would reduce right-angle accidents and possibly right-against. The authors commented that subsequent considerations indicated that right-against accidents were unlikely to be affected, as they often do not involve run-the-red offences.

A total of 100 intersections was selected from the ranked list. (It is not stated if they were the top 100 sites). These sites were then divided 50/50 as RLC sites and control sites. The "matching" of the sites appears to have been more related to the number of lanes than to traffic flows or accident frequencies.

According to South et al <u>one</u> camera housing and one flash housing were installed at the RLC sites. The camera being installed, where possible on the approach where running-the-red was most implicated in accidents. Also signs "Red Light Camera Ahead" were installed on all approaches to each intersection. Only 46 of the 50 sites had hardware installed in time to be included in the trial.

The analysis by South et al. was based on a disaggregation of six accident types described as:

1. • "right angle" - vehicles from adjacent approaches and collide at right-angles.

2. • "right angle (turning)" - vehicles from adjacent approaches with one or both vehicles turning.

3. • "right against" - right-turning vehicle collides with oncoming vehicle.

4. • "rear end" - vehicle collides with rear of other.

5. • "rear end (turning)" - rear end accident where front vehicle was intending to turn at the intersection.

6. • "other".

It should be noted that the lack of use of RUM codes in the report to describe the accident-type groups makes historical exactitude impossible when comparing the data from the study by South et al. with the data amassed during this study.

Type 2 were stated not necessarily to involve running-the-red and there was no firm expectation of an effect of the RLC. The same comment was made about Type 3.

Type 4 was said not generally to involve running-the-red but an increase in these accidents was expected due to an increase in cars stopping for the red.

Type 5 involved those where the front vehicle was left-turning or the front vehicle was right-turning. It was stated that 80 per cent of these were left-turning at slip lanes. (It is not clear what exactly this referred to. For accidents at all signalled intersections 1979-1993, the split was roughly 50/50 between right-turning and left-turning rear-end accidents).

The stated result of the study was that there were no significant changes in the six accident categories except for right-angle. However it needs to be pointed out that the authors gave a value of Chi-squared = 3.19 for the change in right-angle accidents and claimed this gave a probability less than .05. This claim is wrong, a value of Chi squared has to be equal to or greater than 3.84 to give a probability of .05 or less, for one degree of freedom. This means that none of the stated Chi squared values for the six accident categories were statistically significant. That is changes at the RLC vis a vis the control sites were not significant. Hence the RLC had no effect on accidents.

3. OTHER AUSTRALIAN RLC STUDIES

According to Zaal (1994) Sweden was one of the first countries to use red light cameras but the RLC were found to have a minimal effect on red light running behaviour. This poor result was purportedly because the violations were already low. (One wonders why they installed them). Zaal also said RLC were first used in Australia in 1979. He said the RLC reduces red light running by 35-60 per cent.

He said that the study by South et al (1988) was the first Australian study to look at the effect on accidents and then lists percentage changes for five accident-types. He omits to tell the reader that only one accident-type was stated to have a statistically significant change! It is misleading to quote all the non-significant changes.

Although Zaal said the South et al report on accidents was the first he quotes Maisey (1981) a report which obviously predates the South study.

The study by Maisey related to the installation of one RLC at one intersection in Perth. He used nine other intersection signals for comparison but lumped the accidents at all nine together. The variation in accident frequency at the nine intersections was not shown. Maisey's results were given as 50 per cent fewer "right angle and indirect right angle" accidents in the first year of operation compared to the previous year. At the nine other sites these accidents increased by 12.5 per cent.

The change in rear end accidents at the RLC was given as an increase of 71.1 percent in the first year (a non significant increase).

Maisey's analysis uses two one year before periods and while he compared the after year with the previous year and then the two previous years he did not compare the two before years. The data in his Table 1 shows the total accidents at the RLC over the three years as 76, 47 and 49. At the nine other intersections the totals were 369, 294 and 285. The two years either side of the installation date were similar while the earliest year at both the RLC and the control sites was quite different respectively to the after year.

The RLC site changes did not mirror the last change at the nine control sites, i.e. it did not continue downward.

Maisey's combining of "right angle" and "indirect right angle" (i.e. right-turn) accidents masked the fact that the right-turn accidents were of a greater frequency than the right angle accidents (14 vs 4 in the before year changing to 8 vs 1 in the after year). The frequency of rear end accidents went from 12 in the before year to 18 in the after year. The change in right-turn and rear end accidents were the same numerically.

Maisey's claim of a significant difference between the before year and the after year for the combined "right angle and indirect right angle" accident for $x^2 = 2.9$ is incorrect. This is not a significant value at the p = 5 per cent level.

Without extending the comment on the Maisey report it can be said that an understanding of the changes would benefit from more years being added to the analysis.

Zaal stated that it is generally accepted that increasing compliance with signals will reduce right angle accidents and increase rear ends. Zaal claims there is evidence in the report by South et al to support the notion that rear end accidents "actually decrease after a certain time period". He selectively cited the reduction in rear end accidents at the RLC in the South et al study in 1985 (the year after the installations) and ignored the increase in 1986. There is no support to Zaal's notion of a decrease over time from the most recent study from Adelaide (Mann et al 1994) which shows a net increase (non-significant) over a five year period after RLC were installed.

This latest Adelaide study shows no statistically significant changes for any of the accident-types. (When there has not been accident diagrams on the accident reports for the last few years one might query the accuracy of classification). There was unfortunately no examination of variation in accident frequencies over the full period. The Adelaide study consists of 8 sites that did not have any changes to the signals during the whole period and 5 sites that did have signal changes. The early study (Department of Road Transport, 1991) did not take account of the changes to the traffic signals at the RLC sites. The study by Mann et al (1994) shows much larger reductions at the RLC sites with signal changes than the other RLC sites. The pre camera frequencies at these sites for right-turn and rear end accidents appear excessively large.

The study of RLC in Sydney by Hillier et al (1993) related to installations at 16 intersections. Two years before and after the year of installation were used for the analysis i.e. 1986 and 1987 versus 1989/90 and 1990/91 (an 18 month gap). The analysis showed a decrease in adjacent approaches accidents combined with right-turn accidents while rear end accidents increased. Why the adjacent approaches accidents were combined with the right-turn accidents for the statistical analysis is not stated. Sixteen control sites were used but how they were chosen is not stated in the report. While the average frequencies of right-turn and rear end accidents at RLC and control sites were similar, the frequencies of adjacent approaches accidents were quite different (4.4 at RLC and 2.9 at control sites). Were the RLC frequencies of adjacent approaches accidents at the RLC sites regressing to the mean?

The general downward trend in accidents in Sydney from 1989 onwards was not really examined by conducting a before and after block analysis. What was happening in the intervening 18 months?

The possibility of there being changes to signals at the RLC sites during the study period is not discussed in the report. However there is an analysis related to camera direction which concluded that camera direction was not a significant factor with respect to the number of accidents in the before and after periods.

Is the use of RLC cost effective is a question that needs to address income from violations as well as any accident savings. The reports from the RLC working group (S.A. Road Safety Division 1989,1991) give details of the setting up costs, income and operating costs. For 15 RLC sites and 5 cameras the setting up costs were at least $1.8 million and annual costs were $285,000. The annual revenue in 1989 was $272,000 which taken together with the latest report that shows no significant reduction in accidents suggests a not very profitable exercise.

4. THE PRESENT STUDY

Since 1986, the last year considered in the South et al. study, many changes have taken place. Changes in the accident report, changes in accident coding, introduction of the Transport Accident Commission (TAC) Act (replacing the Motor Accidents Board), the further installations of RLC, changes and additions to traffic signals, and the economic recession.

The study by South et al. assumed that there were no changes at the two groups of sites apart from the installation of RLC but stated that it was possible that this was not the case.

VicRoads advised that they believed that the control sites used in the South et al. report had RLC installed since 1986 , hence there was little point in doing a repeat of the South et al. study.

A list of 50 sites was provided by VicRoads for this study along with the installation dates of the RLC. Most of the dates were given as February 1984. Three sites with dates after 1984 and one with an unknown date were dropped from the study group. None of the 50 sites in the list had installation dates prior to 1984, which contrasts with South et al. reporting installation dates from August 1983 through to November 1984 with February 1984 marking the halfway point in the installations. Unfortunately, the South et al. report does not give a list of the site names for either the RLC or control sites which would have allowed some cross checking of the data supplied for this study.

It was decided, at the outset, that one consistent system of accident-type coding be applied to the accidents (c.f. changes in coding in 1983 and 1987) and this required examining the report form for each accident. The microfilm records were copied for the accident reports listed for the 50 sites. This was approximately 6,200 forms.

For 480 listed accidents in 1983, 1984 and 1985 there were no images on the microfilm. Of the remaining accidents, 960 were found unrelated to the nominated intersections. They were for totally different sites, further than 10 m from the intersection, or in off-road parking areas (e.g. MacDonalds).

The final assembly of accident reports were then given accident-type codes according to the procedures in the Model Guideline [ARRB ATM 29] (Andreassen 1991).

Each of the sites on the list was visited to identify the camera approach and the presence of signs. (There should have been one camera and one flash at each site and signs on all approaches). Although the cut off period for this study (December 1989) considerably predated the inspection (September 1994), it was noted that signs were missing on some of the approaches. Also at other locations there were two flashes, and one location was found to have a camera and a flash on each of two opposing approaches.

Of the 50 sites on the list three sites were eliminated from the study due to installation dates after 1984, as was one where the installation date was unknown. The full data was missing for five of the remaining sites due to extraction problems and it was decided to conduct the analysis, rather than delay the report further by waiting for the data (One of these five sites was the one with two cameras). The final number of sites included in this study was 41.

5. ANALYSIS OF REPORTED ACCIDENTS

5.1 Methodology

The analysis was addressed in several ways. The first was a grouped analysis taking the predominant accident-types for all the RLC sites together and comparing the changes over time with the changes in the same accident-types for the "Melbourne Metropolitan" and for "Rest of State" as well as traffic signals in Melbourne Metropolitan area (both all reported and casualty accidents). The second, was to separately examine each accident-type for the 41 RLC sites and look for changes over the whole period. The third was to classify the accidents at the individual RLC sites according to whether they involved the approach on which the camera was installed. The fourth was to consider the frequency of each accident-type before RLC installation and stratify the frequencies to ascertain if there was any difference in effect by initial frequency. The fifth was by considering both direction and frequency. The sixth was to compare the changes at the RLC sites with the changes in accidents at traffic signals. To allow for the changing number of traffic signals over the period, accidents per site was used as a measure.

5.2 Results

5.2.1 Trends in accident-types in Victoria and the 41 RLC sites

Taking the accidents together at the RLC sites (ARRB Coding), there were four predominant groups these were -

Code (001-003)	pedestrian hit crossing road	5%
Code (101-109)	vehicles from adjacent approaches	19%
Code (202)	vehicles from opposing directions, right-thru	37%
Code (303-303)	vehicles in same lane, rear end	25%
Total	sum of the four accident-type groups	86%

The remaining 14% was made up by diverse accident-types of low frequency, the predominant of these being Code (308, 309) vehicles in parallel lanes, turning.

VicRoads were asked to supply the equivalent four accident-types from their database. The four accident-type groups were examined for the "Melbourne Metro" area and for the "Rest of State". The frequencies of the four types are plotted in Figures 1 and 2 for casualty accidents (here the VicRoads accident-type codes are used and data is as supplied).

It can be seen that there was a pronounced drop in the frequencies after 1989 in both regions. The drop was also evident for accident-types other than these being studied. The Metro totals for 1988 and 1989 were 17,784 and 17,697 and then 14,356; 11,678; 11,747; and 11,055 for 1990, 1991, 1992, 1993 respectively. It appears that some general effect acted across all accident-types from 1990 onwards causing the drop in accident frequency.

So as not to further complicate the study of the RLC sites, it was decided to use 1989 as the cut-off. This gave an eleven year study period which could be used to give a five year period 1979-83 as a 'before' period and a five year period 1985-1989 as an 'after' period, omitting 1984, the year of installations.

As a "control" for accidents at RLC sites the accidents recorded at Melbourne Metro intersection signals were used. [Note: not all intersection signals necessarily record an accident every year. The number of intersections with accidents was known and is used later in section 5.2.6. These accidents include those at all RLC sites].

The proportion of the four accident-type groups that were recorded at traffic signal intersections in Melbourne Metro area for 1979-1989 (VicRoads Coding) were -

Code (100-102)	pedestrian hit crossing road	6%
Code (110-118)	vehicles from adjacent approaches	20%
Code (121)	vehicles from opposing directions, right-thru	29%

Code (130-132)	vehicles in same lane, rear end	20%
Total	sum of the four accident-type groups	75%

The accidents at traffic signal intersections for the four accident-type groups for 1979-1989 are shown in Figure 3, for casualty accidents, and in Figure 4, for all reported accidents. The blank for 1983 in Figure 4 for all reported accidents is because the data supplied was only casualty accident data for reasons unknown. The drop in 1987 is inexplicable in the accident data as it does not appear in all four types in 1987 for Figures 3 and 4 (Again VicRoads data was used as supplied for figures 3 & 4).

The reported accidents occurring at the 41 RLC sites over the period 1979-1990 for the four accident-type groups are shown in Figure 5.

The decline in numbers from 1989 to 1990 for three of the accident-types is consistent with the general decline. While not strictly proper (statistically speaking), the three two-vehicle accident groups combined are shown plotted on Figure 6 to give a singular view of the changes viz the fall from 1980 to 1985, the increase to 1989, and the start of the general decline. The data for all reported accidents was not available for years after 1990.

From the detail of the data for accident-types, it was found that for the Metro Area the code 199(= unknown) was given to 6,785 accidents in 1987 and 2,888 in 1988. These can be compared with frequencies of 80 and 84 accidents in 1986 and 1989 respectively. Further for the accidents at signalised intersections in 1987 the code 199 accidents numbered 1,569 out of a total of 5,358 (i.e. 29%) and in 1988 there were 693 code 199 of 6,233 (i.e. 11%).

The code 199 appears also for the casualty accidents for 1987 and 1988, there being frequencies of 875 and 442 code 199 casualty accidents in 1987 and 1988 respectively.

The drops in 1987 and 1988 in figures 3 and 4 must be attributed, in a large part, to the number of accidents without an accident-type code.

The number of reported accidents by accident-type at the 41 RLC was produced by examining the report forms and determining the codes as per the procedure in the Model Guideline. No accidents in any year could not be coded. This means that the trends in accidents at the RLC sites cannot be compared reliably with those produced by the VicRoads database (casualty or all reported accidents).

It might be assumed that accidents generally increased over the period 1985-89, but there is no reason to expect that all accident-types would increase to the same extent. For comparisons later in this report, the proportional change 1985 to 1989 for each of the four accident-type groups has been determined, i.e.

$$\frac{\Sigma(1985 \text{ to } 1989)}{1985}$$

This is a conservative estimate (i.e. under-estimate) of the change when the number of omitted code accidents in the mass data was high. The proportional changes for the accident-types at the RLC has been compared with the changes at intersection signals.

5.2.2 The accidents at the 41 RLC sites

For each of the four accident-type groups tables were formed of accident frequency for each of the 41 RLC sites for each year for the period 1979 to 1989 (see tables 1 to 4).

The first test conducted was the Komogorov-Smirnov (K-S) goodness of fit test to ascertain if the annual frequencies for each accident-type at the 41 sites were significantly different from a uniform distribution over the period. The totals at the bottom of each table were used for this test.

The results of the tests were that the pedestrian accidents were essentially uniform, but the other three groups were not.

Code 001-003	hit pedestrian	$p > .05$	no significant difference	(N.S.)
Code 101-109	adjacent approaches	$p < .01$	significant difference	(S.)
Code 202	right-thru	$p < .01$	" "	(S.)
Code 301-303	rear end	$p < .01$	" "	(S.)

The question then was whether the three non-uniform groups had increased or decreased and if such changes were related to 1984 (the year the RLC were installed).

For the second test, the matrices of the 41 RLC sites by accident frequency for 1979-1989 for each accident-type group were examined with the Friedman two way analysis of variance test for any difference between the eleven years. The results of the tests were -

Code 001-003	hit pedestrian	$p >> .05$	N.S.
Code 101-109	adjacent approaches	$p < .001$	S.
Code 202	right-thru	$p > .05$	N.S.
Code 301-303	rear end	$p < .001$	S.

This shows that codes 101-109 and 301-303 had significant differences between the years, therefore pair comparisons were conducted on their data sets.

- The results for Code 101-109 (adjacent approaches) were -

  1985 was significantly different from 1980, 1981 and from 1988 and 1989 ($p < .05$)

This shows a significant drop from 1980-1981 to 1985 and a significant increase from 1985 to 1988-1989. When 1984 was used as the base year for comparison, significant differences were found with 1980, 1981 and with 1989. Again a significant drop followed by a significant increase.

- The results for code 301-303 (same lane, rear end) were -

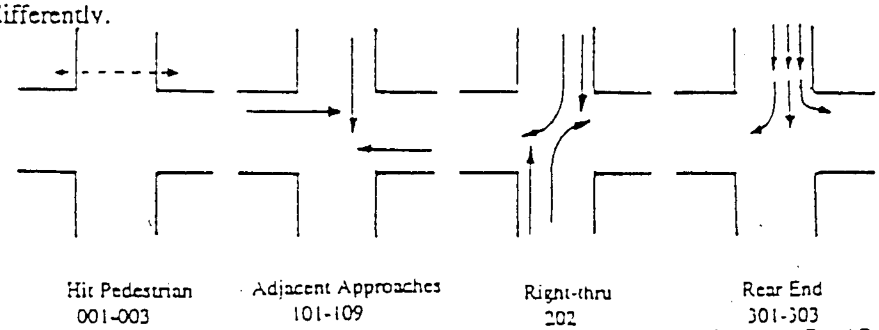
  1983 was significantly different to 1987, 1988, 1989
  1988, 1989 were significantly different to 1979, 1980, 1981, 1983, 1985

This suggests that the accidents in the first period were significantly less than those in the second period.

When 1984 was used as a base year for comparisons no significant differences were found. Values approaching significance were for 1983, 1988, 1989. The situation that 1984 is almost significantly different to 1983 (and higher) is probably the cause of there being no differences when 1984 is used as a base year.

5.2.3 Directional analysis at the 41 RLC Sites

Consideration was given to whether the approach to which the camera was fitted might exhibit the only effect of the RLC or a more pronounced effect than other approaches. All approaches were initially equipped with signs and it might be considered that the effect was the same on all approaches. However, it is equally tenable that frequent users of a particular RLC would soon spot the approach to which the camera was fitted and behave differently.



The accidents as illustrated were counted as "camera approach" accidents. It was decided to compare the ratio of the camera approach accidents to the rest of the accidents. The average percentage of accidents on the camera approaches for each period are shown in Table 5.

Table 5

Accidents on "Camera Approach" for the 'Before' and 'After' RLC installation periods

Accident-type Group		1979-1983	1985-1989
001-003	Hit Pedestrian	21.6%	30.8%
101-109	Adjacent Approaches	53.8%	52.6%
202	Right Thru	57%	46%
301-303	Rear End	29%	28%

The specific changes were as follows -

Code 001-003 *(pedestrian)*		**1979-83**			**1985-89**		
camera approach	(22%)	19	88	→	78	24	(31%)
other approaches		69				54	

Code 101-109 *(adjacent approaches)*		**1979-83**			**1985-89**		
camera approach	(54%)	203	377	→	287	151	(53%)
other approaches		174				136	

Code 202 *(right thru)*		**1979-83**			**1985-89**		
camera approach	(57%)	314	551	→	676	313	(46%)
other approaches		237				363	

Code 301-303 *(rear end)*		**1979-83**			**1985-89**		
camera approach	(29%)	84	288	→	522	147	(28%)
other approaches		204				375	

A simple Chi-squared test showed that the directional split for accident-type Code 202 was the only one that changed significantly ($p < .01$). The observed number was significantly less than expected if it increased in the same proportion as the total for all approaches. Given that the observed numbers in the two periods remained the same on the camera approach, the increase has been on the other approaches. There is some evidence of changes to signal phases at the RLC, as well as the addition of right turn arrows, which would have "reduced" the number of expected Code 202 accidents.

Inquiries were made of VicRoads traffic signals group about the changes at signals and it seems that the historical records have been archived. From the data that was obtained for three intersections (Mahoneys/Hume, Bell/St Georges & Punt/High), it was apparent that a number of changes had taken place. These changes included additional through lanes and the construction of left and right turn slip lanes, changes in phases as well as phase and cycle times and provision for green arrows. The changes to the intersections were apparent, but the dates these changes took effect was not. For this reason the changes could not be related back to subsequent changes in accident frequency. Further investigation into signal changes would be worthwhile to explain some of the abrupt changes at individual RLC sites.

Matrices were formed of RLC sites by camera approach proportion in the two time periods for each accident-type group and tested by the Wilcoxon signed ranks test (41 x 2).

The results were -

Code 001-003	p = .26	N.S.
Code 101-109	p = .45	N.S.
Code 202	p = .18	N.S.
Code 301-303	p = .40	N.S.

This suggests there is no clear evidence of an effect limited to the camera approach.

5.2.4 Effects by initial frequency at 41 RLC Sites

A scan of the matrices of the four accident-types groups at the 41 sites (Tables 1 to 4) showed some very low initial frequencies at individual sites. The report by South et al. said sites were chosen from a list of signals ranked by "right angle" and "right against" casualty accidents. The data in these tables is based on all reported accidents (not just casualty), and three quarters of the sites had initial average frequencies for the adjacent approaches accident-type group of two or less accidents per year. For this reason, it is hard to understand why many of these sites were chosen for implementation of a RLC. Sites with low annual frequencies of recorded accidents are not good candidates for testing treatments.

The following Figures 7 to 10 show the changes in accident frequency for each accident-type group in relation to the frequency in the period 1979-1983. There are horizontal lines in the graphs at one accident per year intervals.

For the Code 101-109 (adjacent approaches) accidents, at low frequencies (2 or less), there are more increases in the after period than decreases. At higher frequencies, the changes were decreases, with two exceptions.

For the Code 202 (right-thru) accidents, at low frequencies (3 or less), there were far more increases than decreases (about three times as many). For three to six accidents per year, there was almost a balance (3 decreases vs 4 increases), and above six per year three out of four sites showed decreases. (Above three per year there were six decreases, five increases).

For the Code 301-303 (rear end) accidents, only five sites showed a decrease, the remainder had increases even at low frequencies. Although the vast majority of sites had low frequencies (three or less), the preponderance to increase was quite marked.

For the Code 001-003 (hit pedestrian) accidents, for the sites that showed a change, there was about a balance (15 decreases, 12 increases, 14 no change). All sites were low frequency sites.

The earlier Friedman Tests on the matrices of 41 sites by 11 years for each accident group (section 5.2.2) showed two accident-types with significant differences between years (these being 101-109 & 301-303). However for the three groups (101-109, 202 & 301-303) the possibility of a difference in effect by initial frequency was explored.

The two accident-type groups (Code 202 & Code 101-109) were split into three or less and more than three accidents per year in the before period for Code 202 and for Code 101-109 two or less and more than two accidents per year in the before period.

These subdivisions were then tested by the Friedman test for differences between the years.

- The results for Code 202 (right-thru) were -

More than 3 per year	$p >> .05$	N.S.	(n = 11)
Three or less per year	$p < .001$	S.	(n = 30)

The first result suggests no effect over time at the higher frequencies, whereas there was an apparent effect in the lower frequency group i.e. a difference between the years, therefore pair comparisons were made on the three or less subdivision with the following results -

(a) When 1984 was used as a base year, no significant differences were found.

(b) When no base year was specified, 1983 was found to be significantly different to 1987 and to 1989.

The second result suggests that these accidents have generally increased at the low frequency sites since 1983.

- The results for Code (101-109, adjacent approaches) were -

More than two per year	$p < .001$	S.	(n = 10)
Two or less per year	$p < .01$	S.	(n = 31)

This result suggests a difference over time at both low and high accident frequency sites, therefore pair comparisons were made on both subdivisions, with the following results -

(i) More than two per year -

(a) When 1984 was used as a base year, significant differences were found with 1980, 1981, 1982. This suggests a drop in accidents to 1984 but no decrease (or increase) afterwards.

(b) When no base year was specified, 1980, 1981 were found to be significantly different to 1984, 1985. This confirms an initial drop but no change after 1985.

(ii) Two or less per year -

(a) When 1984 was used as a base year, no significant differences were found.

(b) When no base year was specified, 1985 was found to be significantly different to 1989. This suggests that accidents have increased from 1985 to 1989.

- The Code (301-303, rear end) accidents were, with the exception of three sites, of an initial frequency of less than three accidents per year, and the earlier test showed a significant difference between years, therefore pair comparisons were made with the following results -

  (a) 1988 and 1989 were found to be significantly different to 1979, 1980, 1981, 1983, 1985. This suggests a general increase in accidents in the second period compared to the first.

- In summary, the effects of stratifying the initial frequency are -

Code 001-003 (hit pedestrian)	-	no significant change over time.
Code 101-109 (adjacent approaches)	-	sites with more than two accidents per year had a decrease in accidents from 1980, 1981 to 1984, 1985, but did not decrease or increase afterwards.
	-	sites with two or less per year, had an increase in accidents from 1985 to 1989 of about $2^1/_2$ times.
Code 202 (right-thru)	-	sites with more than three accidents per year had no change over time.
	-	sites with three or less accidents per year have shown a general increase from 1983 to 1989 of more than 1.8 times.
Code 301-303 (rear end)	-	a general increase in accidents from 1985 to 1989 of more than two times.

5.2.5 Directional analysis by initial frequency

The previous two sections dealt with directional analysis and initial frequency as two individual aspects. This analysis looked at the two aspects combined. The accidents related to the camera approach for accident groups (101-109) and (202) were divided by initial frequency as in section 5.2.4, that is more than two and two or less accidents per year for Code (101-109) and more than three and three or less accidents per year for Code 202. The results were all non significant in respect to a change in the proportion of accidents related to the camera approach.

Camera Approach Accidents:

Type	101-109	Initial Frequency	>2	N.S.
		Initial Frequency	≤2	N.S.
Type	202	Initial Frequency	>3	N.S.
		Initial Frequency	≤3	N.S.

5.2.6 The 41 RLC sites and trends at Intersection Signals

This analysis addressed the question as to whether the changes at the 41 RLC sites were similar or different to the changes in the accident-types at signalised intersections over the period 1979-1989.

There are a number of changes that have taken place in the State accident data system and outside it which have affected the precision and frequency of the accident-types from 1979. These include -

- a change in coding procedures in 1983

- a change in the coding system in 1987
- a change in computer input in 1983
- a revised accident report form 1983 and 1986
- no inclusion of damage accidents after 1990
- the introduction of the Transport Accident Commission (TAC) Act in 1987
- introduction of road reference points (RRP) etc in addition to Melway-based location codes in 1983.

The above changes should have affected RLC sites and other sites in like fashion, except for those that affected the coding of accident-types and location codes. For the period 1979-1982 inclusive, the "RUM" codes apply. For the period 1987 to present, "DCA" codes apply. For the period in between a retrospective conversion of RUM codes to DCA codes was made but, as the DCA codes have some types that the RUM codes did not, the conversion to DCA is not perfect. The change in coding procedures in 1983 adversely affected continuity with earlier periods. This was previously reported on by Andreassen (1986). The only accident-type examined in this study that might have been affected was RUM 37 (rear end at intersection). A requirement to be in or partly in the same lane was removed from coding instructions, resulting in a 15 per cent increase in 1983 compared to the average for 1979-1982.

The major problem, however, relates to the large number of accidents in 1987 and 1988, particularly 1987, that are classified as code 199 (= unknown) discussed in Section 5.2.1. At signalised intersections in the Metro Area, code 199 was 29 per cent in 1987 and 11 per cent in 1988.

The number of accidents in total over the period 1979-1989 at the 41 RLC sites was 3,610 and at all signalised intersections in the Metro Area 50,123 (i.e. 7.2 per cent of the accidents were at the 41 sites). The total number of signalised intersections with accidents rose from about 900 in 1979 to about 1,400 in 1989.

The proportion of traffic signal accidents at the 41 sites was 8.3 per cent in 1979 and 6.7 per cent in 1989. The average number of accidents per signalised intersection with accidents was 4.06 in 1979 and 4.71 in 1989.

(a) Relative change in the numbers of accidents before and after 1984

In the before period, the number of all reported accidents at traffic signals was not supplied for 1983, because of some software or extraction problem, so the only pre-1984 data was for the period 1979-1982. The average changes over the period relative to 1979 $\left\{ \text{i.e. } \frac{\Sigma(1979 \text{ to } 1982)}{(4\times 1979)} \right\}$ for each of the four groups were:

<u>Before period 1979 to 1982</u>

	hit pedestrian (001-003)	adjacent approaches (101-109)	right-thru 202	rear end (301-303)
41 RLC sites	0.912*	1.183	0.976	0.980
Accidents at signals	1.007	0.942	1.059	1.034

* *Note:* value of 1.0 means accident frequencies have remained constant over the period. A value less than 1.0 means frequencies decreased and a value greater than 1.0 frequencies have increased.

For the period 1979-1982 the rates of change at the RLC sites were less for three accident groups and more for the fourth than all signal accidents. There were no known wild swings or large numbers of non-coded accidents for the accidents at signals during this period.

A 4 x 2 table of the mean number of all reported accidents of each of the four accident-types at the 41 RLC sites, and at traffic signals with reported accidents for the period 1979-1982 was subjected to a Chi-squared test. A non significant value was obtained, suggesting that the proportion of each accident-type was the same in the 41 sites as all the accidents at signals group.

For the after period 1985-1989, the average changes relative to 1985 for each group were -

<u>After period 1985 to 1989</u>

	hit pedestrian (001-003)	adjacent approaches (101-109)	right-thru 202	rear end (301-303)
41 RLC sites	0.918	1.972	1.176	1.740
Accidents at signals	0.943	1.357	1.256	1.207

Comparing the two sets of changes for 1985-1989, it appears that the rate of change in Code (101-109) was much greater at the RLC sites, that Code 202 was less and Code (301-303) was much greater. For the 1985-1989 period, the accidents at signals in 1987 and 1988 are known to be deficient in coded accidents. In order to make some comparison, 'extreme' values for 1987 and 1988 equal to that of 1989 were adopted. This then gives average changes in accident frequencies at all signalised intersections compared to 1985, of -

	(001-003)	(101-109)	202	(301-303)
Accidents at signals	0.974	1.435	1.734	1.362

The biggest alteration being in Code 202, and the difference between that and the RLC sites becomes wider (i.e. much less at the RLC sites).

If the data as recorded and as adjusted to 1989 values, are used as two estimates, the differences between the RLC sites and accidents at signals are -

	(001-003)	(101-109)	202	(301-303)
RLC Sites	0.918	1.972	1.176	1.740
Signals (a)	0.943	1.357	1.256	1.207
Signals (b)	0.974	1.435	1.734	1.362

(*Note:* Signals (a) refers to the 'as supplied' VicRoads data while Signals (b) refers to the adjusted data).

The relative changes in the accident-types in the after period at the RLC sites compared to the accidents at signals were -

- 001-003 Slightly greater decrease at the RLC.
- 101-109 Much greater increase at the RLC.
- 202 Lesser increase at the RLC.
- 301-303 Much greater increase at the RLC.

It should be noted that the number of RLC sites remained constant while the number of signalised intersections and the expected number of accidents increased over the period. The greater increases for the two accident types is even more pronounced when this factor is considered.

A similar test as previously carried out for the before period on the mean number of accidents of each type was conducted for the period 1985-1989 using the "as supplied" data for all signals, produced a significant value ($p < .01$), suggesting a difference in the proportion of each accident-type in the two location groups. The test was repeated using the 1989 figures for 1988 and 1987 and a significant difference ($p < .02$) was obtained. The Chi-squared value for this test was less than for the test with the "as supplied" data, which confirms that the "as supplied" is in error.

The RLC sites might therefore be said to have been similar to accidents at signals for the before period 1979-1982, but significantly different for the after period 1985-1989. The sources of the differences over 1985-1989 were the Code 101-109 and Code 301-303 accidents.

(b) Accidents per site

While the number of RLC sites in this study remained constant, the number of traffic signal sites with reported accidents increased over the period 1979-1989. Also the number of signalised intersections increased over this period. The data for 1983 was not supplied due to software and/or extraction problems with the accident database, so the comparison was between 1979-1982 and either 1984-1989, or 1985-1989, if the year of RLC installation (1984) is left out. The comparison of the RLC sites and accidents at traffic signals was made on the basis of the number of accidents per year per site with accidents.

Table 6

Accidents per site per year for the 'Before' & 'After' RLC installation periods

(a) 41 RLC sites

	Before 1979-1982	After 1 1984-1989	Percentage Change	After 2 1985-1989	Percentage Change
Code (001-003)	0.463	0.366	-20.9	0.380	-17.9
Code (101-109)	1.561	1.309	-16.1	1.395	-10.6
Code 202	2.537	3.175	+25.1	3.298	+30.0
Code (301-303)	1.854	2.394	+29.1	2.546	+37.3
Total of above	6.415	7.244	+12.9	7.619	+18.5

(b) Accidents at Intersection Signals

	Before 1979-1982	After 1 1984-1989	Percentage Change	After 2 1985-1989	Percentage Change
Code (001-003)	0.241	0.245	+1.7	0.237	-1.7
Code (101-109)	0.847	0.720	-15.0	0.874	+3.2
Code 202	1.059	1.223	+15.5	1.256	+18.6
Code (301-303)	0.775	0.880	+13.5	0.884	+14.1
Total of above	2.922	3.068	+5.0	3.251	+11.3

In the period 1979-1982, the sum of the four accident-types at the RLC sites was 2.19 times the average for the accidents at signals. In the period 1984-1989, the sum was 2.36 times and for the period 1985-1989 it was 2.34 times. The widening of the difference in the 'after' period would, in part, be due to the loss of coded accidents in 1987 and 1988 in the accidents at signals data.

The 'after' period of 1985-1989 shows an increase in accidents per site for the RLC sites compared to the use of 1984-1989 as the after period for all four accident-types. The accidents at signals has a different result, the Code (001-003) reduces in 1985-1989 while the other three increase. The comparison with the 'before' period for Code (101-109) shows a substantial difference from -15.0% to +3.2% if 1984-1989 or 1985-1989 is chosen. This is due to 1984 being a low year and this was discussed earlier in Section 5.2.2.

The values for each accident-type over the period 1979-1989 for the RLC sites and the accidents at signals are shown in Figures 11 to 14. As can be seen in the Figures, the rate of increase in the period 1985-1989 is faster for the RLC sites than the accidents at signals for the Codes (101-109), 202, and (301-303). The deficit in numbers of coded accidents is obvious for Code 202 and (301-303) for 1987.

The average number of accidents per site with accidents per year for the period 1985-1989 for the four accident-type groups are compared in Table 7. The average annual frequencies per site at the RLC sites are on average 2.3 times those at signalised intersections with accidents.

Table 7

Average accidents per site per year 1985-1989

	41 RLC	Signals	41 RLC / Signals
Code (001-003)	0.380	0.237	1.6 times
Code (101-109)	1.395	0.874	1.6 times
Code 202	3.298	1.256	2.6 times
Code (301-303)	2.546	0.884	2.9 times
Total	7.619	3.251	2.3 times

The accidents at the RLC sites were above the average number of accidents per site before the cameras were installed and have remained above the average rate since then.

The information above is aggregated data for the purposes of crude comparison. The variation by years as shown on Figures 11 to 14 needs to be kept in mind.

6. ANALYSIS OF CASUALTY ACCIDENTS AT RLC (41 SITES, VICROADS DATA)

6.1 Methodology

At VicRoads' request, the casualty accident data at the 41 RLC sites has been included in this report. This data was supplied by the Road Safety Department, whereas the other computer data used in this report came from the Road Information Services Department. The accident-type codes are those assigned by VicRoads and not the Model Guideline codes in the all reported accidents table shown earlier in this report. It should be noted that some of the casualty accident frequencies in particular years exceed the all reported accident frequencies. Again, this highlights problems in the accident database and/or the process of data extraction.

As the same details were not available for this analysis as for the analysis of the reported accidents, comparisons were made only for the period 1983 to 1993 i.e. from only one year before the RLC installation. The trends of the ARRB coded accidents were compared to the trends of the VicRoads coded casualty accidents. Accidents at traffic signals in Melbourne were also compared.

6.2 Results

The trends in the four accident-type groups are shown in Figure 15 for the period 1983-1993, (It might be recalled that no damage accidents are in the computer after 1990). The general decline in accident frequency after 1989 is evident.

The three two-vehicle accident-type groups combined for ARRB coded all reported accidents and the VicRoads coded casualty accidents are shown in Figure 16, and are also shown as relative frequencies in Figure 17.

There is a drop in 1986 in the casualty accident frequencies which (referring back to Figure 15) is caused by a drop in VicRoads code 121 (right-thru) accidents. As discussed in section 5.2.1, there were large numbers of accidents in 1987 and 1988 that were coded as 199 (= unknown) at traffic signals. This absence of specific coding presumably would affect the frequency of the accident-type groups being analysed here for 1987 and 1988, but does not explain the drop in 1986 at the 41 RLC sites.

When the casualty accidents at signalised intersections was plotted (Figure 18), it can be seen that while there is a small decrease in right-thru accidents in 1986 it is nowhere near the same magnitude of change as at the 41 RLC sites. The drop at the 41 sites was more than 30 percent.

The trends in the four accident-type groups in Figure 15 for casualty accidents for 1983-1993 can be compared with the trends in the all reported accidents for 1979-1990 in Figure 5. It can be seen from Figure 5 and Figure 15 that -

- Rear End — Casualty and reported accidents are similar.
- Hit Pedestrian — Casualty and reported accidents are similar.
- Right-thru — Casualty and reported accidents are dissimilar.
- Adjacent Approaches — Casualty and reported accidents are similar.

For the adjacent approaches accident-type group for 1983-1990 for both the casualty and the reported accidents there is a general increase from 1984 to a peak in 1989.

7. DISCUSSION

The matter of the size of initial frequencies and trends prior to installation are important in this study. Low frequency sites are not good candidate sites for the study of treatments. Any effect and the "random noise" can be confused. Existing trends, up or down, prior to the installation need to be recognised.

The drop in accidents Code (101-109, adjacent approaches) in the period leading up to 1984 was shown in the report by South et al. (1988). Their Figure 5 shows the number of right angle casualty accidents for camera sites and control sites for the period 1979-1986. The upturn at RLC sites from 1985 to 1986 is shown, and the later data observed in this report has continued this upward trend to 1989. The control sites used by South et al. showed a similar downward trend over 1979-1986 as for the RLC sites. The existing downward trend in accident frequency prior to cameras being installed should have provided a warning to avoid a simple before and after block analysis.

The choice of the particular sites for the RLC remains a major point of concern; 31 of 41 sites had average initial frequencies of two or less reported "adjacent approaches" accidents per year.

The study of RLC in Adelaide (Mann et al. 1994), which used five year before and after periods at 8 sites, had the following initial frequencies -

Adjacent approaches accidents	3.3 per year per site			
Thru-right accidents	3.3	"	"	"
Rear end accidents	9.0	"	"	"

The study of RLC in Sydney (Hillier et al. 1993), which used two year before and after block periods at 16 sites had the following initial frequencies-

Adjacent approaches accidents	4.4 per year per site			
Thru-right accidents	3.8	"	"	"
Rear end accidents	2.0	"	"	"

These can be compared with the initial frequencies at the 41 RLC sites in this study of -

Adjacent approaches accidents	1.84 per year per site			
Thru-right accidents	2.74	"	"	"
Rear end accidents	1.45	"	"	"

The RLC sites in Melbourne had more of a thru-right accident problem on average than an "adjacent approaches" accident problem. The average frequency of the adjacent approaches accidents at the Sydney sites was about 2.4 times that of the Melbourne sites. Those in Adelaide were 1.8 times those at the sites in Melbourne.

Questions still to be answered are :-

(1) Would there have been a different result if sites with higher initial frequencies had been chosen?

(2) Did the sites chosen for further RLC installations after this initial group have higher frequencies or lower?

(3) Are there any current sites that might justify the implementation of RLC?

(4) What are the current accident frequencies at all RLC sites?

These would appear to be areas that requires further investigation or an ongoing study in an attempt to answer these and other questions raised within this report.

8. DATA FROM VICROADS ACCIDENT DATABASE

In the process of carrying out this study a number of problems arose in regard of the accident data from the VicRoads database. The data is stored in two time periods viz. prior to 1983 and 1983 to present, and different software is needed to access the data but that is not one of the problems raised here.

A major problem was the location of the accidents. Some 960 accidents were found not to relate to the RLC sites although they had been listed by the computer search. Some of these were for totally different sites, some were beyond the intersection-accident zone, and some were in parking areas.

Although tables of reported accidents could be produced for the period 1979-1990, a subset of the data, accidents at the intersection signals for the year 1983, could not be produced.

The coding of accident-types suffered a change in procedures in 1983 which gave some differences from preceding years, in this case from 1979 to 1982. The whole process was altered in 1987 with the introduction of DCA codes. The RUM codes on the accidents from 1983 to 1986 inclusive were translated to DCA codes. This process was imperfect because some accident-types were not provided for in the RUM codes but are in the DCA codes.

A further problem with the codes was discovered for accidents in 1987 and 1988 with large quantities not having any specific accident-type code. In 1987 there were 6,785 such accidents and in 1988 there were 2,888. The usual number of such accidents pre and post these years was about 80. This problem was accentuated when looking at the accidents at intersection signals. Some 30 per cent in 1987 and 11 per cent in 1988 of the accidents at signals were not given a specific accident-type. These "missing" accident codes appear particularly for right turn and rear end accidents.

Data from the computer for reported accidents was also confused by the infusion of accidents from sources other than the principal police accident report form (Form 513A at that time). This extra information applies across 1983 to 1986. (The extra accidents were not included in this study).

There are implications for past and future studies, apart from this study of RLC, which use the data from the VicRoads database. Misleading results could easily be obtained by assuming the information produced straight from the computer is accurate. Some "fixing" of the information stored in the computer seems highly desirable.

9. CONCLUSIONS

A longitudinal study of this type needs good data. While report forms were extracted for the RLC sites to enable consistent coding over time, a number of problems arose concerning the reliability of the lists of the accidents at the RLC sites. A wider variety of problems came with the accident information supplied from the computer database.

An examination of the changes at 41 RLC sites has been made in a variety of ways. The results were as follows -

- There were four predominant accident-type groups involved viz. Code (001-003), pedestrian hit crossing road; Code (101-109), vehicles from adjacent approaches; Code 202, vehicles from opposing directions, thru-right; and Code (301-303), vehicles in same lane rear-end.

- The Code (001-003) accident numbers show a uniform distribution over the period 1979-1989. The other three groups were tested for a change over the eleven years. Only Code (101-109) and Code (301-303) showed significant changes.

- For Code (101-109) there was a significant drop from 1980, 1981 to 1985 and a significant rise from 1985 to 1988, 1989.

- For Code (301-303) the accidents in the first part of the period were significantly less than those in the second part (e.g. 1988, 1989 were significantly different to 1979, 1980, 1981, 1983 and 1985).

- When 1984 (the installation year for RLC) was used as a base year for comparisons, the result for Code (101-109) was confirmed but for Code (301-303) no significant differences were found due to 1984 being unusually high compared to both 1983 and 1985.

- A directional analysis was made of the accidents at each site to determine if the RLC had an effect related to just one approach, that is the camera approach. The sites showed a constancy of proportion of accidents related to the RLC approach in the 'before' and 'after' periods. The Code 202 accidents showed a change at an aggregated level with the proportion of accidents being less in the 'after' period. There is some evidence that right-turn arrows have been installed at the RLC and this needs to be investigated further.

- The number of accidents occurring in the 'before' period can influence the size of the reduction in the 'after' period when a treatment is installed so an analysis was made of initial frequency and changes for each accident-type. This analysis showed that -

Code 001-003 (hit pedestrian)	- no significant change over time.
Code 101-109 (adjacent approaches)	- sites with more than two accidents per year had a decrease in accidents from 1980, 1981 to 1984, 1985 but did not increase or decrease significantly after that.
	- sites with two or less accidents per year had a significant increase in accidents from 1985 to 1989 (about $2^1/_2$ times).
Code 202 (right-thru)	- sites with more than three accidents per year had no change over time.
	- sites with three or less showed a general increase from 1983 to 1989 (about $1^3/_4$ times).
Code 301-303 (rear end)	- a significant general increase in accidents from 1985 to 1989 (more than two times).

- The changes in the accidents at the RLC sites were compared to those that occurred at signalised intersections over the same period. The computer database information gave problems for this comparison due to 29 per cent of the accidents at signals in 1987 being designated as Code unknown. A further 11 per cent were also unknowns in 1988. The analysis suggests that the increases in accident frequency over the period 1985-1989 at the RLC sites were greater than those for the accidents at signalised intersection in the Melbourne Statistical Division. That is, the general increase in accidents at signalised intersections did not account for the increases at the RLC sites.

- There appears to have been an increase in accidents at the RLC sites from 1985 to 1989 in Code (101-109) at low frequency sites, in Code 202 at low frequency sites and in Code (301-303) at all frequencies. The increases at the RLC sites were greater than the increases in accidents at traffic signals over the same period.

- A summary of some of the findings are in the table below.

Table 8

Summary for Accident-types

1. Four Predominant Accident Types	Code (001-003) Hit Pedestrian	Code (101-109) Adjacent Approach	Code 202 Right-thru	Code (301-303) Rear End
2. Average initial accident per site per year (1979 - 1983)	0.43	1.84	2.74	1.45
3. Uniform distribution across time 41 Sites x 11 Years	Yes	No	Yes	No
Details of change	N/A	drop from 1980 to 1985 then increase to 1989	N/A	after period greater than before
4. Directional effect	No	No	Yes - Probably due to the installation of turn arrows.	No
5. Effect of initial frequency	N/A	>2 , decrease to 1985 and then uniform ≤2, uniform and then an increase from 1985 to 1989	> 3, uniform ≤3, an increase from 1983 to 1989	increases from 1985 to 1989
6. Relative change at RLC compared to intersection signals.	Slightly greater decrease at RLC	Much greater increase at RLC	Lesser increase at RLC	Much greater increase at RLC

- The original choice of the sites for the purpose of installing the RLC must be questioned. Three quarters of the sites experienced two or less reported Code 101-109 (adjacent approaches) accidents in the 'before' period. Low frequency sites are not good candidates for testing treatments.

- This study suggests that the installation of the RLC at these 41 sites did not provide any reduction in accidents, rather there has been increases in rear end and adjacent approaches accidents on a before and after basis and also by comparison with the changes in accidents at intersection signals.

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