The effectiveness of dedicated right turn signals at signalised intersections: Perth Western Australia

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Abstract
This report presents the results of an evaluation of the dedicated right turn signals at intersections between 2006 and 2011 in the Perth metropolitan area, Western Australia. The purpose of this study is to evaluate the effectiveness in terms of reduction in right angle/right turn through crashes and serious injury crashes.

This evaluation includes 13 sites where dedicated right turn signals were introduced (at specified times or permanently) into the loop of the traffic signal control. Filter movements were then restricted at the sites so the majority of right turn movements were performed under the control of the traffic signal phase. The number of crashes, particularly right turn through/ right angle crashes, before and after treatment at 13 sites was examined for the road safety benefit from the introduction of dedicated right turn signals. The average length of follow up crash data post treatment for all treated sites was 854 days, compared to 5 years of before data.

The preliminary results found that after introducing dedicated right turn signal phase, a significant reduction was found in all reported crashes (24%), right angle/ right turn through crashes (69%), rear-end crashes (10%) and serious injury crashes (58%).

The results provide Main Roads WA and other road safety organisations with preliminary information about the effects of reduction in filter movements at signalised intersections in Western Australia.

Keywords
Intersection filter, right angle crash, right turn through crash, crash migration, intersection safety

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EXECUTIVE SUMMARY

This report presents the preliminary results of an evaluation of dedicated right turn signal phase into signalised control at intersections with permitted filter movements (drivers need to screen/filter the coming traffic and then make a right turn movement when they think it is safe to do so) in the Perth metropolitan area. Main Roads intend to reduce filter movements at signalised intersections as part of an initiative to improve intersection safety under the Towards Zero Road Safety Strategy 2008-2020 in Western Australia. The effectiveness of this initiative was evaluated in terms of reduction in crash frequency for all crash types and specifically for right angle/ right turn through crashes, rear-end crashes and serious injury crashes. It is expected that these findings will provide preliminary information for Main Roads WA and other road safety organisations to inform and enhance strategies for future road safety investments.

The study adopted a quasi-experimental "*before*" and "*after*" design to examine changes in crash frequency at intersections where filter movements were completely or partially removed due to the introduction of dedicated right turn signals between January 1, 2006 and December 31, 2011 in the Perth metropolitan area. Crash reductions or increases at these intersections were examined by crash type, specifically, changes in right angle/ right turn through crashes. It was not possible to identify comparison sites in this project. Crash data was obtained from the Integrated Road Information System (IRIS) using police reported data, which is maintained by Main Roads Western Australia. Information on locations and dates of the introduction of right turn signals at sites were obtained from Downer Australia.

The major findings from the evaluation are summarised below.

Overall

A total of 14 sites across the Perth metropolitan areas introduced dedicated right turn phase into intersection signals between 1st January 2006 and 31st Dec 2011. Subsequently, filter movements at these intersections were not allowed at any time or only allowed outside specific time periods (such as peak hours). For the 13 sites included in the analysis (one site excluded due to small no. of crashes in the "before"

period), the average length of follow up crash data post treatment was 854.2 days (SD=508.21 days).

Crash Effectiveness

The results showed a 24% significant reduction in all-reported crashes after the introduction of dedicated right turn signals. More importantly, right angle/ right turn through crashes were significantly reduced by 69%, while a significant 58% reduction in serious injury crash frequencies was also found. A 10% decrease was found in the number of rear-end crashes.

Treatment Sites (n=13)	**Crash Reduction**	**p-value**
❑ All-reported Crashes	24%	<0.0001
❑ Right angle/right turn through Crashes	69%	<0.0001
❑ Rear-end Crashes	10%	<0.0001
❑ Serious injury Crashes*	58%	0.008

Discussion

Preliminary analysis confirmed that the introduction of dedicated right turn signals to remove right turn filter movements at intersections in the Perth metropolitan area was highly effective in reducing overall crashes, as well as specific crashes such as right angle/right turn through crashes and serious injury crashes. This study also found a significant decrease in rear end crashes at treated intersections. These findings are compatible with previous international and national studies which found a reduction in right turn through crashes.

A limitation of this study was the lack of appropriate comparison sites for adjusting the observed effects for the crash type trends at similar signalised intersections over the same study period. Although these initial findings are informative, an evaluation with more treated sites, a longer period of follow-up data and incorporation of comparison sites would provide more conclusive evidence of the effectiveness of the introduction of dedicated right turn signals, which aims to remove/reduce filter movements from intersections.

Recommendations and Conclusion

In conclusion, the preliminary results of the study found that the introduction of dedicated right turn signal into the loop of signalised intersections in Western Australia to be an effective road treatment. The results should be interpreted with caution due to the small number of sites in the evaluation and the post-treatment period was relatively short. However, the effectiveness of the introduction of dedicated right turn signal should continue to be monitored.

Recommendations include:

- Identification of intersections where a dedicated right turn signal phase is needed to reduce filter movements in order to minimise the right angle/ right turn through crashes.
- Re-evaluation of these treatment sites when more follow-up data is available and inclusion of more sites where dedicated right turn signal phases are used to remove/reduce filter movements.

ACKNOWLEDGEMENTS

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1. INTRODUCTION

Intersection crashes accounted for nearly half of the total crashes in Western Australia between 1995 and 2004 (WA) (Data Analysis Australia 2006). While the monetary cost resulting from crashes at intersections in WA has not been documented, the large number of intersection crashes still represents an enormous cost to the community. Intersection safety has been prioritised as one of the key road safety issues in WA, particularly in metropolitan areas (Corben, Logan et al. 2010) where drivers usually have to deal with a large volume of road users and multiple traffic signals.

Despite improvements in road safety in WA, one-third of people killed or serious injured in road crashes in WA were involved in intersection crashes, with 44% occurring in the metropolitan area between 2005-2007 (Office of Road Safety 2009). While rear-end crashes at intersections may lead to minor injuries or vehicle damage only, right angle and right turn through crashes often lead to serious injury crashes. In addition, intersections in WA seem to be high risk locations for road users who are 60 or above, as 51% of older people (60+) seriously injured or killed in a crash, occurred at an intersection (Office of Road Safety 2009).

Recent research found that the number of crashes at three and four-way intersections were significantly reduced by 15% to 30% after the installation of traffic control signals (Elvik and Vaa 2004). However, an increase in the number of rear-end crashes was observed in several studies (Elvik and Vaa 2004). Previous research has identified factors that may influence safety at signalised intersections. These include: a fully controlled right turn signal (or left turn signal in countries where driving on right hand side is the norm), a leading right turn phase before the through movement phases, an increased inter-green time, the provision of advance warning to motorists, red light cameras, the provision of mast arms, and the provision of skid resistant pavements (Ogden, Newstead et al. 1994; Elvik and Vaa 2004). Australian-based studies also have confirmed that the introduction of fully controlled right turns have been effective in reducing right turn through crashes and serious injury crashes (Nguyen, NHodge et al. 1986; Corben, Ambrose et al. 1990; Bui, Cameron et al. 1991).

From road engineering point of view, the installation of a fully controlled right turn phase (a dedicated green arrow to allow drivers turn to right) into signalised intersections would benefit road safety. This is evident that previous research has generally found a greater reduction (10-58%) in the number of crashes when right-turn phase separations are used at intersections (Nguyen, NHodge et al. 1986; Corben, Ambrose et al. 1990; Bui, Cameron et al. 1991). Nevertheless, public may prefer the use of intersection filters (drivers need to screen/filter the coming traffic and then make a right turn movement when they think it is safe to do so) at signalised intersections (Agent 1979).

"Intersection filters" (intersections allowing for filter movements) have been used to facilitate traffic flow in busy metropolitan areas in many states in Australia. Several jurisdictions have gradually replaced intersection filters into fully controlled right turn signals at intersections. Main Roads WA (MRWA) is also reviewing these filter movements on arterial roads and are planning to remove them to increase intersection safety in WA. To date, dedicated right turn signals were introduced into the loop of 14 signalised intersections between 2006 and 2011 to remove or reduce filter movements at these intersections. Main Roads also plans to remove filter movements from another 13 intersections that have a history of right turn through crashes. The effectiveness of such treatment in WA is unknown.

1.1. Aim

This project aims to evaluate the effectiveness of introducing dedicated right turn signals to reduce filter movements at a sample of signalised intersections in the Perth metropolitan area between 2006 and 2011. Overall crash reductions as well as right angle/right turn through crashes, rear-end crashes and serious injury crashes were also examined.

1.2. Significance

The results of this analysis support the State Towards Zero Strategy (Office of Road Safety 2009) and the Main Roads WA Road Safety Strategy (Main Roads WA 2011). It includes relevant information for road authorities in WA which may guide future investments in new intersection design and treatments to reduce road casualties.

2. METHODS

2.1. Study Design

A quasi-experimental '*before*' and '*after*' study design was used to assess the reduction in all reported crash frequencies, as well as specific crash types including right angle/right turn through and rear-end crashes, after reducing filter movements by introducing dedicated right turn signals. The reduction in serious injury crashes (fatal and hospitalisation crashes) was also assessed.

This study compared the number of crashes occurring over a five-year period at each of the 13 sites '*before*' treatment compared to '*after'* treatment. At least six months of crash data was needed after treatment to be included in the analysis. Five year period was used to account for regression to the mean. It was not possible to match a comparison group in this study due partly to the unique intersection layout (T-junction) for most treated intersections.

2.2. Intersection Filter Treatment

Filter movements can be found at various intersections across the Perth metropolitan area. They have been allowed to assist with the flow of traffic for more than a decade. Nevertheless, emerging evidence shows that filter movements may be a cause of an increase in right angle/ right turn through crashes at an intersection (Wang and Abdel-Aty 2008). These filter movements may not have been a safety issue originally but can become a major road safety concern due to an increase in traffic flow in the areas as well as other factors, such as more risky driving behaviours on roads. To reduce the likelihood of misjudgement at these intersections and make Perth's roads safer road authorities need to make necessary changes.

The most common treatment for filter intersections is to introduce dedicated right turn signals into the loop to reduce filter movements and thus reduce the likelihood of right angle/ right turn through crashes at intersections. Nevertheless, the introduction of dedicated right turn signals may not always be feasible or appropriate in the current road transportation system. Extending the right turn pocket, for example, is also used to treat sites where filter movements are still required to make the traffic flow better. Instead of removing the filter movements from the site

permanently, some intersections only prohibit filter movements at peak hours or during weekdays. Regardless of types of treatment, an improvement in intersection safety is expected, however some motorists may experience slightly longer travel time. Appendix A contains a list of the sites where dedicated right turn signals were introduced to reduce filter movements between 2006 and 2011. These sites are widely distributed across the Perth metropolitan area.

2.3. Data Collection

Information on each of the intersection filter sites, the date of introduction of dedicated right turn signals into the loop of signalised intersections and a specific ban time on filter movement was obtained from Downer Australia, which is the leading provider of engineering and infrastructure management services to many areas including road and rail infrastructure. Police reported crash data from January 1, 2001 to September 30, 2012 was obtained from the Integrated Road Information System (IRIS) which is maintained by Main Roads Western Australia.

2.3.1. Integrated Road Information System (IRIS)

The Integrated Information System (IRIS) database contains detailed information on the characteristics of those involved in road crashes, including crash circumstances, police reported injury, vehicle characteristics and road information related to the crash location. Crash data was extracted for the period of January 1, 2001 up to and including September 30, 2012.

The definition of a crash used throughout this report is the definition used by the Road Safety Council in its annual publication "Reported Road Crashes in Western Australia" (Legge, Kirov et al. 2006; Hill, Thompson et al. 2012). A crash is "*any apparently unpremeditated collision reported to the police which resulted from the movement of at least one road vehicle on a road open to and used by the public and involving death or injury to any person, or property damages*". In WA during the study period, it was mandatory to report a crash to the police if a person was injured or if property damage exceeded $1,000 before July 1, 2008 and $3,000 from July 1, 2008.

In addition to all reported crashes, specific types of crashes were also evaluated separately. These crash types were right angle/right turn through crashes, rear-end crashes and serious injury crashes. A serious injury crash in this report is defined as "*a road crash which resulted in a person being killed or hospitalised*".

Critical data retrieved for use in the study were:

- Crash date and time;
- Crash severity;
- Crash type (identified by the "Nature" code) ;
- Specific crash location.

The preparation work for introducing dedicated right turn signals into the loop usually took 4 to 6 weeks by the time the project was authorised and received by Downer Australia. The physical implementation work, such as modifying the lantern configurations, changing the traffic signal controller program and updating the technical site documentation, was done on sites within 4 hours.

Figure 2.1 shows a typical filter movement at a two by two intersection in Perth. While both car A and car B are filtering traffic in order to make a right turn movement, car A's filter movement conflicts with car C's movement as the figure shows (where the red star is), and thus the site has an increased risk of right angle/right turn through crashes. Such risk is further increased if the driver's vision of car A was blocked by the car B or other physical features of the roads (e.g. an incline). Figure 2.2 further shows a typical treatment by adding a dedicated right turn arrow at site. Car A and car B can only make a right turn when a dedicated right turn arrow is shown in the figure and car C car now has to stop at the stop line.

Figure 2.1 Filter movements at a 2x2 intersection

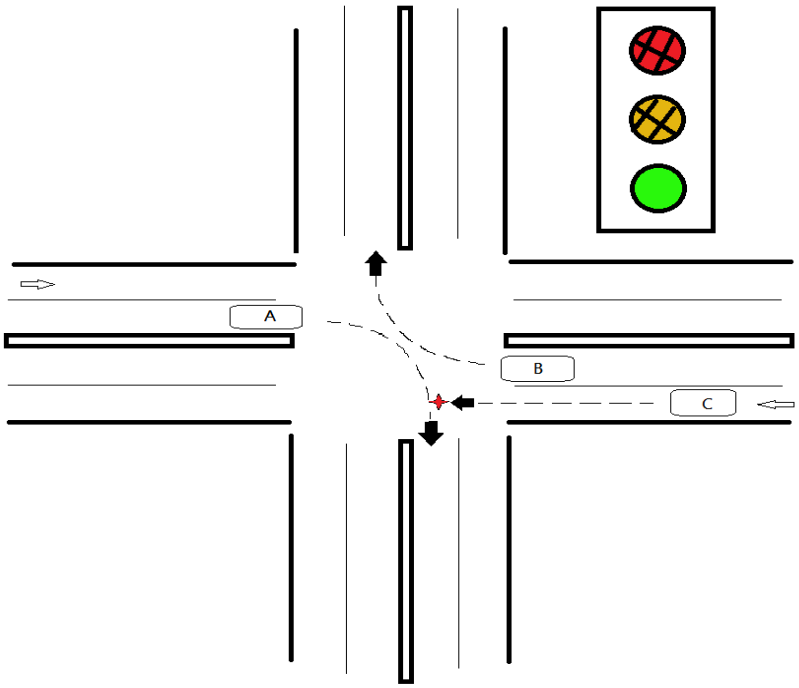
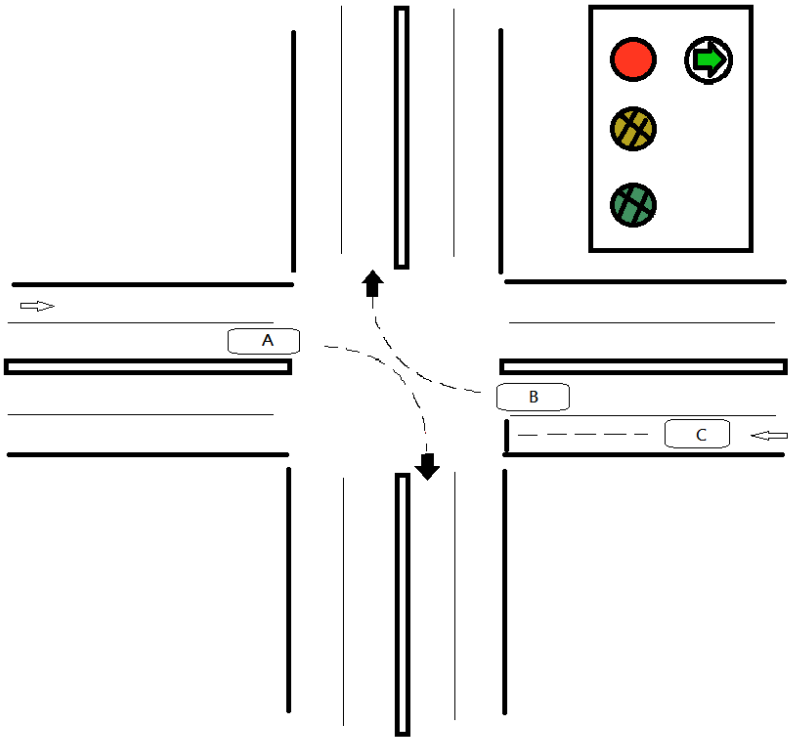


Figure 2.2 Right turn movements under control of a dedicated right turn arrow.



2.3.2. Intersection Filter Sites

An initial list of intersections where filters were removed/ banned was provided by Main Roads WA and then verified by Downer Australia. This included information related to location, the road, the intersecting road, the date of introduction of dedicated right turn signals and the ban time if the filter was not permanently removed from sites. See Appendix A for site details.

Information included:

- Site number;
- Treatment location (intersection);
- The date of introduction of dedicated right turn signals(filter ban date);
- The ban time (if a filter was not completely removed);

A cost-effectiveness analysis was not undertaken because specific costs for each site were not available. Downer Australia has indicated that the approximate costs of a change of an existing turning movement from filter to non-filter ranged from $5,000 to $10,000 depending on the complexity of the work.

2.3.3. Alternative of Incorporating Comparison Sites into Analysis

Ideally, this evaluation should have included comparison sites which had identical characteristics to each treated site, on the premise that crash frequencies and crash types at comparison sites would be identical or at least very similar to treatment sites. Comparison sites provide an indication of what would have happened at the treated sites if no treatment was applied, thereby increasing the validity of the findings on the effectiveness of treated sites. However, it was not possible to match comparison and treatment sites particularly on intersection layout and speed limits in this study. The match is particularly challenging when some filter movements are not permanently removed from sites.

2.4. Factors That May Affect an Evaluation of Dedicated Right Turn Signals

All known factors that have the potential to affect the evaluation should be accounted for when estimating the treatment effect. However, as found by Elvik (1997) the more factors that are accounted for, the less effective the treatment appears to be.

Some of the factors that may affect this evaluation of the effectiveness of introducing dedicated right turn signals are described below. These include site-specific factors, misclassification bias and regression-to-the mean.

2.4.1. Site Specific Factors

The observed change in the frequency and severity of crashes at intersections may be attributed to specific events or factors other than the introduction of dedicated right turn signals. These can include an increase in traffic flow in some areas but not the others, the installation of red light speed cameras around the area and the other road safety treatments. These factors may lead to an increase in driver caution, which could lead to a reduction in crashes that has little to do with the introduction of dedicated right turn signals. While it was not possible to assess these effects in this study, it seems unlikely that site specific factors would have a significant impact on the evaluation of the introduction of dedicated right turn signals as a whole. However, these factors may have an effect on the analysis at a particular site (Bureau of Transport Economics 2001).

2.4.2. Regression to the Mean

Regression to the mean is a statistical phenomenon where the second measurement of a variable will tend to be closer to the average, especially when the first measurement is extremely high. It is possible that this occurred in the current study when the number of crashes “before” and “after” the treatment at a particular site was counted. The reductions in crashes observed may simply be attributed to chance or other hazards at the sites or a combination of both, rather than the treatment (the introduction of dedicated right turn signals in this study). This indicates a potential for overestimating the effectiveness of the introduction of dedicated right turn signals if regression to the mean effect is not considered.

Previous work found that at least three, and preferably five years of data is the preferred before and after time period to smooth out any random fluctuations, as well as providing sufficient evidence of any trend or change in an established pattern of crashes (Nicholson 1986). Although all sites evaluated in this study used five-years of pre-treatment crash data, the average 2.6 years of follow-up may be too short to accommodate the random fluctuation of the data. However, the statistical methodology used in this report recognised the level and distribution of random variation in the data and provided appropriate confidence intervals and significance levels.

2.4.3. Misclassification Bias

Misclassification is a form of information bias, which may occur for a variety of reasons. The number of crashes shown in the police reports for the two intersecting roads may not reflect the true number of crashes. This is particularly true for intersections where filter movements are only allowed in one road not the other. Similarly, misplacement of crashes might have happened for intersections determined by two roads with separate intersections for each carriageway where intersection filters were removed in a different time point e.g. Reid Hwy and Michelle Freeway, North and South intersections. In this report, such intersections were counted as two sites to minimise the potential of misclassification bias.

2.5. Statistical Analysis

The analysis compared the rate of crashes for sites where intersection filters were removed/ banned "*before*" and "*after*" treatment using a generalised estimating equation (GEE) Poisson regression model. The number of crashes in one year is a discrete "count" variable and is assumed to follow a Poisson distribution. The use of Poisson regression is appropriate to establish whether changes in the number of crashes that occurred before and after the treatment at treated sites were significantly different. However, the longitudinal nature of the observations render the application of standard Poisson regression analysis inappropriate, and methods such as the GEE Poisson model should be used to accommodate the inherent correlation of the longitudinal data. A GEE Poisson model takes account of the correlated nature of the

repeated measures taken before and after a treatment as well as the different exposure periods post treatment. Details about the GEE technique can be found in Dupont (2002) and Twisk (2003).

The SAS (9.2) data package was used for data extraction and statistical analysis. The SAS default, the robust variance estimator, may be biased when the number of clusters (number of sites) is small (Horton and Lipsitz 1999). As the number of sites was less than 20, the model-based variance estimator, which provided better estimates (Prentice 1988), was used to undertake the GEE modelling.

When interpreting the results from GEE Poisson models, the incident rate ratio (IRR) was estimated from the regression coefficient, which was generated from the GEE Poisson model. In this report, IRR indicates the ratio of after- and before-treatment incident rate (crash rate). Thus, an IRR greater than 1 indicates an increase in incident rate after the treatment, and vice versa for an IRR lower than 1. The 95% confidence interval indicates the interval estimate for the IRR and is used to indicate the reliability of an estimate. The narrower the range of the confidence interval, the more reliable the results are likely to be. The p-value indicates the statistical significance of the reduction or increase and, in general, $p<0.05$ indicates a significant finding.

3. RESULTS

The results for all-reported and specific types of crashes, including right angle/ right turn through crashes, rear-end crashes and serious injury crashes are presented below.

3.1. Crash Effectiveness Evaluation

This study examined 13 sites where dedicated right turn signals were introduced to reduce filter movements. The average length of follow-up crash data for these sites was 854.2 days (SD=508.21 days) with a minimum of 284 days (8 months) and a maximum of 5 years. Appendix B shows the crash numbers at each site before and after the treatment.

3.2. Crash Reduction by Crash Types

3.2.1. Crash Reduction Estimation by GEE Poisson model

Table 3.1 shows the effect of the introduction of dedicated right turn signals into the signal loop of 13 sites for all-reported crashes, right angle/ right turn through crashes, rear-end crashes and serious injury crashes. Based on the estimated incidence rate ratio (IRR), a significant reduction of 24% ($p<0.0001$) was found for all-reported crashes in the post treatment period for the 13 treated sites. The estimated incidence rate of right angle/ right turn through crashes was also found to significantly reduce by 69% (95% CI: 59-76%) post introduction of dedicated right turn signals. A significant reduction of 58% in serious injury crashes was found after treatment. A 10% significant decrease (95% CI: 10%-11%) in rear-end crashes was also found. Appendix C contains the full results.

Table 3.1 Crash reduction after removing filter movements at 13 intersections, 2001 – 2012

	IRR[1]	95% Confidence Interval		p-value	Crash reduction
Crash type					
All-reported crashes[2]	0.76	0.72	0.80	<0.0001	24%
Right angle/ Right turn through crashes	0.31	0.24	0.41	<0.0001	69%
Rear-end crashes	0.90	0.89	0.90	<0.0001	10%
Serious injury crashes[3]	0.42	0.22	0.80	<0.01	58%

1 Incidence rate ratio
2 Includes all crashes-fatality, hospitalisation, injury and property damage major and minor crashes
3 Only includes crashes leading to any fatality or hospitalisation

4. DISCUSSION

This report presents the preliminary results of the evaluation of the effectiveness of the introduction of dedicated right turn signals into the loop to reduce filter movements from intersections in the Perth metropolitan area. The overall analysis found a significant 24% and 69% reduction for all-reported crashes and right angle/ right turn through crashes. A significant 58% reduction in serious injury crashes and 10% reduction in rear-end crashes was also found.

The overall findings of this study are consistent with previous studies in Australia as well as in other countries. Studies conducted in Victoria found a significant reduction in right turn through crashes as well as other crashes, such as casualty crashes, pedestrian crashes, after the installation of right turn phases into the traffic signal controls (Nguyen, NHodge et al. 1986; Corben, Ambrose et al. 1990; Bui, Cameron et al. 1991), even though the effect size varied with studies. The findings from international studies were also compatible. For example, Agent (1979) found that the use of permissive left turn phasing (allow filter movements) resulted in an increase in left-turn crashes, even though it was popular with local drivers and reduced traffic delay substantially. The overall results from this report as well as other studies prove that removing filter movements from intersections by installation of a fully controlled right turn phase provide safety benefits, especially at locations with a history of right turn through crashes.

As a part of MRWA's practice of supporting the Towards Zero strategy (Office of Road Safety 2009; Main Roads WA 2011), the decision was made to remove the use of right turn filter movements from existing sites and to ban filter movements for new traffic signal installations for roads classified District Distributor A, which carry traffic between different industrial, commercial and residential areas, and Primary Distributors, which carry longer distance traffic to, from and across the urban area. Intersections with high frequencies of right turn through crashes have been shortlisted and the dedicated right turn signals are planned to be implemented to reduce filter movements from those intersections. A more comprehensive plan can further reduce right-turn though crashes not only at treatment intersections but also at surrounding areas.

A major limitation of the preliminary results of the study was the lack of comparison sites. Finally, a cost-effectiveness analysis was not able to be performed in this study because specific costs for each site were not available. In future, cost data should be routinely collected in order to better quantify the safety benefit due to road infrastructure improvements.

5. CONCLUSIONS AND RECOMMENDATIONS

In conclusion, the preliminary results of this study found the introduction of dedicated right turn signals to be effective and may produce positive outcomes for the WA community in terms of road safety.

Recommendations

The results of this research should be interpreted with caution due to the small number of sites in the evaluation and the post-treatment period was relatively short. However, the effectiveness of the introduction of dedicated right turn signals should continue to be monitored.

Recommendations include:

- Identification of intersections where a dedicated right turn signal is needed to reduce filter movements in order to minimise the right angle/ right turn through crashes.
- Re-evaluation of these treatment sites when more follow-up data is available and inclusion of more sites where dedicated right run signals are used to remove/reduce filter movements.

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APPENDIX A INTERSECTIONS WHERE FILTER MOVEMENTS REMOVED OR BANNED BY END OF 2011

ID	LM_No	InterX_no	Road1	Road2	Date change	Specific ban time
1	755	3642	Reid Hwy	Mitchell Fwy South	2/12/2009	Monday to Friday 6:45 to 9:30 & 14:15 to 18:30
2	755	3641	Reid Hwy	Mitchell Fwy South	7/04/2011	Monday to Friday 6:45 to 9:30 & 14:15 to 18:30
3	767	62856	Highclere Blvd	Marangaroo Dr	4/10/2009	
4	99	37751	Old Collier Rd	Wellington Rd/Walter Rd	21/12/2011	
5	106	4426	Belgravia St	Stoneham St / GT Eastern Hwy	24/11/2006	
6	803	40435	Bannister Rd	Willeri Dr	22/01/2010	
7	787	51270	Hill St	Wittenoom St	6/12/2006	8am-9pm
8	311	45282	Welshpool Rd East	Hale Rd	2/03/2011	
9	702	81673	West Cost Hwy	North St	24/07/2009	
10	736	13981	Wanneroo Rd	Dundebar Rd	19/08/2011	
11	275	37757	Walter Rd	Crimea St	28/07/2011	
12	473	119137	Balcatta Rd	Reid Hwy Exit	2/12/2009	
13	791	48384	Murdoch Drive	Somerville Blvd	16/11/2011	
14	872	62674	Ocean Reef Road	Trappers Dr	12/03/2010	

***Site 12 was excluded from the analysis due to only 3 crashes before removing filter movements**

APPENDIX B NUMBER OF CRASHES BEFORE AND AFTER TREATMENT BY TYPE OF CRASH AT EACH TREATMENT SITE

Treatment site	All-reported crash		Right angle/right turn through crash		Rear-end crash		Serious injury crash	
Site ID	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**
1	83	17	12	0	69	17	0	0
2	162	90	21	17	136	71	3	3
3	32	13	18	4	12	6	3	0
4	90	18	36	2	42	14	2	0
5	111	104	28	7	72	85	6	1
6	140	27	88	3	44	23	10	1
7	8	4	2	0	3	1	0	0
8	40	19	16	4	19	14	3	1
9	38	10	20	0	10	8	3	0
10	50	10	21	5	21	5	2	0
11	68	16	33	9	24	6	2	1
13	39	2	27	0	4	1	4	0
14	114	41	37	1	65	39	6	2

APPENDIX C ESTIMATED CRASH REDUCTION AT 15 TREATMENT STIES BY GEE POISSON, BY CRASH TYPES

Area	No. of Sites	Avg. Pre – exposure data (days)	Avg. Post-exposure data (days)	No. of Crashes before treatment	No. of Crashes after treatment	Estimate (β)	Standard Error	P-value	Crash Reduction (%)	95% CI-Lower	95% CI Upper
All-reported crashes	13	1826	854.2	978	371	-0.27	0.028	<0.0001	24	20	28
Right angle/ right turn through crashes				359	52	-1.17	0.14	<0.0001	69	59	76
Rear-end crashes				522	290	-0.11	0.002	<0.0001	10	9	10
Serious injury crashes				44	9	-0.87	0.33	0.01	58	20	78