

CRASHES AT TRAFFIC SIGNALS

Guidelines for a Traffic Engineering Safety Program
of Replacing Selected Intersection Signals with Roundabouts

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Guidelines for a Traffic Engineering Safety Program of Replacing Selected Intersection
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Abstract:

Traffic signals, though effective in reducing crashes between vehicles on intersecting streets, do not alleviate all intersection crash types and, in fact, often results in an increase in right-turn-against crashes. Furthermore, intersections controlled by traffic signals generally exhibit lower safety performance than comparable intersections controlled by roundabouts.

This study examines the scope for achieving immediate safety benefits through the replacement of selected intersection signals with roundabouts, where it is both appropriate in terms of safety and overall traffic management objectives and economically justified.

The report recommends:

- program-based traffic engineering safety guidelines for replacing intersection signals with roundabouts at appropriate locations.
- that guidelines for the assessment of proposed new signals be reviewed to ensure that full recognition is given to the inherent differences in safety performance of roundabouts and intersection signals.

The concept is shown to have a sound economic base and is well suited to a targeted approach, directed at locations collectively contributing a sizeable proportion of the casualty crash problem in Victoria.

Key Words:

Hazardous locations, engineering (traffic), intersection accidents, traffic signals, roundabouts, program guidelines, economic assessment, traffic management

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CRASHES AT TRAFFIC SIGNALS

Guidelines for a Traffic Engineering Safety Program of Replacing Selected Intersection Signals with Roundabouts

1.0 BACKGROUND

Traffic signals represent the most common form of control at major intersections in metropolitan Melbourne. In general, this type of control is effective in reducing crashes involving vehicles on intersecting roads.

However, various studies have shown that traffic signals do not alleviate all intersection crash types and, in fact, may result in an increase in some types, notably right-turn-against crashes (Triggs, 1981, and Howie and Oulton, 1989). It has also been reported in a number of studies that intersections controlled by traffic signals generally exhibit lower safety performance than comparable intersections controlled by roundabouts (Howie and Oulton, 1989, Road Construction Authority, 1982, Maycock and Hall, 1984 and Hall, 1987). The results from these studies are discussed in Appendix 1.

There is a widely held view among the traffic engineering profession that at least some intersections presently controlled by traffic signals would operate more efficiently and safely under a less restrictive form of control. This is particularly true at intersections where circumstances have changed substantially since signal installation.

There would appear, therefore, to be scope for achieving immediate safety benefits through the replacement of some intersection signals with roundabouts, where it is both economically justified and appropriate in terms of safety and overall traffic management objectives.

2.0 OBJECTIVE

This particular part of the *Crashes at Traffic Signals* study has the objective of developing program-based traffic engineering safety guidelines, to be used by traffic management practitioners, for replacing intersection signals with roundabouts at appropriate locations.

3.0 PROGRAM GUIDELINES

Given the superior safety performance of roundabouts compared with signals at some intersections, roundabouts represent a crash countermeasure with potential to be applied using a targeted approach. That is, signalised intersections which have characteristics making them suitable for conversion to roundabout control would be systematically identified, individually assessed against an appropriate set of safety, economic and overall traffic management criteria and, where justified, treated as part of a structured traffic engineering safety program.

This study is concerned with the opportunities available to cost-effectively reduce the incidence and severity of crashes at existing traffic signals. As such, it does not explicitly address the important issue of selecting the best control option in the first instance: - that is, installing intersection signals when a roundabout would provide safer and more efficient operation overall.

It is, therefore, important that existing guidelines for the assessment and selection of intersection control type take proper account of the inherent differences in the safety performance of roundabouts and traffic signals.

3.1 Identification Procedures

A simple and effective procedure, based on general traffic management objectives, is needed to eliminate from the large number of existing signalised intersections those which would not be suitable for roundabout control. The following criteria provide a framework for initial screening of intersections. *In general*, a candidate signalised intersection would:

- not be located within a co-ordinated signal route, unless the intersection forms a logical break between two adjacent, but essentially independent, components of the co-ordinated system;
- not be in need of central monitoring and/or control, such as for processions /motorcades and other special events;
- not be on a tram route nor be required to provide active priority for buses or other special categories of vehicle;
- not be at the intersection of roads with road/amenity classifications separated by more than one level;
- not be an element of an off-road bicycle route nor other bicycle facility.
- not require special timing nor directional control to achieve specific traffic management objectives.

If these criteria are applied to the population of existing intersection signals a proportion of intersections will remain as candidates for site-specific assessment. Intersections where replacement of signals is likely to be effective will typically have a number of readily identifiable physical and/or traffic characteristics. These are described in Section 3.2.

3.2 Roundabout Assessment Criteria – physical and traffic characteristics likely to lead to successful roundabout operation

There are well documented procedures in existence for roundabout assessment and design, dealing with a wide range of criteria, such as vehicle turning paths, design speeds, provision for pedestrians, public transport, freight and emergency vehicles, etc. While these procedures are appropriate for use in this site-specific assessment stage, there are particular features or characteristics which warrant special attention.

Signalised intersections with one or more of the following characteristics are likely to be suitable for treatment under this program:

- a relatively large number of right-turn-against crashes (together with limited opportunity to use fully controlled right-turn phases to alleviate the problem);
- a relatively large number of cross-traffic crashes;
- a geometric layout requiring pedestrians to cross no more than two approach or departure lanes per vehicle direction. This characteristic is especially important if there

are significant numbers: of pedestrians in known high risk groups, using the intersection. (Note: elderly, young and alcohol-affected pedestrians are over-represented in pedestrian casualty crashes);

- adequate sight distances;
- where there are no major vertical or horizontal road alignment deficiencies requiring the continued use of signal displays (which are more conspicuous and generally mounted higher than roundabout signs);
- multi-leg approaches and/or irregular intersection geometry; and
- balanced vehicle flows and a relatively high proportion of turning movements;

The presence of one or more these characteristics at a particular location will increase the likelihood of safety benefits being derived from the conversion of signals to roundabout control and of efficient roundabout operation.

3.3 Project Assessment Procedures

This procedure is based on that developed for the assessment of traffic engineering safety projects for funding as part of the Traffic Management :Services Program (Road Traffic Authority, 1988). The procedure involves estimating, over the life of the project, the following impacts of replacing intersection signals with a roundabout:

- **the monetary value of reductions in crash occurrence.** On the basis of previous studies, summarised in Appendix 1 of these: guidelines, a reduction in accident rate (per vehicle entering the intersection) of approximately 25% represents a reasonable assumption;
- **the monetary value of significant travel time and vehicle operating cost savings** (small travel time savings to individual users are of highly questionable value and should not be included in the assessment procedure);
- **the savings in traffic signal maintenance and operational costs;** and
- **the capital and maintenance costs of the roundabout.**

During this site-specific assessment procedure, additional traffic management considerations or physical constraints, such as an inappropriate balance of traffic flows for the roundabout to operate effectively, inadequate road space, presence of "fixed" underground services, etc., may be identified and effectively exclude the intersection from further serious consideration.

The procedure for undertaking these: assessments is given in Appendix 2, together with some typical results for a range of feasible examples. These show that replacement of signals by a roundabout: at an intersection with two casualty accidents per annum would result in Net Present Worth values of \$175,000 to \$305,000 (for roundabout capital costs of \$200,000 to \$50,000 respectively). The assumptions made in this analysis are conservative and therefore tend to under-estimate the economic: worth of the projects considered.

3.4 Program Development and Implementation Procedures

The estimation of these individual project impacts can be used to calculate the Net Present Worth (NPW) of each roundabout proposal. If there is a large number of intersections for assessment after the initial screening procedure has been applied, NPW assessments should be carried out in order of reported frequency of the sum of cross-traffic and right-turn-against casualty accidents at each intersection. This will increase the likelihood of projects of high economic worth being assessed and available for implementation sooner.

Projects with NPW values greater than zero would then be ranked in descending order of their ratios of NPW to costs to form a list of candidate projects at any point in time. A targeted program could be formed on an annual basis, with the program cut-off occurring at the point in the ranking where all budgeted funds have been allocated. Theoretically, this method would maximise the economic worth of expending funds on this program.

Alternatively, projects identified through this procedure could be ranked with other traffic safety projects, competing for available funds in accordance with overall NPW rankings.

4.0 SUMMARY AND RECOMMENDATIONS

Previous research has shown that, in general, roundabouts have: a superior safety performance to traffic signals when installed at comparable (and appropriate) intersections. There is a case, therefore, for developing a program for the replacement of signals with roundabouts, where justified by quantitative assessment.

This concept has a sound economic base and is well suited to a targeted approach and accordingly should be based on systematic guidelines for identification, assessment and implementation. This report sets out guidelines for such a program.

It is recommended that an annual program of replacement of traffic signals with roundabouts, at appropriate locations, be implemented by the Roads Corporation, using the guidelines described in this report and developed as part of the Centre's *Crashes at Traffic Signals* study. This program would yield immediate road safety benefits at location IS collectively contributing a significant proportion of the casualty crash problem in Victoria.

In relation to proposed new signals, it is recommended that guidelines for the selection of the most appropriate type of intersection treatment should be reviewed and, if necessary, revised to ensure that full recognition is given to the inherent differences in safety performance of roundabouts and intersection signals. In this way, crashes resulting from the selection of inappropriate control types can be avoided.

APPENDIX 1

A SUMMARY OF THE RESULTS FROM VARIOUS STUDIES OF THE RELATIVE SAFETY PERFORMANCE OF INTERSECTION SIGNALS AND ROUNDABOUTS

The current study of Crashes at Traffic Signals (Howie and Oulton, 1989) cites a number of other studies which have reported on the relative safety performance of signalised intersections and roundabouts. This appendix summarises a number of key findings and provides relevant extracts from the report.

Howie and Oulton (1989) analysed data on reported casualty crashes and casualties in Victoria over the period 1982-1986 inclusive. The analysis found that signalised intersections had an average casualty crash record of 0.90 crashes per site per year compared with 0.57 casualty crashes per site per year for roundabouts. It was also found that the average number of casualties (i.e. the sum of fatally injured, hospitalised and medically treated people) was 1.24 per site per year for signals compared with 0.72 per site per year for roundabouts.

These results were qualified by the authors as being indicative only, as they did not take into account relative traffic volumes at roundabouts and traffic signals. However, the authors judged that, overall, the results of the analysis were likely to have over-estimated the average crash rate of roundabouts.

The following extracts from this study provide further information on the relative safety performance of roundabouts and signals.

1. "The UK Accident Investigation Manual (DoT, 1986) indicates that roundabouts have the potential to achieve a 50-60% reduction in injury crash(:(s compared with a 40% reduction from the installation of traffic signals when installed at an identified hazardous site (Blackspot). These figures are indicative only but suggest that there may be further gains by installing roundabouts to replace signals".
2. "There are also potential off-peak operational savings and lower operational costs in addition to safety gains. Pretty (1983) concludes from an analysis of the operational costs of different intersection layouts that 'roundabouts should be installed at many more locations unless there are special circumstances requiring traffic signals'".
3. "Maycock and Hall (1984) found an average crash frequency of 3.31 reported personal injury crashes per year for a sample of 84 four arm roundabouts on main roads in the UK. Hall (1987) in a study of 7,000 signalised junctions in Great Britain found an average crash frequency of 2.65 personal injury crashes per year per signalised junction. That is, a frequency some 24% lower than for roundabouts.

However, the average rate for signalised junctions was 34.4 per 100 million entering vehicles compared with 27.5 per 100 million vehicle passages for roundabouts. On the basis of crashes per unit of exposure, signalised junctions have a crash rate that is some 25% higher than the rate found for roundabouts."

In addition to the studies mentioned above, the Road Construction Authority (1982) reported the following results of various internal evaluations:

- the installation of intersection signals reduces mean casualty accident rates from 3.4 to 1.5 per 10 million entering vehicles, a reduction of 55%.
- the construction of roundabouts reduces mean casualty accident rates from 3.1 to 0.8 per 10 million entering vehicles, a reduction of 74%.

These results further support the view that, in general, roundabouts exhibit superior safety performance to intersection signals. This may, however, only apply at intersections where a roundabout is more appropriate than intersection signals, taking into account traffic mix, traffic flows and turning movements, as well as intersection geometry. Hence, there is a need for guidelines for the systematic selection of appropriate intersections for conversion, as well as for evaluation of the program after implementation.

APPENDIX 2

ECONOMIC ASSESSMENT OF A PROGRAM OF REPLACING SELECTED INTERSECTION SIGNALS WITH ROUNDABOUTS

As a means of estimating the economic worth of implementing; this program, a preliminary Net Present Worth analysis of a range of feasible projects was carried out. The method used is based on techniques described in Heggie (15172) and de Neufville and Stafford (1971). The results are summarised below:

Net Present Worth Assessment:

Net Present Worth of Project

= NPW of Benefits - NPW of Costs

= NPW (accident cost savings)

+ NPW (travel time and vehicle operating cost savings)

+ NPW (signal maintenance and operation savings)

- NPW (roundabout capital and maintenance costs)

Assumptions:

1. **the monetary value of reductions in crash occurrence** is based on the average casualty accident cost being \$53,500 for urban areas and \$84,000 for rural areas (the urban areas value has been used in this analysis). These estimates were derived by increasing, by a nominal 7% for inflation, the average costs recommended for use in such analyses by the Road Traffic Authority (March, 1988).
2. **the monetary value of significant travel time and vehicle operating cost savings** is nominally assumed to be \$10,000 per year, comprised entirely of vehicle operating cost savings. While an authoritative estimate has not been derived at this stage, \$10,000 per year is thought to be conservative for most cases.
3. **the savings in traffic signal maintenance and operational costs** is estimated to be \$8,000 per year, including an allowance for salary and overhead costs of Roads Corporation staff.
4. **the capital and maintenance costs of the roundabout** vary in the analysis to cover a range of typical values. A fixed roundabout maintenance cost of \$1,(K)() per year has been assumed.
5. **future year's benefits and costs** have been discounted at the rate of 4% per annum to express project impacts in present day values. This is the currently recommended rate of the Victorian Department of Management and Budget.
6. **the project life** of each roundabout is 10 years.
7. **a reduction of 25% in casualty accident rate** is assumed for the replacement of signals with a roundabout (on the basis of the results of studies by the RCA (1982), this also represents a conservative assumption).

Applying these assumptions results in the following tabulation of Net Present Worth values for a range of casualty accident frequencies and roundabout capital costs.

Table 1: Net Present Worth estimates for the replacement of intersection signals with roundabouts for a range of casualty accident frequencies and roundabout capital costs.

Capital Cost of Roundabout (\$000s)	Net Present Worth (\$000s)			
	Annual Casualty Accident Frequency			
	4	3	2	1
50	522	414	305	197
80	492	384	275	167
120	452	344	255	127
150	422	314	225	97
180	392	284	195	67
200	372	264	175	47

It is apparent from Table 1 that all projects considered in this illustrative analysis would be economically worthwhile in that each NPW value is greater than zero. As mentioned in Section 3.4, the group of projects which will maximise the program's economic worth (for a fixed budget) may be identified by ranking projects in order of the ratio of each project's NPW to cost, until the entire budget has been allocated.

It should be noted that the NPW of \$10,000 per year for vehicle operating cost savings over the project life of 10 years is \$81,000 and even if this estimated benefit is ignored, it can be seen that all but two of the cases in Table 1 would still have a positive NPW value.

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