Observational analysis of road user interactions

Stop sign controls, left turn on red and zebra crossings

Prepared for Queensland Department of Transport & Main Roads

CDM RESEARCH

Contents

Document history and status

Revision	Date issued	Author	Revision type
1	11/6/2014	C. Munro	Draft-1 for CARRS-Q comment
2	18/6/2014	C. Munro	Edited in response to CARRS-Q comments
3	3/7/2014	C. Munro	Additional commentary on Aberleigh Rd give way signs
4	16/7/2014	C. Munro	Edits regarding Aberleigh Rd and compliance

Distribution of Copies

Revision	Media	Issued to
1	PDF	CARRS-Q / DTMR
2	PDF	TMR
3	PDF	TMR
4	PDF	TMR

Printed:	16 July 2014
Last saved:	3 July 2014 11:30 AM
File name:	0049 Observation analysis or road users (Issue-3).docx
Project manager:	C. Munro
Name of organisation:	Queensland Department of Transport & Main Roads
Name of project:	Observational analysis of road user interactions
Project number:	0049

Executive Summary

The Queensland Parliament's Transport, Housing and Local Government Committee tabled a report into cycling issues in November 2013. The report covered a wide range of issues related to cyclist safety, road rules, enforcement and road design practices in Queensland. Among the recommendations within the report were:

- **Recommendation 18 ("Rolling stop"):** The Committee recommends that the Minister for Transport and Main Roads amend the relevant Queensland road rules to allow for a 'rolling stop' rule which permits cyclists to treat stop signs as give way signs where it is safe to do so.
- **Recommendation 19 ("Left turn on red"):** The Committee recommends that the Minister for Transport and Main Roads amend the relevant Queensland road rules to allow a 'left turn on red permitted after stopping' rule for cyclists at red lights.
- **Recommendation 20 ("Riding on pedestrian crossings"):** The Committee recommends that the Minister for Transport and Main Roads amend the Queensland road rule 248 to permit cyclist to ride on a pedestrian crossing ("Zebra") or children's crossing.

This report describes an observational study of road user interactions at nine intersections (three for each recommendation) to provide objective evidence on current behaviours relevant to these three recommendations. In addition to the observations a review of the evidence for each recommendation was undertaken.

General comments

A very high level of rider and motorist non-compliance was observed at stop signs, and similarly high non-compliance by riders at zebra crossings. The proposed changes to the road rules would bring the rules in line with these observed user behaviours. However, it is unlikely to markedly change the user behaviours (as they are already undertaking the behaviours the recommendations would allow). As such, we see only marginal likelihood of any change in road safety as a result from the recommendations. This change may be positive or negative; there are plausible arguments in both directions, none of which can be predicted with great confidence.

Rolling stop

The rolling stop recommendation would allow riders to treat stop signs in the same way as give way signs. There are few jurisdictions that exclude riders from stopping at stop signs (the most commonly cited being the US state of Idaho), and very few studies into the safety repercussions of this exclusion. There is no robust evidence on the impact of these signs on bicycle rider safety and the evidence for motorists is mixed and generally inconclusive. Most studies have been unable to identify a significant change in safety outcomes, and where a safety benefit has been detected the magnitude of the benefit has generally been small. It appears that factors other than the presence of a stop or give way sign are more important factors in unsignalised intersection safety.

What the literature overwhelmingly suggests is that non-compliance by both motorists and bicycle riders with stop signs is very large. At low volume intersections non-compliance rates of 80% or more are to be expected. The main factor contributing to higher compliance is traffic volumes on the major road, rather than the presence of a stop sign.

This study observed three intersections with high bicycle rider demand and found, in a manner consistent with the literature, very high rates of non-compliance by both riders and motorists. Bicycle non-compliance varied from 85% (Fagan Road southbound) to 98% (Feez Street and Fagan Road northbound). Motorist non-compliance varied from 80% (Fagan Road southbound) to 97% (Feez Street).

Approach speeds were measured between 5 and 3 m from the intersection, and 3 m to the intersection stop lines. At all sites the mean, median and 85th percentile speeds of bicycle riders were higher than motorists by 2-5 km/h. Bicycle riders approached the intersections between 5 and 3 m at average speeds of between 14.8 km/h (Fagan Road southbound) and 18.6 km/h (Ivory Lane), compared with 9.8 km/h (Fagan Road southbound) to 14.0 km/h (Feez Street) for motorists.

The sample of compliant (i.e. stopping) motorist and bicycle rider observations was only adequate at Fagan Road to compare clearance times across the intersection. For bicycle riders the median clearance time in the northbound direction was 2.1 seconds where the rider did not stop and 3.7 seconds where they stopped. A similar difference was observed for motorists.

Our recommendations with regard to this proposed road rule are as follows:

- First and foremost, that the use of stop signs be reviewed and converted to give way sign control except where there is a compelling safety case for a stop sign. This would bring the sign controls in-line with observed motorist and rider behaviours, and there is contradictory and generally inadequate evidence to suggest that one type of control offers safety benefits over another. Furthermore, widespread non-compliance may reduce the credibility of both sign controls and road rules more generally. As such, predominant user behaviour and mobility should take priority.
- There will be minimal change in rider behaviour should the road rule change, as most riders (>80%) already treat stop signs as give way signs.
- We expect a negligible change in safety outcomes. At the margin, it is conceivable that safety outcomes could be slightly positive (as riders can pass through an intersection faster, and need not deal with starting from stationary) or negative (if stopping encourages more careful scanning for conflicting traffic). However, any such benefits are speculative and likely to be small at most.
- The decision as to whether to adopt this proposed road rule ought to be based on a subjective assessment of the likely wider community reaction and acceptance of the exemption for one road user group (i.e. bicycle riders). If the rule were to engender elevated tensions between some motorists and some bicycle riders there may be a net safety disbenefit.

- Where stop signs are retained, and there is a demonstrated safety problem related to road user non-compliance, then highly visible enforcement may be beneficial. However, this would presumably need to be sustained over a prolonged period to ensure it has an effect. Furthermore, it is recommended that any such enforcement be accompanied by a before-after behaviour study to evaluate the effectiveness of the enforcement.

Left turn on red

There is no empirical evidence on the safety repercussions of exempting bicycle riders turning left at signal controlled intersections. There are isolated examples of rider exemptions in Europe, and widespread use of left turn on red exemptions in North America for both motorists and bicycle riders (which, in general, require that the road user stop before proceeding through the intersection). The evidence suggests these exemptions increase the risk of injury to pedestrians on the adjacent crossing, although no increased risk of conflict between motorists has been observed.

In this study, three intersections with moderate cyclist volumes were observed in inner Brisbane. Cyclist non-compliance with the signal phase varied greatly; from 18% (Annerley Road) to 38% (Mollison Street) and 94% (Agnew Street). Non-compliance appears to be related to level of service; the long cycle times at Agnew Street and the convenience of the footpath as an alternative route implicitly encourage rider non-compliance. Motorist non-compliance varied from 5% (Agnew Street) to 15% (Annerley Road) and was generally related to motorists entering the intersection immediately after the amber phase had turned to red.

Bicycle riders who disobeyed the signal generally ensured they had a large gap to conflicting traffic (e.g. a median gap of 4.6 seconds at Agnew Street and 58 seconds at Mollison Street). Most were observed to slow and scan for conflicting traffic before entering the intersection. Not all who disobeyed the signal entered the conflicting roadway; between 10% (Annerley Road) and 52% (Agnew Street) entered the footpath at the intersection in order to travel to the left. This suggests the provision of off-road bypasses for riders may improve level of service and reduce signal non-compliance at some sites.

Overall, in our view allowing for a general exemption for bicycle riders to turn left at traffic signals would be unwise given the potential safety repercussions. It could be argued at specific sites that an exemption is warranted (such as with the use of signs) if sightlines are good and signal cycle times are so long that riders are otherwise unlikely to obey the signal in any case. However, even in these circumstances there remains the prospect that the credibility of signal control is diminished. This would be highly undesirable given the critical importance of this type of intersection control to safety and mobility on the road network. Given these concerns, in our view this proposed road rule change should not be adopted.

Instead of adopting this rule, it is suggested that where riders are observed to disobey signals (such as at Agnew Street) further investigation is warranted into the motivation for doing so, and in providing safer alternatives. Possible measures may include:

- Improve signal timing (cycle times) so as to reduce delay to riders (and motorists) turning left.
- Where detection is present ensure inductive loops are positioned such that riders will travel over them when approaching the intersection, and they are tuned such that they will detect bicycles.
- Provide off-road bypass routes, such as angled kerb ramps onto footpaths to allow riders to safely avoid signals while maximising level of service.

Riding on pedestrian crossings

The current road rule that prohibits riding on pedestrian crossings creates an anomaly within the road rules; a rider in Queensland can ride on the footpath and cross a road without dismounting at any point other than a pedestrian crossing (where they must dismount).

Observations of riders at three sites (two slip lane sites along the Western Freeway Bikeway at Moggill Road) and at Bennetts Road (Norman Park) found almost universal non-compliance with the existing road rule; 95% of riders at Bennetts Road rode across the crossing, as did all riders at the Moggill Road sites. On between 44% (Moggill Road south) and 66% (Moggill Road north) rider crossings a rider encountered a motorist. On at least 80% of occasions the motorist slowed or stopped to give the rider priority at the crossing (although they are not obliged to do so). The likelihood of encountering a pedestrian on the crossing was low; 2.5% of crossings at Bennetts Road were made when a pedestrian was present (always accompanying the rider), and none at Moggill Road.

Permitting bicycle riders to ride across pedestrian (zebra) and school crossings would, in our view, be consistent with existing rider behaviour and have negligible safety repercussions. The main safety issue will arise not with the rider on the crossing itself but rather approaching the crossing and ensuring sightlines are sufficient for them to see motorists and vice versa. One option may be to require riders to stop before proceeding to ride across these crossings. While this would clearly resolve this safety issue if riders were to do so, our view is that this is highly unlikely given the desirability of riders to maintain balance and momentum. Far better in our view would be to address the overall design of these crossings by seeking to reduce speeds between the conflicting movements to within safe limits.

There is good empirical evidence to suggest that the use of raised tables at pedestrian crossings improves safety for pedestrians. It seems reasonable that similar benefits would accrue to bicycle riders, as well as to motorists. In our view, the outcome that would maximise both safety and mobility would be to allow riders on pedestrian crossings and to prioritise the upgrading of crossings where significant numbers of riders are expected.

1 Introduction

1.1 Background

The Queensland Parliament's Transport, Housing and Local Government Committee tabled a report into cycling issues in November 2013 (Queensland Parliamentary Committees 2013). The report covered a wide range of issues related to cyclist safety, road rules, enforcement and road design practices in Queensland. Among the 68 recommendations within the report were:

- **Recommendation 18 ("Rolling stop"):** The Committee recommends that the Minister for Transport and Main Roads amend the relevant Queensland road rules to allow for a 'rolling stop' rule which permits cyclists to treat stop signs as give way signs where it is safe to do so.
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- **Recommendation 20 ("Riding on pedestrian crossings"):** The Committee recommends that the Minister for Transport and Main Roads amend the Queensland road rule 248 to permit cyclist to ride on a pedestrian crossing ("Zebra") or children's crossing.

All of these recommendations relate to changes to the Queensland Road Rules and have implications for the engineering guidance within the Manual of Traffic Control Devices (MUTCD). In considering these recommendations, the Department of Transport and Main Roads has commissioned a literature review and observational study to assist in building an evidence-base against which to assess these recommendations. This report documents this literature review and observational study.

1.2 Objectives

The objectives of this study are threefold:

1. undertake field observations of road user interactions in typical locations where the three recommendations are relevant,
2. obtain objective, quantitative data from these observations upon which to assess the current behaviours, and
3. draw recommendations from this data as to the possible road safety and operational impacts of the recommendations.

1.3 Methodology

The methodology for this study was twofold:

- identify the relevant literature that may provide insight into the implications of the recommendations, and
- conduct an observational study of road user behaviours at a selection of locations to provide insight into current behaviours relevant to the recommendations.

The literature review consisted of relevant keyword searches using TRID[1] and Google Scholar.[2] Relevant public domain reports, journal articles and conference papers were obtained. No criteria on location or age were set; in most cases the relevant literature is so small that no screeners are required. Furthermore, current traffic engineering practices are often based on research conducted several decades ago – hence older research reports are still relevant today insofar as they influence design practices through the current engineering guidance.[3]

1.4 Caveats

In any study of this kind it is impossible to be able to conclude with certainty that one option is "safer" than another. Road crashes are, fortunately, very infrequent events. As such, it is highly unlikely one would observe property damage or injury crashes over any reasonable period of observation. Instead, it is necessary to draw inferences based on observations of "risky" behaviours. This in turn requires an assumption to be made about what is "risky" without objective evidence to link these behaviours to crash likelihoods. Furthermore, we are interested in how the risks may alter in some hypothetical future scenario (i.e. should the road rules be changed). This requires extrapolation of the current observed behaviours to how they may change should the road rules change. Invariably, this will require a deal of subjective interpretation. In this report we offer our interpretation of the objective data and its' implications; other interpretations are also likely to be valid. However, general and absolute statements are unlikely to be defensible. There will be locations where the proposed road rule changes will have positive effects, and others where the effects will be negative. Furthermore, what is relevant is not whether a particular course of action is "safe" or "unsafe" but rather whether it is safer (or less safe) than the status quo. This is a relative measure, and acknowledges that safety is not absolute – there is always a level of risk. What is relevant is to minimise these risks while also facilitating the primary purpose of the transport network – of providing mobility.

1.5 Outline of this report

The three recommendations are considered independently in this report. Within each section covering the three recommendations the structure is as follows:

- The recommendation is described.
- The current road rules as they apply to the recommendation are discussed.
- The purported advantages and disadvantages of the recommendation are discussed; the validity of these are not addressed in this section, rather they are an attempt at presenting the pros and cons as completely and objectively as possible.
- The relevant engineering guidance is identified from the Queensland MUTCD and TRUM, as well as from Austroads.

[1] Transportation Research Board Transportation Research Information Database (TRID): http://trid.trb.org.

[2] http://scholar.google.com.

[3] There is, of course, the question as to how applicable research and observations conducted several decades ago is to the current road environment.

- The literature is reviewed to identify the current evidence relevant to the recommendation.
- The observational methodology is introduced, as well as the sites selected for observation.
- The results of the observations are presented.
- The observational results, along with the wider research evidence, is discussed into order to provide some insight into the possible ramifications of the recommendation.

After discussing each of the three recommendations general conclusions are presented in Section 5.

1.6 Peer review

The methodology used in this study, and this report, has been subject to peer review by Professor Narelle Haworth of the Centre for Accident Research and Road Safety – Queensland (CARRS-Q) at the Queensland University of Technology.

2 Rolling stop

2.1 Introduction

The Parliamentary Committee's recommendation 18 states:

> *The Committee recommends that the Minister for Transport and Main Roads amend the relevant Queensland road rules to allow for a 'rolling stop' rule which permits cyclists to treat stop signs as give way signs where it is safe to do so.*
>
> *(Transport, Housing and Local Government Committee, p. xvii)*

This recommendation would allow for cyclists approaching a stop sign to look for a gap in traffic along the major road and proceed with caution without needing to stop. This approach is colloquially referred to as a "rolling stop".

2.2 Current road rules

Queensland Road Rules section 67 and 68 establish the requirements of road users (including bicycle riders) in regard to stop signs:

> ***QRR section 67: Stopping and giving way at a stop sign or stop line at an intersection without traffic lights***
>
> *(1) This section applies to a driver at an intersection without traffic lights who is facing a stop sign or stop line.*
>
> *(2) The driver must stop as near as practicable to, but before reaching—*
>
> *(a) the stop line; or*
>
> *(b) if there is no stop line—the intersection.*
>
> *(3) The driver must give way to a vehicle in, entering or approaching the intersection except—*
>
> *(a) an oncoming vehicle turning right at the intersection, if a stop sign, stop line, give way sign or give way line applies to the driver of the oncoming vehicle; or*
>
> *(b) a vehicle turning left at the intersection using a slip lane; or*
>
> *(c) a vehicle making a U-turn.*
>
> *(4) If the driver is turning left or right or making a U-turn, the driver must also give way to any pedestrian at or near the intersection crossing the road, or part of the road, the driver is entering.*
>
> *(5) For this section, an oncoming vehicle proceeding through a T-intersection on the continuing road is taken not to be turning.*
>
> ***QRR section 68: Stopping and giving way at a stop sign or stop line at other places***
>
> *(1) This section applies to a driver approaching or at a place with a stop sign or stop line, unless the place is—*
>
> *(a) an intersection; or*
>
> *(b) a children's crossing; or*

(c) an area of a road that is not a children's crossing only because it does not have—

(i) children crossing flags; or

(ii) children's crossing signs and twin yellow lights; or

(d) a level crossing; or

(e) a place with twin red lights.

A "driver" in these rules applies to both a motor vehicle driver and a bicycle rider. These rules are largely consistent across Australian states and territories.[4] The term "stop" is not explicitly defined in the road rules. For riders this probably means a full stop with at least one foot on the ground for balance or less often a track stand (where the rider balances on the bicycle with feet on both pedals). The recommendation would, presumably, insert an exemption clause in these road rules for bicycle riders.

2.3 Advantages and disadvantages

A number of advantages and disadvantages have been claimed for the recommendation. The potential advantages include:

- Riders can clear an intersection faster if they do not need to stop completely, reducing their exposure (time) within the intersection. This reduced gap requirement would also allow for more frequent acceptable gaps (improving rider level of service).
- Once established, riders naturally seek to preserve their momentum and balance – unnecessarily requiring riders to lose and regain these attributes unduly discourages riding.
- Starting from stationary imposes greater physical and mental burdens on the rider than rolling slowly through an intersection, as they must focus on regaining balance, momentum and (where equipped) cleating into their pedals. These actions distract riders from the safety critical task of observing the intersection for conflicting movements.
- Particularly for cleated pedals, the action of cleating can be difficult and errors can increase crossing time and significantly distract from observing the roadway.
- Cyclists have better visibility than motorists due to their typically higher eye position (than a normal car) and absence of obstructions from within the vehicle. Furthermore, cyclists are located much closer to the front of their vehicle than motorists (less than one metre compared to two metres or more for motorists).
- Cyclists will be more risk averse and therefore more cautious than motorists, as they will almost invariably fare worse in a collision with a motorist.
- The property damage created by a cyclist in a collision is minor in comparison to a motor vehicle.

[4] While harmonisation across the states and territories has long been an objective, there remain critical differences. One of the most relevant to this study is that bicycle riders may ride on a footpath in Queensland unless otherwise indicated.

- Connected routes along minor streets will become more attractive relative to major road routes, which should improve overall rider safety.
- Places the emphasis on the rider (and motorist) abiding by the most safety critical task – of looking for a safe gap in traffic, rather than the procedural task of simply stopping.
- There is no obvious correlation in the police-reported crash statistics between riders rolling through stop signs and crashes.
- Overuse of stop signs will diminish their effectiveness at locations where they are most likely to be effective and risks reducing the credibility of traffic control more generally.
- The rule is widely ignored by riders, hence devaluing other rules which are more safety critical.
- Road users respond best to regulatory signage when it is consistent with their expectation. Conversely, signage is less effective when this expectancy is violated.
- Cyclists will avoid stopping at intersections by entering and exiting the footpath either side of the intersection. While legal, this manoeuvre increases risk of injury to pedestrians and to riders (as emerging onto the roadway is a significant contributor to rider injuries).

Potential disadvantages of the recommendation include:

- Bicycle riders will expose themselves to greater risk of injury.
- It would introduce a lack of consistency in the road rules between modes (i.e. motorists are required to physically stop, bicycle riders are not).
- Potential aggravation among some motorists towards riders when observing a rolling stop, particularly if they are unaware of the rule exemption. This may lead to aggressive motorist behaviours towards riders, leading to overall negative safety outcomes.
- Queensland would be out of step with the other Australian states and territories; this runs contrary to the desire to harmonise road rules as much as practicable.

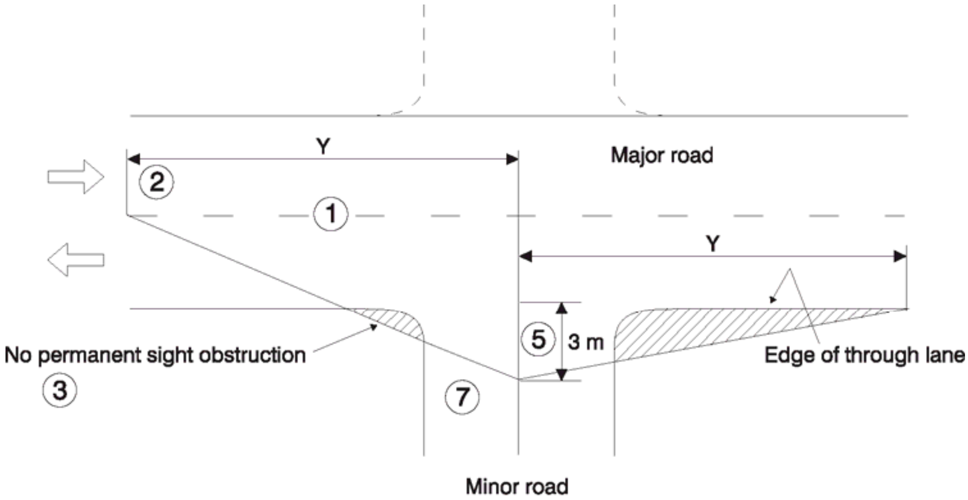
2.4 Engineering guidance

The decision as to whether a stop sign or give way sign is appropriate at unsignalised intersections is based on sight distance requirements from the minor road. The general principle is noted in the Austroads Guide to Traffic Management (AGTM) (2007, p22):

> *STOP signs should normally be installed only where justified on the basis of sight distance requirements, otherwise the signs will lose 'credibility' and their effectiveness in general will be compromised. An exception to this may apply in some jurisdictions where the use of STOP and GIVE WAY signs within the same intersection is not allowed.*

The sight distance requirements are specified in AS1742.2 (Australian Standard 2009). This standard is replicated in the Queensland Manual of Traffic Control Devices

(Department of Transport and Main Roads 2013a), which requires road authorities to install stop signs on minor roads where the sightlines shown in Figure 2.1 are not met. The MUTCD is explicit that stop signs shall not be used where the sight distance is equal or greater than that shown in Figure 2.1.



Major road speed (km/h) (see Note 4)	Distance along major road: Y(m) (see Note 6)
40	20
50	30
60	40
70	55
80	65
90	80
100	95
110	115
120	140

■ Figure 2.1: Sight distance restrictions requiring the use of stop signs (MUTCD Part 2 Figure 2.2)

The origin of these sight distance requirements are not specified in the guidance, but it appears likely they are based on assessments of the critical gap required to enter a major road based on the US Highway Capacity Manual. It is not clear whether these distances have been validated for Australian conditions (although we are not suggesting there is likely to be a material difference in gap acceptance between US and Australian motorists). The distances appear to be derived from speed, reaction time and braking distance assumptions. While reasonable, we are not aware of any Australian study that has attempted to correlate crash likelihood to critical gaps and sight distances.[5]

[5] Nor are we aware of international studies to have attempted this. The variables involved, and the low crash frequencies, mean it would be difficult to do so in any case.

The guidance is clear that the default position is for a give way sign unless the sight distance condition is met. The rationale for this view, as stated in AGTM and reiterated in MUTCD, is to maximise the credibility of the signs. Concerns about the overuse of stop signs have been present for some time; Jordan and Morgan (1990) described the changes that occurred in the sightline guidance in the late 1980s in Victoria with the intention of reducing the number of stop signs. At the time it was argued that widespread non-compliance would devalue the safety impact of stop signs at safety critical intersections. Somewhat earlier, in the late 1970s, there was a similar move in the USA to reduce the number of stop signs although the motivation there was primarily to reduce fuel usage following the oil shocks during that decade (Todd 1993).

Although now dated (and probably superseded by the current Austroads guidance), earlier advice by the New Zealand Traffic Agency (NZTA 1990) was as follows:

> *(i) Stop signs*
>
> *Stop signs should be installed on a crossroad approach if lack of visibility makes it unsafe to approach the intersection at speeds greater than 10 km/h.*
>
> *It is unsafe to approach an intersection at more than 10 km/h if, from a point 9 metres from the intersection on a controlled approach, a driver could not see a vehicle on an uncontrolled approach at a distance (in metres) of 1.2 times the speed (in km/h) of vehicles approaching on the priority route. The speed of priority route traffic is taken as the speed exceeded by 15% of vehicles on that route, i.e. the 85th percentile speed measured in km/h.*
>
> *(ii) Give Way signs*
>
> *Give Way signs should be installed at all crossroads that do not have visibility constraints which require the installation of Stop signs, or are not controlled by other methods.*
>
> *Stop signs should not be used instead of Give Way signs for reasons such as the violation of driver expectation (see Section 3.2), to establish or reinforce a road hierarchy (see Section 3.1), or as a routine response to an actual or expected accident problem. This use of Stop signs is generally ineffective, and can reduce their effectiveness when used correctly in other locations. Where the above problems do occur then additional devices such as central islands with duplicated signs, kerb extensions or threshold treatments as mentioned in Section 3.2 will be required.*

This guidance differs somewhat from the sightline-based approach in the current Austroads and MUTCD guidance. Nonetheless, a common theme through both sets of guidance is that the prerogative should be to install give way signs, and that stop signs should <u>only</u> be installed if the warrant (be it sightline or speed-related) is met. The supposition is that the widespread installation of stop signs where they are not absolutely required will devalue their effectiveness where they are required. We are not aware of this assertion having being tested empirically.

2.4.1 Gap acceptance

Theory

A gap is the time interval between two successive vehicles in the major road stream. A lag is the time interval between the arrival of a vehicle on the minor road at the stop line and and the subsequent arrival of a vehicle on the major road to a point opposite this line.

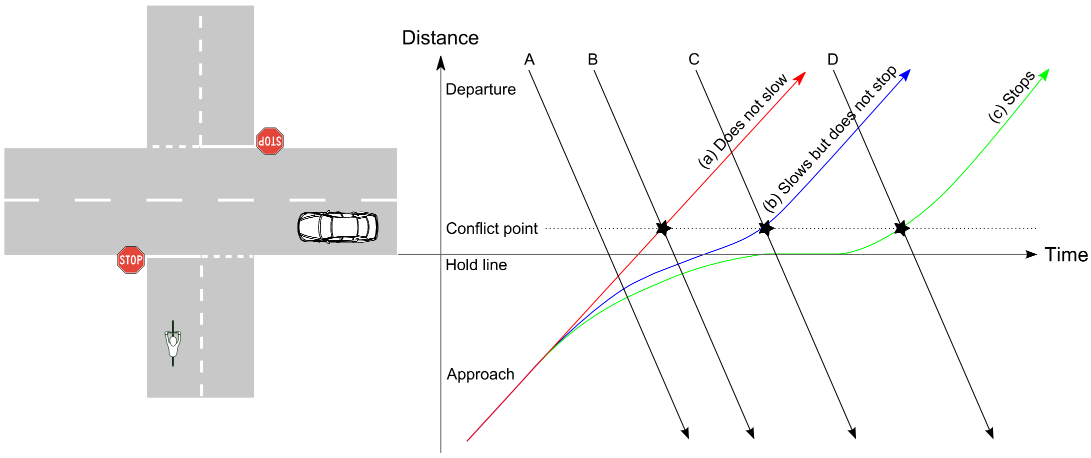
The acceptable gap is the elapsed time which the second road user will tolerate entering the location of the leading road user. This acceptable gap will vary widely between individuals; there will be no threshold which all road users will choose to accept. For example, some riders at an unsignalised intersection would tolerate a two second gap between conflicting traffic, but others would not. As a result, the gap acceptance is usually expressed as a probability function (usually a cumulative Weibull distribution). The critical gap is the elapsed time at which half of road users will accept and the other half will reject the gap. This cannot be determined directly from field observations. Rather, it must be estimated; two of many approaches are the maximum likelihood method of Troutbeck (1992) and the macroscopic model of Wu (2006).

There are practical difficulties in measuring the gap, as road users (be they motorists, bicycle riders or pedestrians) will tend to slow approaching a major road and decide at some unknown point prior to the intersection whether to go or to stop. This decision point cannot be determined by observation. One approach, adopted by Alhajyaseen et al. (2011) in a gap acceptance study at zebra crossings, was to measure the gap when the road user reached the crossing. Specifically, the time is measured as (a) for a motorist that slows but does not stop the time when the vehicle reaches the conflict area, and (b) when the motorist stops the gap is measured from the moment the motorist stops. This approach neglects rejected gaps whereby a motorist slows and then proceeds through the following accepted gap without stopping.

There are three distinct behaviours that a rider approaching a priority intersection may adopt:

- they may proceed through the intersection without slowing,
- they may slow but not come to a complete stop, or
- they may slow and stop.

These behaviours are illustrated in Figure 2.2. Only the stopping behaviour is in compliance with the road rule at a stop sign controlled intersection. The first behaviour – of neither slowing nor stopping – seems improbable. Instead, we would expect most riders to either stop or slow but not come to a complete stop. Whether they slow or stop, and for how long, will presumably be dependent on the rider and the presence of conflicting traffic.



■ Figure 2.2: Typical time-distance plots approaching a priority crossing

Consider now the presence of motorists approaching from the right (i.e. in the nearside lane) in a typical four-arm intersection shown in Figure 2.2. There are four such motorists, shown in Figure 2.2 by the black lines labelled A, B, C and D. Motorist A passes ahead of the approaching rider, such that even if the rider does not slow down they will not be in conflict with the motorist. However, a second motorist (B) travelling behind A will conflict with the rider if they do not slow down. If, as is more likely, the rider slows down to look for traffic (and perhaps sees motorist B) they will avoid conflict with B. If the rider does slow down to allow B to pass, but does not see motorist C travelling behind B they may conflict with C. However, if the rider instead stops they will not conflict with C but may misjudge their crossing such that they conflict with motorist D. The problem in defining a gap as the time from when the rider reaches the hold line is that this will underestimate the rejected gaps. For example, for the rider slowing towards the intersection the rejected gap to motorist B will be underestimated if measured only when the rider reaches the hold line. To at least partially redress this problem, the gap in this project is measured both from the hold line and five metres behind the hold line. This distance is chosen as a likely point at which riders are making their final decision as to whether to stop or go.

Empirical research

The safety of riders crossing a stop or give way controlled intersection will be related to their selection of an appropriate gap between conflicting traffic, and judging this gap and their speed such that they safely clear through the intersection. There has been only limited empirical research undertaken on cyclist gap acceptance. For example, Plumert, Kearney and Cremer (2007) conducted experiments with children (aged 10-12) and adults in a bicycle simulator. They found that there was no difference in gap acceptance between adults and children, but that children cleared the intersection more slowly. They also found that gap acceptance decreases as waiting times increase, and also at latter intersections when a sequence of intersections were crossed.

2.5 Precedents

The most frequently cited precedent for a rolling stop rule for bicycle riders is the US state of Idaho. In that state, which is primarily rural (the largest city, Boise, has a population of 200,000), a rule was introduced in 1982 exempting bicycle riders from needing to stop at stop signs. [6] The current wording of this law is cited in Section 49-720 of the Idaho legislation. [7] There has been pressure to adopt this exemption in other US states and cities, but these have been unsuccessful to date.

2.6 Research evidence

In this section we consider the published literature on stop and give way sign control safety and road user compliance. We treat the evidence in this section in three distinct categories:

- identify the evidence on the relative safety of stop and give way sign controls for both motorists and bicycle riders,
- consider the compliance of motorists and bicycle riders with these alternative treatments, and
- consider what evidence exists on rider preferences towards (or away from) routes with frequent stopping.

2.6.1 Safety

For such a widespread and widely accepted form of traffic control there is a lack of published research evidence on the relative safety of stop and give way signs at intersections. Furthermore, there is only limited and peripheral evidence we are aware of to substantiate the sightline criteria that forms the basis of the Austroads and Queensland MUTCD guidance that dictates when a stop sign is required.

Safety outcomes

Most research evidence on safety outcomes refers to motorists, and much of this is based on research from the USA:

- US National Cooperative Highway Research Program (NCHRP) Report 320 (McGee and Blankenship 1989) found that converting unsignalised intersections from stop sign control to give way control (i.e. a before-after evaluation) would produce (an average) one additional crash every two years. The adverse crash finding was strongest for higher volume major road sites, hence the report recommended that conversions to give way control be limited to sites with major street volumes under 1,500 ADT and minor street volumes under 600 ADT. However, the changes in crash rates were inconsistent across the three study areas and significant increases in crash frequencies were also observed in the (small) control groups. A number of methodological issues were subsequently

[6] At the same time a rule was introduced to allow riders to treat stop lights as stop signs for straight ahead and left turns; that is, they are required to stop at red lights but can proceed to travel straight ahead or turn left after stopping. Right turns can be performed during red lights without stopping (that is, the light should be treated as a give way sign).

[7] http://legislature.idaho.gov/idstat/Title49/T49CH7SECT49-720.htm.

reported (Hauer 1991) which weaken some of the conclusions drawn from that study, most particularly with regard to the claimed influence of traffic volumes. It has also been argued that the safety benefits reported in NCHRP Report 320 are outweighed by the travel time, emissions and fuel cost disbenefits such that give way control is the most cost effective treatment in most cases (Todd 1993). Nonetheless, this study appears to form the justification for the current US guidance on the use of stop signs.

- A cross-sectional study in Indiana at 53 low volume intersections found no significant difference in crashes between stop sign controlled and give way controlled intersections, and that the operating cost savings to road users were significantly better for give way control (Bandyopadhyay 1976). This resulted in FHWA guidance that recommended at under 200 vph on the sign controlled leg no sign was acceptable, from 200-800 vph give way signs are as safe as stop signs and after 800 vph stop signs are preferred (FHWA 1980).
- A cross-sectional study of 140 low volume intersections in three US states found no correlation between intersection control (no control, give way and stop sign) and crashes (Stockton, Mounce, and Brackett 1981).
- The conversion of several hundred stop sign controlled intersections to give way control in Perth was found to increase crashes by 11% in the two years after treatment (Pegrum, Lloyd, and Willett 1972).
- Crash frequency was indistinguishable between a selection of give way controlled and stop sign controlled intersections in New Zealand (Kitto 1980).
- A before-after evaluation of 160 intersections in Israel found inconsistent and generally statistically insignificant changes in crash frequency (Polus 1985). In that study some intersections had give way signs replaced with stop signs (23 intersections), no control replaced with give way signs (65) and no control replaced with stop signs (75). Among their more relevant findings were an increase in accepted gaps at those intersections controlled with stop signs than give way signs. This is an expected result; a stopped vehicle will require a larger gap than a moving one. It was argued that although in principle this should increase safety it was observed to have the opposite effect, perhaps because (some) motorists would have become impatient having to wait for a longer gap and so taken undue risks.

In summary, the evidence on the safety benefits of stop sign control relative to give way sign control is inconclusive. We speculate that (a) there are other intersection characteristics which are more critical to safety outcomes than the type of sign control, and (b) the sign control is having minimal impact on motorist behaviour (so is unlikely to influence safety outcomes). Evidence on this latter issue is discussed in the next section.

There is limited discussion within the literature that attempts to link motorist behaviours with crash outcomes at sign controlled intersections. For example, a study in four US cities found that 17% of crashes at stop sign controlled intersections could be attributed to a motorist failing to stop *at all* (Retting, Weinstein, and Solomon 2003). Furthermore, the majority (70%) of crashes were attributed to a motorist who *did* stop (according to their police statement), but then proceeded into the intersection. While this does not provide an indication of the relative safety merits of stop or give way control it does suggest that an issue is not whether a motorist complies with a stop sign, but rather whether they are able to correctly judge a safe gap in traffic. This view is reiterated by Stokes et al. (2000) based on crash data analysis in Kansas:

> *"The results of this study (and previous studies) suggest that* ***disregard for Stop signs and other traffic control devices is not the primary cause of accidents*** *at rural two-way stop controlled intersections. The majority of the accidents appear to be due to drivers who enter the major roadway and do not (or cannot) accelerate quickly enough to avoid being struck by major roadway vehicles. This would suggest that drivers on the minor roadway either did not see oncoming vehicles or failed to accurately estimate the speeds of oncoming vehicles on the major roadway" … "In short, the results of many previous studies suggest that* ***accidents*** *at two-way stop controlled intersections* ***are more closely related to driver error****, such as failure to accurately judge the speed of major roadway vehicles,* ***than to*** *roadway geometry, sight distance and* ***driver compliance with traffic control devices****"*
>
> (Stokes et al. 2000) – p. 31

If these arguments have merit then the choice of stop sign or give way sign control is dependent on whether motorists are better (or less) able to accurately detect safe gaps if they stop. Furthermore, there is the question of intersection exposure and whether stopping results in longer intersection crossing times which present greater risk (as the safe gap is reduced).

There is very little research that has investigated the safety of bicycle riders at stop or give way sign controlled intersections. Meggs (2012) researched the effect of the Idaho rolling stop exemption and noted that overall rider injuries declined the year after the introduction of the exemption by 14%, and the overall trend between 1976 and 1984 (the exemption was introduced in 1982) was constant. However, the overall injury count may mask increases in some crash types and decreases in others. In any case, the time periods and frequencies are unlikely to have been sufficient to detect a significant change in crashes.

Finally, a caveat is warranted in considering both time-series and cross-sectional crash studies such as reported in this section. Site selection for give way or stop sign control is not random, indeed it is controlled by the relevant engineering guidance with some room for judgement by the traffic engineer. The systematic treatment of sites means there will be confounding variables that will influence safety outcomes. For example, stop sign controlled sites are likely to have poorer sightlines than give way controlled sites and so may have higher underlying crash rates. A naïve cross-sectional crash analysis may conclude, incorrectly, that the stop sign has adverse safety impacts relative to give way controls. Equally, time-series comparisons are confounded by background changes in safety. While control sites are advisable, and commonly used, these can be counterproductive if the crash frequencies at the control sites are low (Hauer 1991).

Visual scanning

When approaching a give way or stop sign a road user is required to (a) scan for conflicting traffic, (b) correctly identify the location and speed of this traffic and (c) assess whether there is a sufficient gap to enter or cross the major road. An argument in support of stop sign control is that by stopping road users have a greater period of time to undertake these tasks, and are more likely to make correct (i.e. safe) assessments of safe gaps. However, there has been only limited research into the scanning and processing behaviour of road users at sign controlled intersections.

Bao and Boyle (2009) found that older drivers (aged 65-80) scanned significantly less to their left and right during intersection negotiations at a stop sign controlled intersection than younger drivers. That older drivers are more susceptible to errors of judgement at sign controlled intersections is widely cited in the literature (e.g. Oxley (2006)), and is usually attributed to greater difficulty this age group has in judging approaching motorist speed and distance (Braitman et al. 2007). However, these findings do not provide an indication of the relative scanning behaviour between stop sign and give way sign controlled intersections.

Sightlines and speed compensation

It is occasionally argued that an intersection that has good sightlines encourages greater road user speeds and more cursory visual scanning, which may be less safe than an otherwise similar intersection with more constrained sightlines which encourage slower approach speeds and more cautious visual scanning. This risk compensation behaviour is difficult to measure empirically and is contrary to typical traffic engineering practice. The evidence on this behaviour is limited. Charlton (2003) treated a stop sign controlled intersection with a hessian screen to reduce visibility and reported a 30% reduction in approach speeds soon after the treatment. What is not known is whether these slower approach speeds affected crash outcomes.

Self-reinforcement and overconfidence

Driving a motor vehicle and riding a bicycle are relatively low risk activities; the likelihood of being involved in a crash on any particular trip is very low. Furthermore, motorists and riders may undertake “risky” behaviours such as travelling at excessive speed or paying only limited attention at intersections and will – most of the time – avoid a crash. As such, these minor infractions (or simply inattention) become self-reinforcing. The tendency for motorists to roll through stop sign controlled intersections in Japan was found to be motivated in large part by a sense of overconfidence by motorists that they could sufficiently observe conflicting motorists (Takemoto, Kosaka, and Nishitani 2008). What may occur is that road users treat stop signs as give way signs, do not incur a collision, and so develop a habit of such behaviours. Their perception of safety and risk may not accord with the reality (as they are unlikely to have been involved in a crash as a result of rolling through a stop sign).

2.6.2 Compliance

The levels of compliance with a stop sign control vary greatly by location and time of day, primarily because the presence of traffic on the major road will greatly increase the compliance with a minor road stop sign. Conversely, a relatively low traffic major road will be more likely to encourage motorists and bicycle riders to roll though the stop sign. Very few studies of compliance seem to have classified compliance conditional on the presence of conflicting traffic (Lebbon et al. (2007) being one of very few examples).

Bicycle riders

There are few bicycle rider stop sign compliance observational studies in comparison to motorists. However, the relevant results of two published studies are:

- 25% of bicycle riders disobeyed stop signs at 48 sites in California, Florida and Texas (Hunter, Stewart, and Stutts 1999). In 13% of cases where a rider disobeyed the stop sign an observer rated the movement as unsafe (that is, they either did not look sufficiently or left an uncomfortably small gap to conflicting traffic).
- 86% of riders disobeyed the stop sign at three intersections near a major university in the USA (Farris et al. 1997); the proportion of helmet wearing riders who did not stop (68%) was lower than for the non-helmet wearing group (88%, who represented 91% of the sample).

Motorists

Observational studies of motorist compliance with stop signs are widespread, although most have been conducted in North America. [8] For example:

- van Houten and Retting (2001) found that 45% of motorists at three stop sign controlled intersections in Florida failed to do so, and 21% of motorists were not observed to look to their right (the farside of the intersection).[9]
- Woldeamanuel (2012) found that at four stop sign controlled sites in Minnesota 65% of motorists failed to completely stop. That study found that strong predictors of stopping compliance were age (younger drivers were more likely to stop than older drivers), presence of passengers (vehicles with one or more passenger were significantly more likely to stop), presence of law enforcement and darkness (motorists were more likely to stop at night).
- There is evidence to suggest that motorist compliance with stop signs has decreased over time. Trinkaus (1997) observed four T-intersections in New York annually between 1979 and 1987, and then again in 1992 and 1996. This observational study reported a drop in full stop compliance from 37% to 1% of motorists from the beginning to the end of the series.
- Lebbon et al. (2007) found that motorists stopped on 100% of occasions when conflicting traffic was observed, and 4.6% of occasions when no conflicting traffic was present at a T-intersection in Michigan.

[8] The interpretation of some of these results from the USA to Queensland should be treated with caution; the USA has traditionally used stop signs more commonly than most Australian jurisdictions, and also use “four way stop” signs at some cross-intersections.

[9] This later statistic probably overstates the proportion who fail to look, as the experimental method relied on observers looking at video recordings of drivers (who may have moved their eyes rather than their head).

- An early study in the USA (Feest 1968) reported that motorists stopped on 35% of occasions, but only 15% once events where there were conflicting traffic were removed.
- A recent study of two intersections in Virginia found non-compliance to be 7% at one site and 5% at another (Cottrell Jr and Dougald 2009).
- Al-Omari (2013) found from a single intersection in Jordan that 48% of motorists did not stop, and that females were more likely to comply than males, driver age increased compliance but that passengers decreased compliance (contrary to the findings of Woldeamanuel (2012)).
- A study of 140 low volume intersections across three US states found that 19% of motorists stopped at stop sign controlled intersections, and 8% at give way controlled intersections (Stockton, Mounce, and Brackett 1981).
- Mounce (1981) observed 66 stop sign controlled intersections in the USA and found that, unsurprisingly, non-compliance was high when traffic on the major roadway was up to around 2,000 vehicles per day and low beyond around 5,000 vehicles per day. There was no relationship between non-compliance and crashes.
- A study in Quebec found when motorists were alone 18% did not stop even when traffic was present on the major road, increasing to 59% when no traffic was present. When the vehicle had at least one passenger and there was traffic non-compliance was 24%, and 57% when no traffic was present.

We are not aware of any before-after studies where the change in stopping behaviour has been observed after a change in sign control; indeed, it appears the difference in stopping compliance between stop and give way controlled sites is not great. Other factors, and especially the presence of conflicting traffic, appear to be the primary influencers of stopping behaviour.

2.6.3 Convenience

Clearly, all road users will prefer routes that have fewer stops (all else being equal). This will be particularly true for bicycle riders, for whom momentum and balance is important. There is limited empirical evidence on the stated preference of riders with regard to stop signs. Sener et al. (2009) in a stated preference experiment found that riders in the USA disliked routes with busy traffic most, followed by routes with frequent stopping.

The issue of convenience, and of route choice, is related to safety insofar as a rider is likely to be less exposed to traffic injury risk on quieter local streets than main roads. However, these local streets are also less likely to have priority at cross streets. A holistic approach to rider safety would need to consider the relative safety of mid-block and intersection risks on alternative routes and of the likely shift between routes should a rolling stop be implemented (or stop signs be replaced with give way signs).

2.7 Observational study method

This section describes the method used to obtain observations of road users at a sample of sites where the rolling stop recommendation would affect road users.

2.7.1 Purpose

The purpose of these observations was to:

- understand the current level of motorist and bicycle rider compliance with stop sign controls at a sample of intersections
- quantify approach speeds of motorists and bicycle riders by their stopping behaviours, and
- measure road crossing times for motorists and bicycle riders by their stopping behaviours.

2.7.2 Measurements

The measurements obtained from the video data is summarised in Table 2.1. As noted in the table, gap acceptance requires an indication of rejected gaps (i.e. occurrences where a road user stops in the presence of conflicting movement). At all sites the number of these observations was very small (less than 10) such that data on gap acceptance is unreliable, and so not presented in this report. Similarly, the interaction severity was very low in almost all cases, and so is not presented.

■ Table 2.1: Rolling stop measurements

Measurement	Mode	Comment
Stop sign compliance	Bicycle riders Motorists	Conditioned on the presence of conflicting movements
Gap acceptance	Bicycle riders Motorists	The very low sample of stopping riders and motorists meant there were very few gap rejection observations.
Interaction severity score	Bicycle riders Motorists	Subjective rating scale
Clearance time	Bicycle riders Motorists	Elapsed time when a reference point on the vehicle enters the roadway to when that reference point leaves the roadway.
Speed	Bicycle riders Motorists	Average speed from 5 m to 3 m from stop line, and from 3 m to stop line

Compliance with the existing stop sign regulation is fairly self-explanatory; it required that the bicycle rider or motorist come to a complete stop at the intersection. Interaction severity was measured on a 1-5 scale as described in Table 2.2.

Clearance times were measured using a fixed reference point on the vehicles. For bicycle riders this was always the point where the front wheel touched the ground. For motorists this was the centre of the front of the numberplate (if the video was positioned facing towards oncoming traffic, as it was in almost all cases) or the centre of the rear numberplate (if the video faced away from traffic, as was the case with the Fagan Road southbound movement). It is noted that this definition does not fully imply a vehicle has "cleared" across the intersection; there will be a small additional time for the rear of a bicycle to leave the intersection, and a marginally longer period of time for a car to do so (note that a bicycle will be around 1.8 m long, compared to >6 m for a car). As such, where the cyclist clearance time in this data is longer than for a motor vehicle the differences will be somewhat overstated.

Speeds were estimated from the video record by marking the road at 3 m and 5 m from the intersection. These locations were used as they are most typically referred to in the engineering guidance, and arbitrary represent "approach" and "near" intersection speeds. The video was recorded at 30 frames per second, and the frame number used to estimate the time between each measurement point. On bicycles the location where the front wheel touched the ground was used as the reference, while on motor vehicles the centre of the front number plate was the reference.

■ Table 2.2: Interaction severity scale

Score	Title	Description
1	No incident	Cyclist does not need to alter course or speed to avoid conflict. The cyclist experiences no apparent stress as a result of the interaction.
2	Minor adjustment required	Cyclist may need to alter course slightly to allow for a comfortable passing distance, or gently brake or alter pedalling rhythm. The situation is unlikely to be perceived by the cyclist as unsafe, but may be perceived as inconvenient. There is unlikely to be any sense of surprise or fright.
3	Major adjustment required	Cyclist may need to significantly alter course or adjust speed to avoid a collision. There is a heightened level of stress, and possibly surprise or fright. However, this adjustment readily avoids a collision.
4	Near collision	A rapid change of course or speed is required by the cyclist or motorist (or both) to avoid imminent collision. A significant degree of fear and fright is likely. The parties may gesture to one another.
5	Collision	There is physical contact between the parties.

2.7.3 Sites

Three sites were chosen on the basis that they (a) were fairly typical examples of stop sign controlled intersections, and (b) had fairly high cyclist demand. The latter was particularly important given the need to observe a sufficiently large sample of observations within a practical period of time. The three sites were:

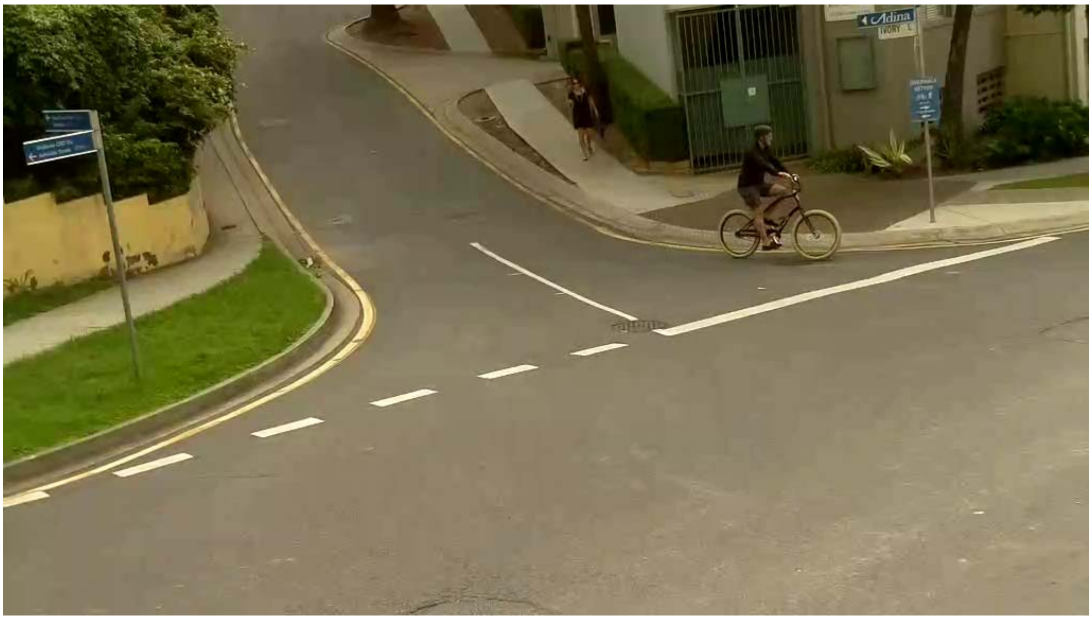
- Ivory Lane / Boundary Street (Fortitude Valley) (Figure 2.3(a))

  - o Only motorists and bicycle riders turning right out of Ivory Lane onto Boundary Street were considered.
  - o The intersection is a T-configuration, with Ivory Lane terminating at Boundary Street with a stop sign control.
  - o Ivory Lane slopes down fairly steeply towards Boundary Street such that rides will approach the intersection at fairly high speed.
  - o Ivory Lane is a cul-de-sac with low traffic volumes, as is Boundary Street, although both have through connections for bicycle riders.
  - o The default urban speed limit of 50 km/h applies to the streets.
  - o The intersection has been subject to onsite police enforcement of the stop sign in the past.
- Feez Street / Yeronga Street (Yeronga) (Figure 2.3(b))
  - o Only motorists and bicycle riders approaching Yeronga Street from Feez Street southbound were considered.
  - o The intersection is a four-arm intersection, with Stevens Street providing a southern continuation of Feez Street slightly offset to the east.
  - o Traffic volumes on all arms are fairly low, particularly the western arm of Yeronga Street which is a cul-de-sac.
  - o Yeronga Street is the major road and movements from the north or south have a stop sign control.
  - o Most rider movements are north-south along Feez Street to Stevens Street.
- Fagan Road / Butterfield Street (Herston) (Figure 2.3(c))
  - o Only motorists and bicycle riders travelling south (from Fagan Road) or north (from Aberleigh Road) were considered.
  - o The intersection is a four-arm intersection with Aberleigh Road providing a southern continuation of Fagan Road.
  - o Road users approaching Butterfield Street from the north along Fagan Road are met with a stop sign, while road users approaching from the south along Aberleigh Road are met with a give way sign.
  - o Traffic volumes are fairly low, particularly Fagan Road which is a cul-de-sac for motorists.
  - o Butterfield Street is the major street, and motorists and bicycle riders approaching from the north or south have a stop sign control.
  - o The default urban speed limit of 50 km/h applies to the streets.
  - o The intersection has been subject to onsite police enforcement of the stop sign in the past.
  - o The sight distance for the southbound movement along Fagan Road is 48 m to the right and 38 m to the left when positioned 3 m back from the intersection with Aberleigh Road. These distances do not meet the MUTCD warrant condition for a stop sign in this speed zone (50 km/h, for which the maximum sight distance is 30 m).

- The stop sign control at Fagan Road replaced a give way control in 2009 as a result of concerns raised by the local community about near misses at the intersection. The give way sign heading northbound at Aberleigh Road has not been changed.
- Although the site does not meet the MUTCD sight distance conditions the road authority installed the stop sign on the basis that traffic speeds on Butterfield Street exceed the speed limit.

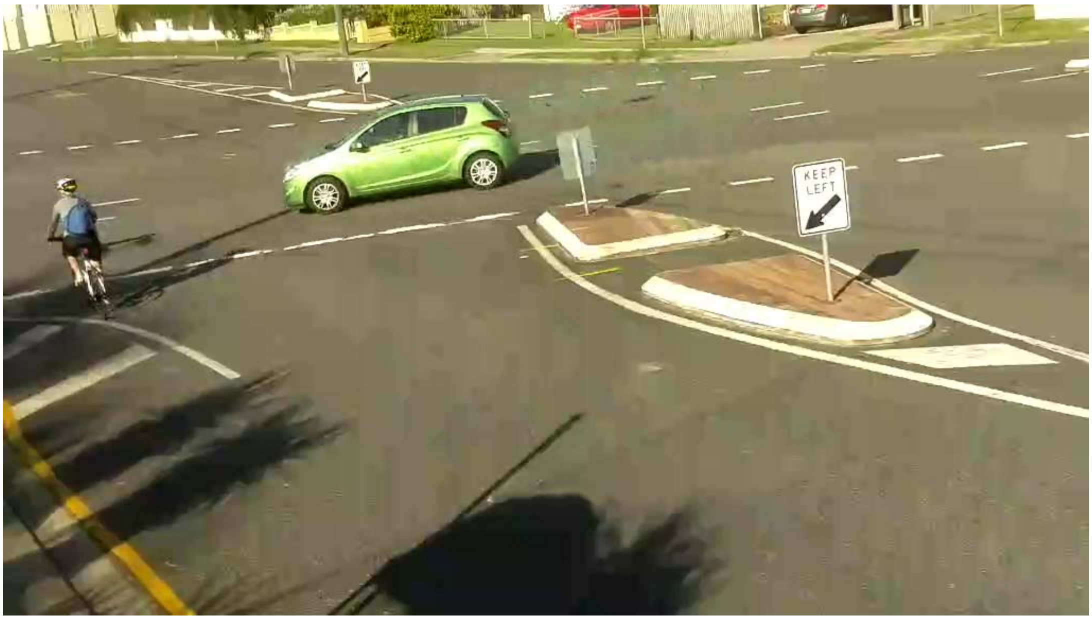
- Figure 2.3: Rolling stop sites

- (a) Ivory Lane / Boundary Street (Fortitude Valley)



- (b) Feez Street / Yeronga Street

- (c) Fagan Road / Butterfield Street



2.7.4 Method

Video cameras were positioned at the selected sites and recorded continuously from 6 am to 7 pm across at least four days. The days of week on which the video was obtained varied by site, and is provided in Table 2.3. In most instances only a subset of the video was processed in order to achieve a reasonable sample size; in most instances the benefit of additional sample would be negligible and would have no material impact on the results.

■ Table 2.3: Rolling stop site observation periods

	Site		
	Ivory Ln	**Feez St**	**Fagan Rd**
Recording period	3 – 7 pm Tue 1 Apr 6 am – 7 pm Wed 2 Apr 6 am – 7 pm Thu 3 Apr 6 am – 7 pm Fri 4 Apr 6 am – 7 pm Sat 5 Apr 6 am – 2 pm Sun 6 Apr	3 - 7 pm Tue 1 Apr 6 am – 7 pm Wed 2 Apr 6 am – 7 pm Thu 3 Apr 6 am – 7 pm Fri 4 Apr 6 am – 7 pm Sat 5 Apr 6 am – 1 pm Sun 6 Apr	2 – 7 pm Mon 7 Apr 6 am – 7 pm Tue 8 Apr 6 am – 7 pm Wed 9 Apr 6 am – 7 pm Thu 10 Apr 6 am – 3 pm Fri 11 Apr
Processed period	3 – 7 pm Tue 1 Apr 6 – 10 am Wed 2 Apr 6 – 10 am Thu 3 Apr 6 – 10 am Fri 4 Apr 6 – 10 am Sat 5 Apr 6 – 2 pm Sun 6 Apr	3 – 7 pm Tue 1 Apr 6 am – 7 pm Wed 2 Apr 6 am – 7 pm Wed 2 Apr	2 – 7 pm Mon 7 Apr 6 am – 3 pm Tue 8 Apr 3 – 7 pm Tue 8 Apr * 6 am – 4 pm Wed 9 Apr *
Comment	School term finished Fri 4 Apr	School term finished Fri 4 Apr	

* Bicycles only

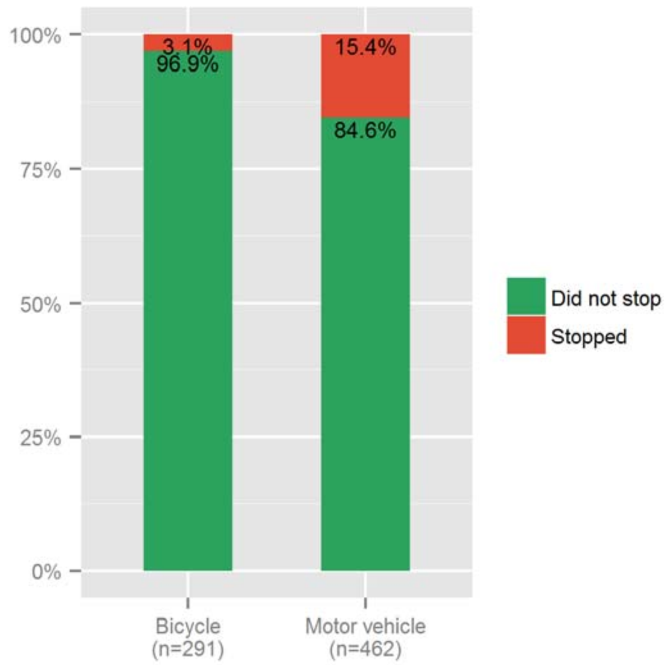
2.8 Fieldwork results

2.8.1 Ivory Lane

Compliance

A total of 291 cyclist movements and 462 motorist movements were observed at the Ivory Lane site. Only 3% of bicycle riders and 15% of motorists stopped completely at the intersection (Figure 2.4). The difference in compliance between the modes is statistically significant (χ^2 = 27.1, p<0.000).

There was no measurable difference in compliance between male and female riders, due in part to the low number of stopping observations (n=11) and the low number of female cyclists (n=27).



■ Figure 2.4: Stopping compliance at Ivory Lane

Interactions

There were very few instances where a bicycle rider or motorist turning right out of Ivory Lane interacted with a motorist on Boundary Street. In only 6 of 291 (2.1%) bicycle rider observations was a motorist observed in either direction along Boundary Street. Similarly, motorists turning onto Boundary Street only encountered other motorists on 21 occasions (4.5% of observations). The difference in the likelihood of encountering a conflicting movement between the modes is attributable to the time of day at which most bicycle riders were observed; most were observed during the AM peak period when motor vehicle traffic on Boundary Street was very low. By contrast, motor vehicle demand was more evenly distributed across the day.

Given the small number of interactions, it is difficult to determine how significant interactions were in motivating stopping compliance. In one of six observations where a bicycle rider stopped there was a motor vehicle on the main road, compared with 8 of 285 observations where the rider did not stop. For motorists the number of observations are somewhat more robust (21 motorists experienced an interaction); on 81% of occasions where a motorist encountered another motorist on Boundary Street they stopped, compared with 12% of occasions when there was no conflicting movement along Boundary Street.

It was observed that many pedestrians used Ivory Lane in preference to the footpath, usually runners. These pedestrians were far more frequent than motorists such that a rider was more likely to encounter a pedestrian than a motorist.

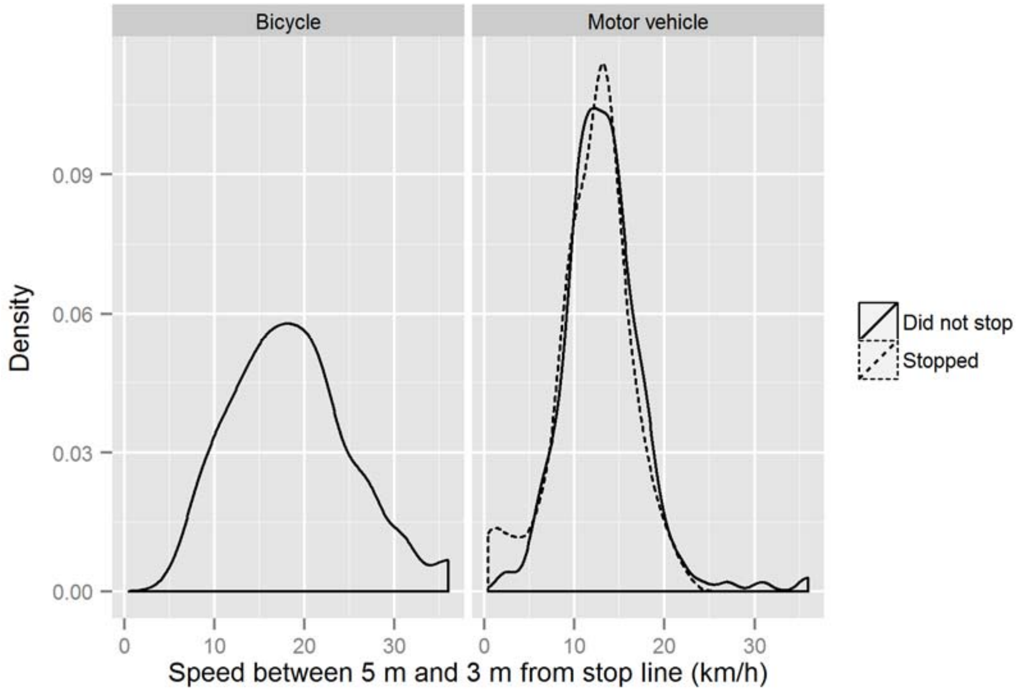
The number of overall interactions was low, and no interaction was observed that could be interpreted as a "near miss" or requiring a rapid change of direction or speed by either road user.

Approach speeds

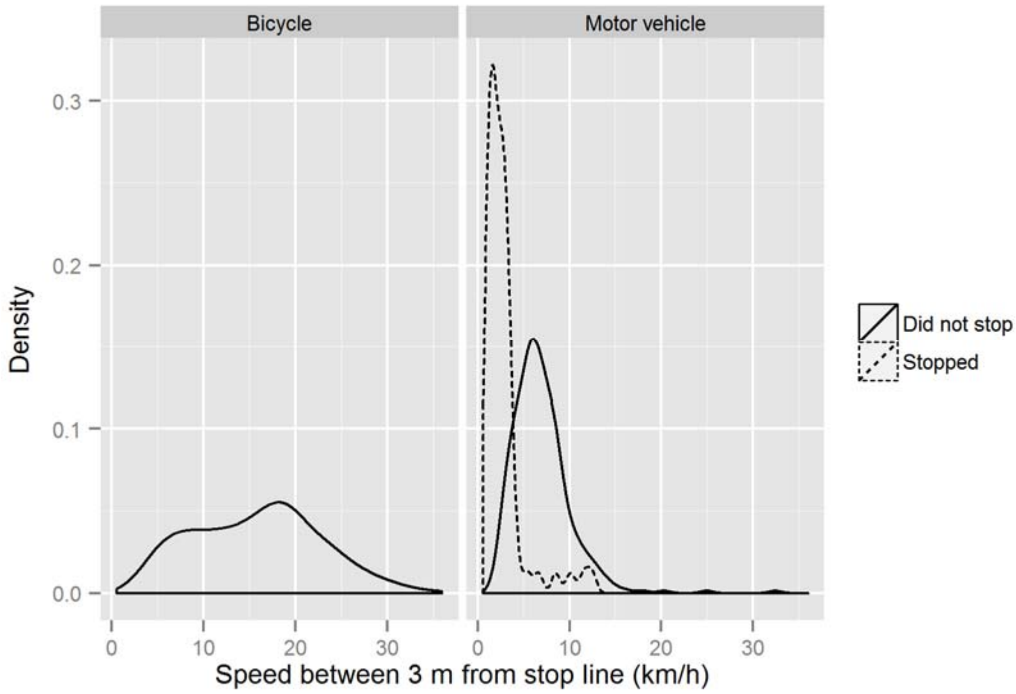
The approach speed distributions measured between 5 and 3 m from the intersection are shown in Figure 2.5. The number of cyclist stopping observations was very low (9) and so are not presented. The speed distributions of motorists who stop, and do not stop, are very similar at this distant timing point. By comparison, at the near timing point from 3 m to the stop line the speeds of stopping road users are much lower (Figure 2.6).

The average rider speed was 14.1 km/h between 5 and 3 m from the intersection among those who stopped (n=9) and 18.6 km/h for those who did not stop (n=282) (Figure 2.7). These speeds reduced to 5.1 km/h and 15.8 km/h within 3 m of the intersection for those who did not and did stop, respectively. Motorist speeds were consistently slower on average, as was the 85th percentile speeds, than for bicycle riders. However, the differences were not statistically significant for those who stopped. [10]

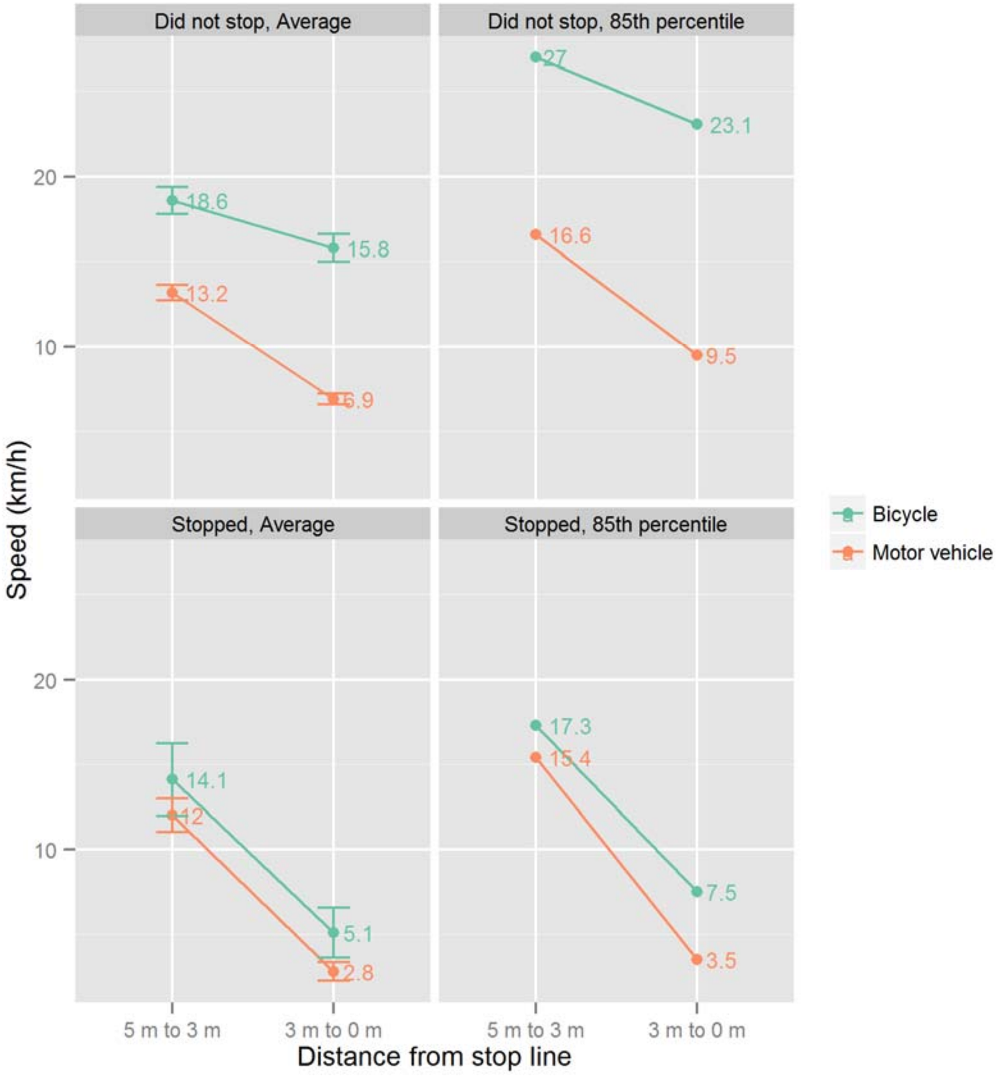
[10] A two-way ANOVA as used to compare speeds across modes. Tukey post-hoc comparisons of the groups reported statistically insignificant differences in mean speeds at the distant timing point between modes (M=2.1, 95% CI: -7.1 – 2.7 km/h. p=0.67) and at the near timing point (M=2.3 km/h, 95% CI: 6.8 – 2.2 km/h, p=0.53).



■ Figure 2.5: Approach speed distribution from 5 m to 3 m from the stop line



■ Figure 2.6: Approach speed distribution from 3 m to the stop line

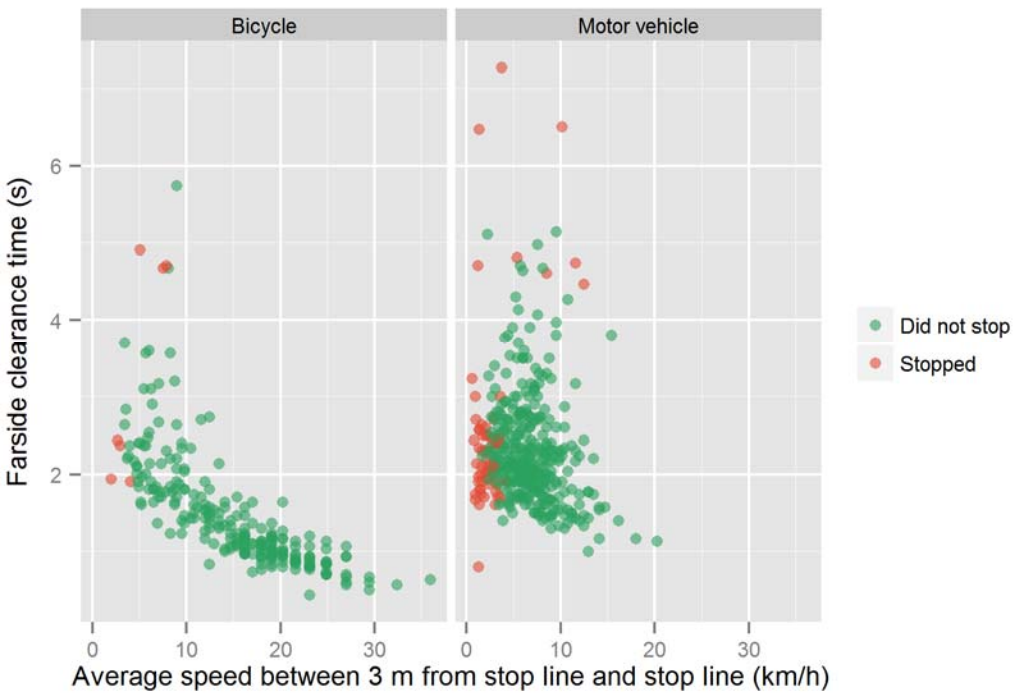


- Figure 2.7: Average and 85th percentile speeds for bicycle riders and motorists by stopping compliance

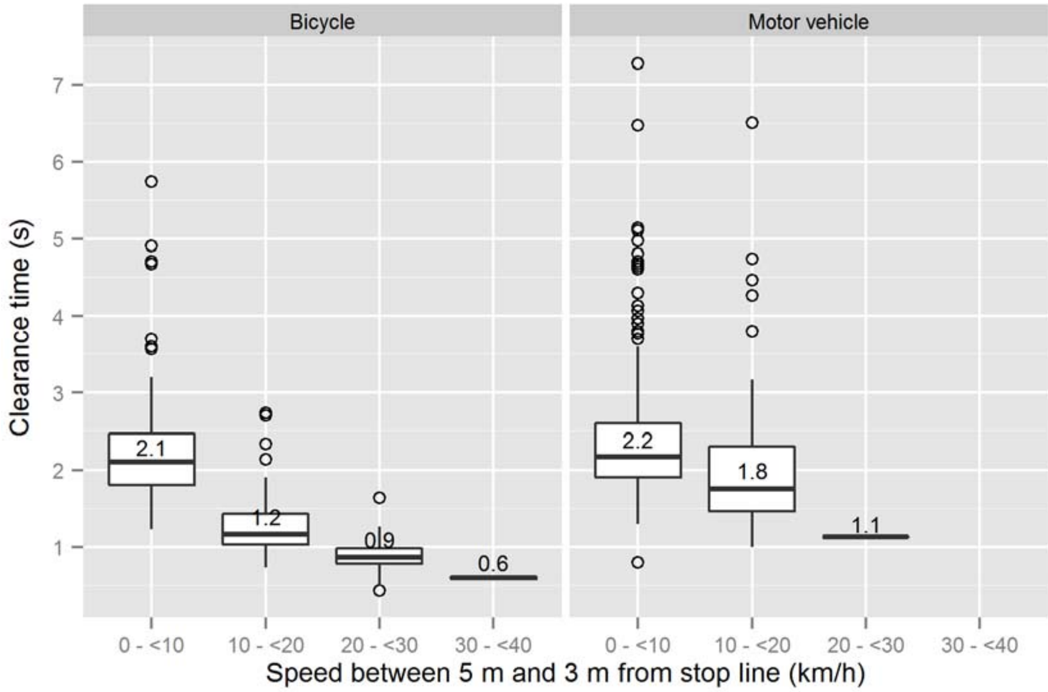
Clearance times

The elapsed time from when the motorist or bicycle rider entered Boundary Street and crossed the centreline to the farside of the street is illustrated in Figure 2.8 as a function of the measured speed approaching the intersection. This comparison suggests the following:

- There is no relationship between intersection approach speed and clearance times for motorists.
- There is a relationship between intersection approach speed and clearance times for bicycle riders; as riders approach at a slower speed so the clearance times increase. This is best illustrated by the boxplot in Figure 2.9, which shows the median clearance time increases from 0.9 seconds for those who approach between 20 and 30 km/h to 1.2 seconds for approach speeds between 10 and 20 km/h and to 2.1 seconds for approach speeds less than 10 km/h.
- Motorist clearance times are generally higher than for bicycle riders; the median clearance time for motorists was 2.2 seconds compared with 1.2 seconds for bicycle riders. This difference is statistically significant (χ^2 = 160.7, p<0.00). Lower approach speeds seem to contribute, in part, to this longer clearance time.
- There are insufficient stopping observations to draw clear conclusions about the effect stop sign compliance has on clearance time. However, the clear effect of approach speed on rider clearance time is strongly suggestive that riders will take longer to clear the intersection if they comply with the stop sign (as would be expected).



■ Figure 2.8: Relationship between approach speed and clearance time



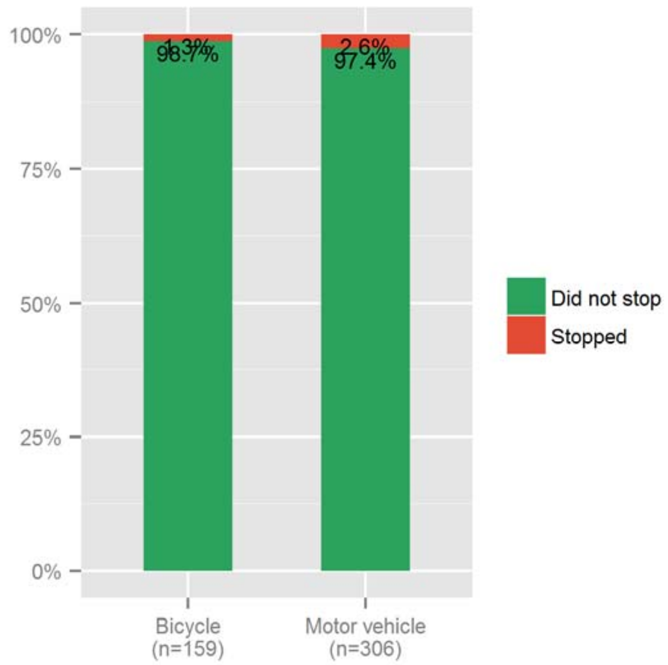
■ Figure 2.9: Clearance times by approach speed bins and mode

2.8.2 Feez Street

Compliance

A total of 199 cyclist movements and 306 motorist movements were observed at the Feez Street site. Only 2% of bicycle riders and 3% of motorists stopped completely at the intersection (Figure 2.10). The difference in compliance between the modes is not statistically significant (χ^2 = 0.7, p=0.530).

There was no measurable difference in compliance between male and female cyclists, due to both the low number of stopping observations (n=3) and the low number of female cyclists (n=3, none of whom stopped).



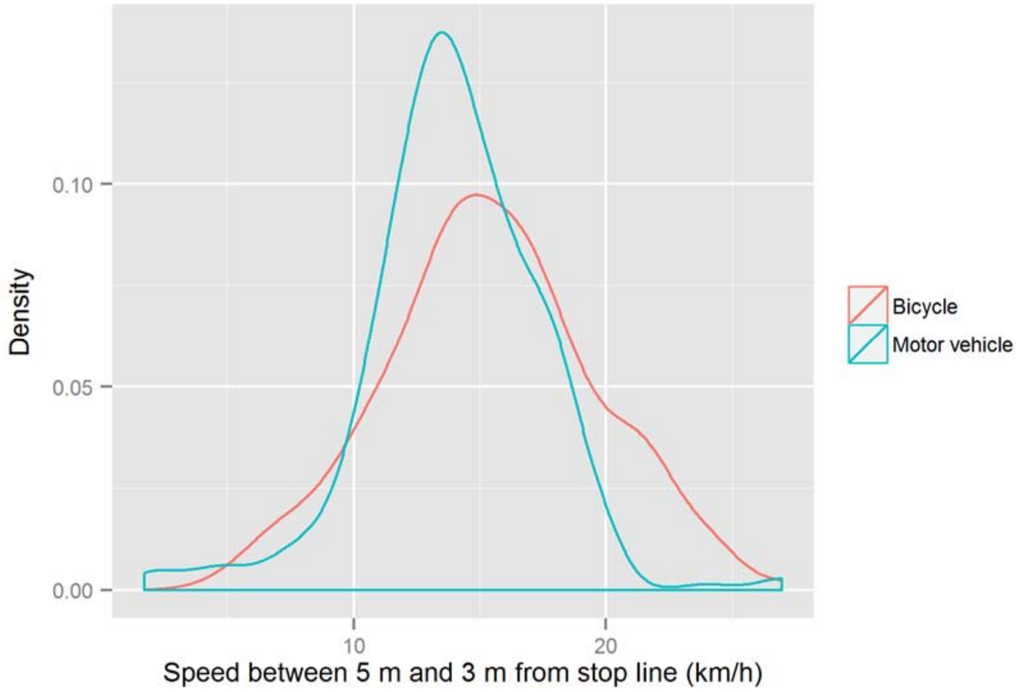
■ Figure 2.10: Stopping compliance at Feez Street

Interactions

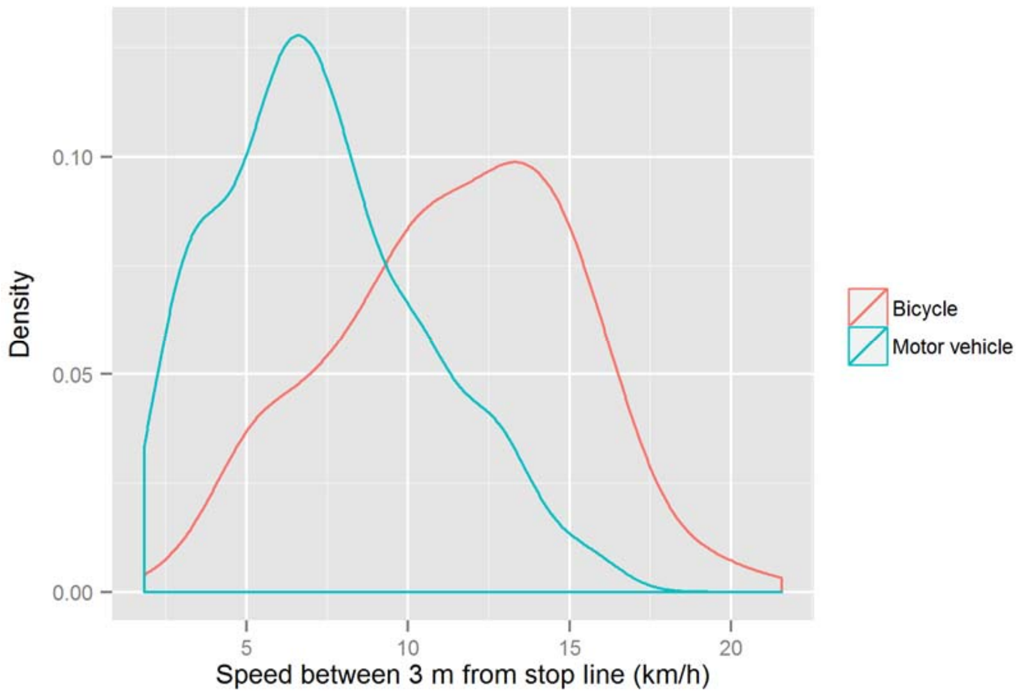
There were no instances where a bicycle rider or motorist heading south out of Feez Street interacted with a motorist on Yeronga Street. Overall, motorist volumes on Yeronga Street were very low (and never occurred at the same time as a motorist or rider approaching from Feez Street).

Approach speeds

The approach speed distributions measured between 5 and 3 m from the intersection are shown in Figure 2.11 for bicycle riders and motorists. The median cyclist speed is 15.4 km/h compared with 13.5 km/h for motorists; this difference is statistically significant (M=1.9 km/h, Z=3.92, p<0.00). Between 3 m and the stop line the slower speeds of motorists is even more pronounced (Figure 2.12). The median speed of motorists is 6.9 km/h compared to 11.6 km/h for bicycle riders.

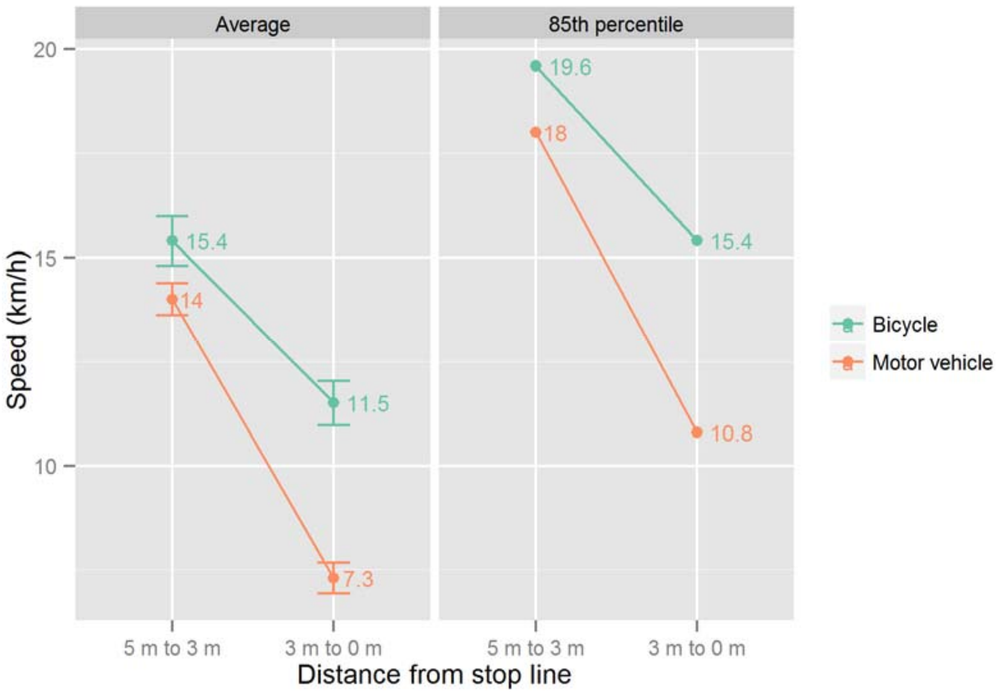


- Figure 2.11: Approach speed distribution from 5 m to 3 m from the stop line (non-stopping observations only)



- Figure 2.12: Approach speed distribution from 3 m to the stop line (non-stopping observations only)

The average rider speed was 15.4 km/h between 5 and 3 m and 14.0 km/h for motorists (Figure 2.13). These average speeds reduced to 11.5 km/h and 7.3 km/h within 3 m of the intersection for bicycle riders and motorists, respectively. Motorist speeds were consistently slower on average, as was the 85th percentile speeds, than for bicycle riders.



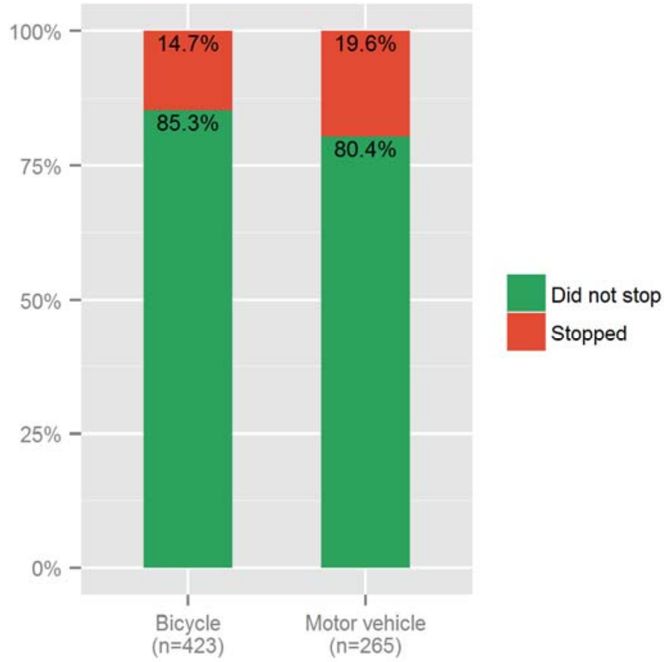
■ Figure 2.13: Average and 85th percentile speeds for bicycle riders and motorists

2.8.3 Fagan Road

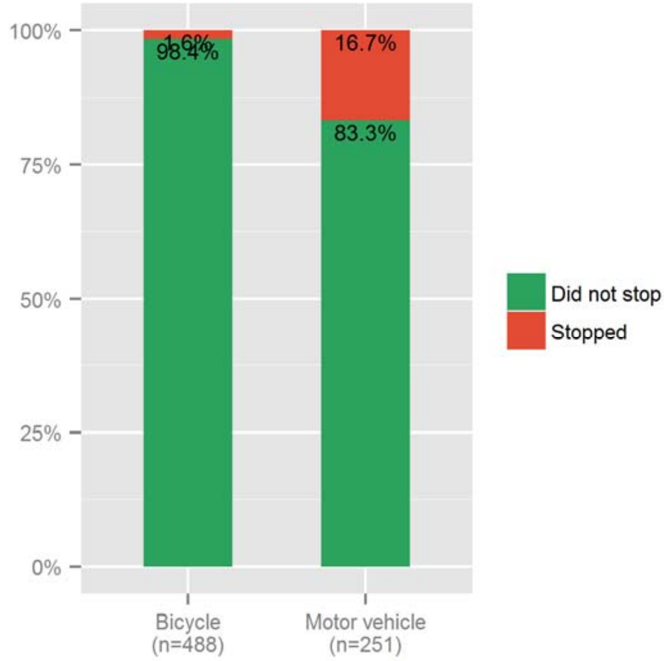
The video position at Fagan Road allowed for stopping frequency in both the northbound and southbound directions to be determined, and for some level of comparison between stop signs (Fagan Road southbound) and give way signs (Aberleigh Road northbound). Intersection approach speeds were measured only in the southbound direction, as was gap acceptance. In the northbound direction crossing times for motorists and riders crossing straight from Aberleigh Road to Fagan Road were also measured (but not approach speeds or gap acceptance).

Stopping behaviours

The compliance with the stop sign in the southbound direction by both motorists and bicycle riders was poor; 85.3% of bicycle riders and 80.4% of motorists did not stop (Figure 2.14). The difference in compliance between modes was not statistically significant at the 5% level (χ^2 = 2.56, p=0.109). In the northbound direction road users are not required to stop given the presence of the give way sign; 98.4% of riders did not stop and 83.3% did not stop. This difference for cyclist stopping behaviour was statistically significant (χ^2 = 57.49, p<0.000) compared with the southbound direction of travel. There was no detectable difference in stopping behaviour between male and female riders.



■ Figure 2.14: Fagan Road (southbound) compliance



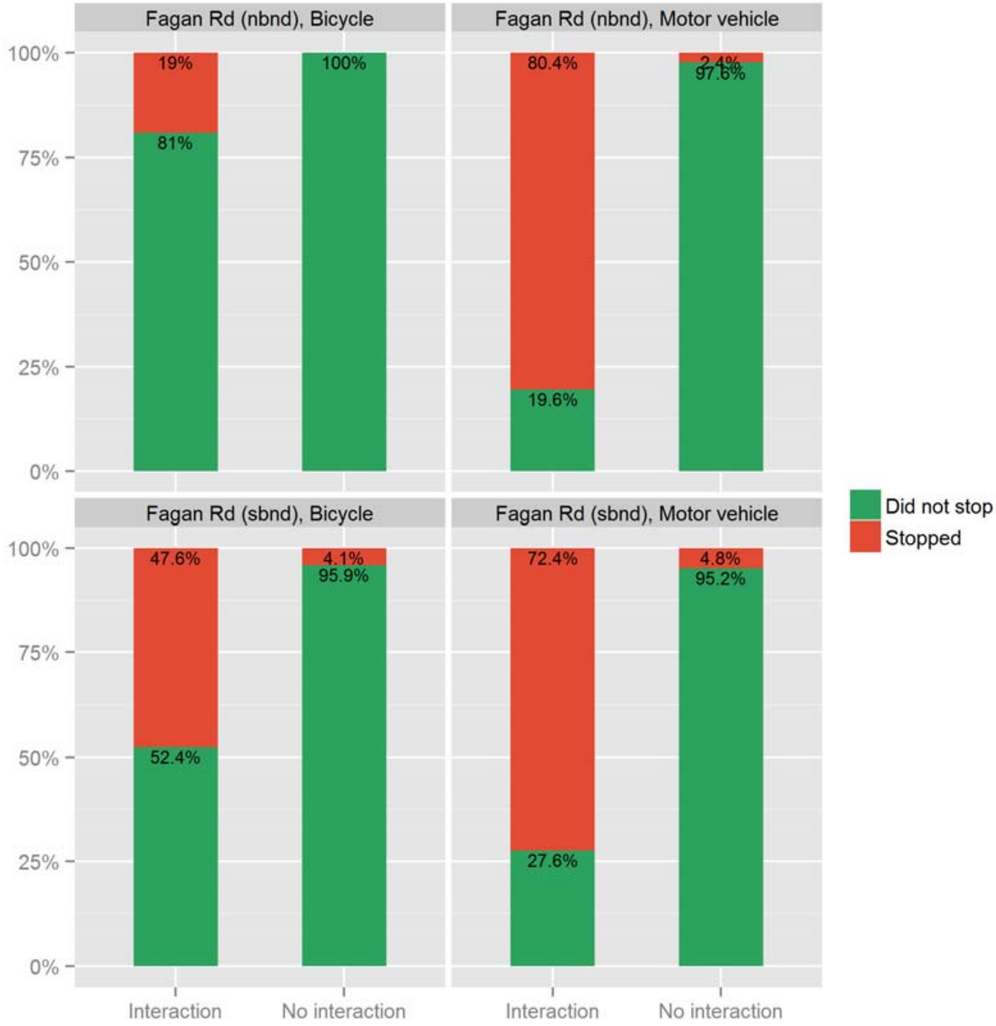
■ Figure 2.15: Fagan Road (northbound) stopping frequency (this arm is give way sign controlled)

Interactions

Motorists and bicycle riders approaching Butterfield Street did not have to interact with road users on the main road in around 80% of cases (Table 2.4). Stopping compliance in the southbound direction is correlated with the presence of road users on the main road; when a conflicting road user is present between 19% (northbound) and 48% (southbound) of riders stop, compared to less than 5% when there is no conflicting road user (Figure 2.16). For motorists this difference is very similar; around three quarters of motorists stop when there is a conflicting road user present compared with less than 5% when there is not. All differences in proportions between modes are significantly significant at the 5% level aside from the proportion who stopped when there was no interaction in the southbound direction of travel.

■ Table 2.4: Interactions and stopping compliance by direction of travel

		Interaction with road user on Butterfield St					
Direction of travel	**Stopping behaviour**	**Interaction**		**No interaction**		**Total**	
		n	**%**	**n**	**%**	**n**	**%**
Bicycle riders							
Northbound	Stopped	8	19%	0	0%	8	2%
	Did not stop	34	81%	446	100%	480	98%
	Subtotal	*42*	*100%*	*446*	*100%*	*488*	*100%*
Southbound	Stopped	49	48%	13	4%	62	15%
	Did not stop	54	52%	307	96%	361	85%
	Subtotal	*103*	*100%*	*320*	*100%*	*423*	*100%*
	Total	*145*	*16%*	*766*	*84%*	*911*	*100%*
Motorists							
Northbound	Stopped	37	80%	5	2%	42	13%
	Did not stop	9	20%	200	98%	290	87%
	Subtotal	*46*	*100%*	*205*	*100%*	*332*	*100%*
Southbound	Stopped	42	72%	10	5%	52	20%
	Did not stop	16	28%	197	95%	213	80%
	Subtotal	*58*	*100%*	*207*	*100%*	*265*	*100%*
	Total	*104*	*20%*	*412*	*80%*	*516*	*100%*



■ Figure 2.16: Stopping behaviour by interaction with road user on main road

In none of the 145 bicycle rider and 104 motorist observations where there was an interaction with a conflicting motorist along Butterfield Street was the conflict rated as requiring anything more than minor adjustment. The typical behaviour appeared to be for a rider to slow approaching the intersection, to scan for conflicting movements and then to either proceed across or ride slowly so as to allow the conflicting movement to pass before proceeding. As conflicting movements generally consisted of only one vehicle the delay incurred was sufficiently small that this slowing behaviour was sufficient for most riders to avoid having to completely stop (and hence lose their balance).

Approach speeds

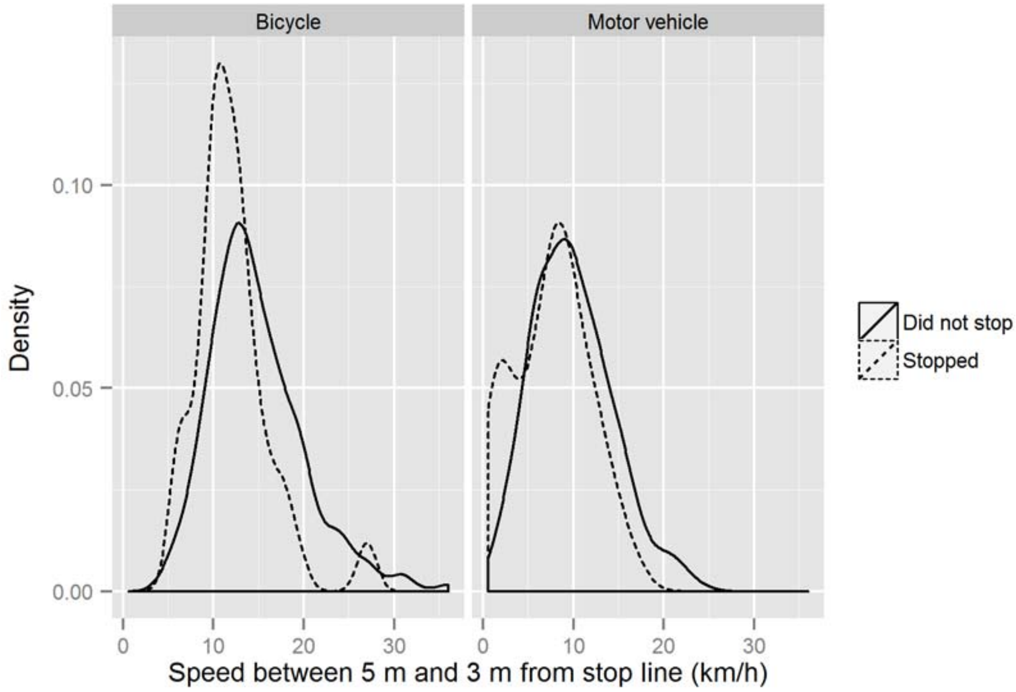
The approach speed distributions measured between 5 and 3 m from the intersection are shown in Figure 2.17 for bicycle riders and motorists travelling in the southbound direction. The median cyclist speed is 13.5 km/h compared with 9.8 km/h for motorists; this difference is statistically significant (M=4.6 km/h, Z=11.61, $p<0.00$). Between 3 m and the stop line the slower speeds of motorists is even more pronounced (Figure 2.12). The median speed of bicycle riders is 9.8 km/h compared to 4.6 km/h for motorists. Again, this difference is statistically significant (M=5.2 km/h, Z=14.63, p<0.00).

Approach speeds are lower for riders and motorists who proceed to stop at the intersection. Bicycle riders who do not stop have a median speed between 5 and 3 m from the intersection of 13.5 m/s compared with 11.4 m/s for those who do stop, a significant difference (M=2.4 km/h, Z=4.26, p<0.00). Similarly, motorists who stopped had a lower median approach speed (8.0 km/h) than those who did not (9.4 km/h). Again, this difference was statistically significant (M=2.2 km/h, Z=3.00, p<0.00).

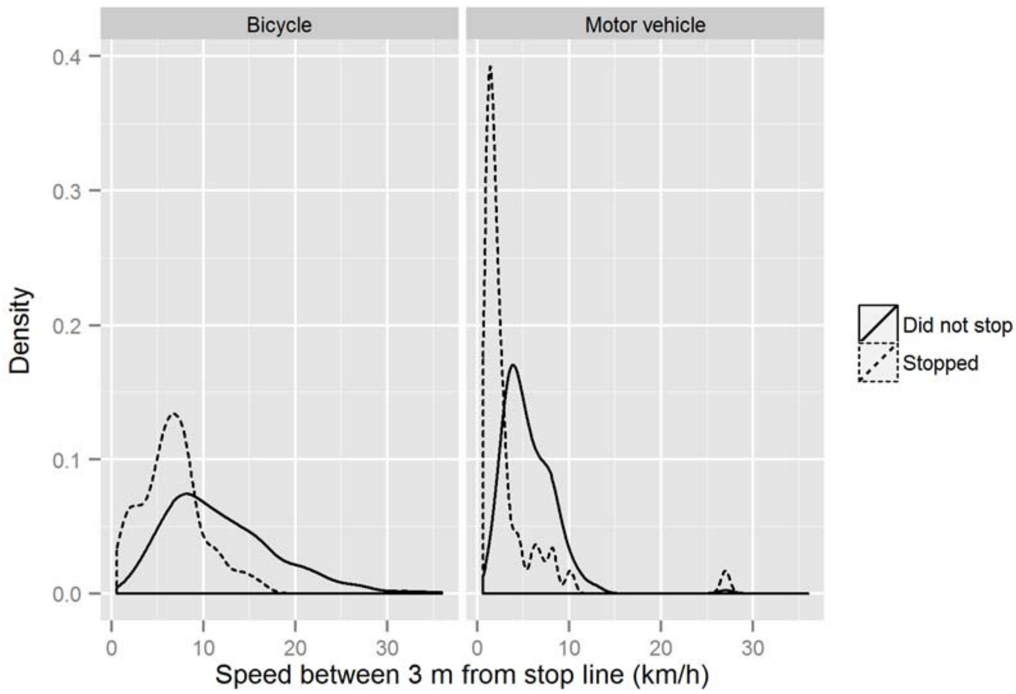
The differences in the average and 85th percentile speeds between the modes and those who stopped and those who did not are shown in Figure 2.19. The three key findings from this data are:

- bicycle riders approach the intersection at around 4-5 km/h faster than motorists,
- bicycle riders and motorists who stop approach the intersection slower than those who do not by around 2 km/h (between 5 and 3 m from the intersection), and
- even when the road user does not stop, their speeds tend to decrease approaching the intersection – by around 2-3 km/h for bicycle riders and by 4-5 km/h for motorists.

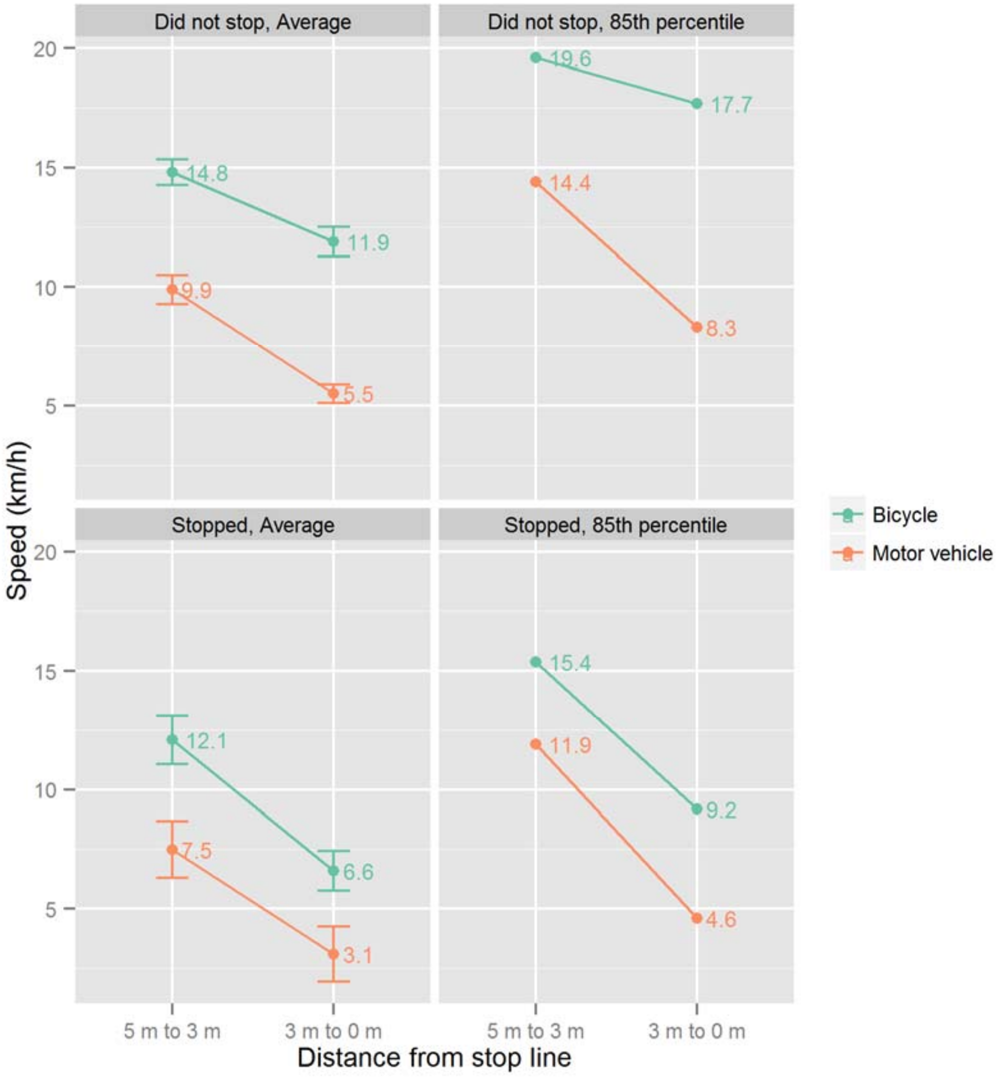
One interpretation of these results is that road users are making the decision whether they will stop more than 5 m back from the intersection.



■ Figure 2.17: Approach speed distribution from 5 m to 3 m from the stop line (southbound)



■ Figure 2.18: Approach speed distribution from 3 m to the stop line (southbound)



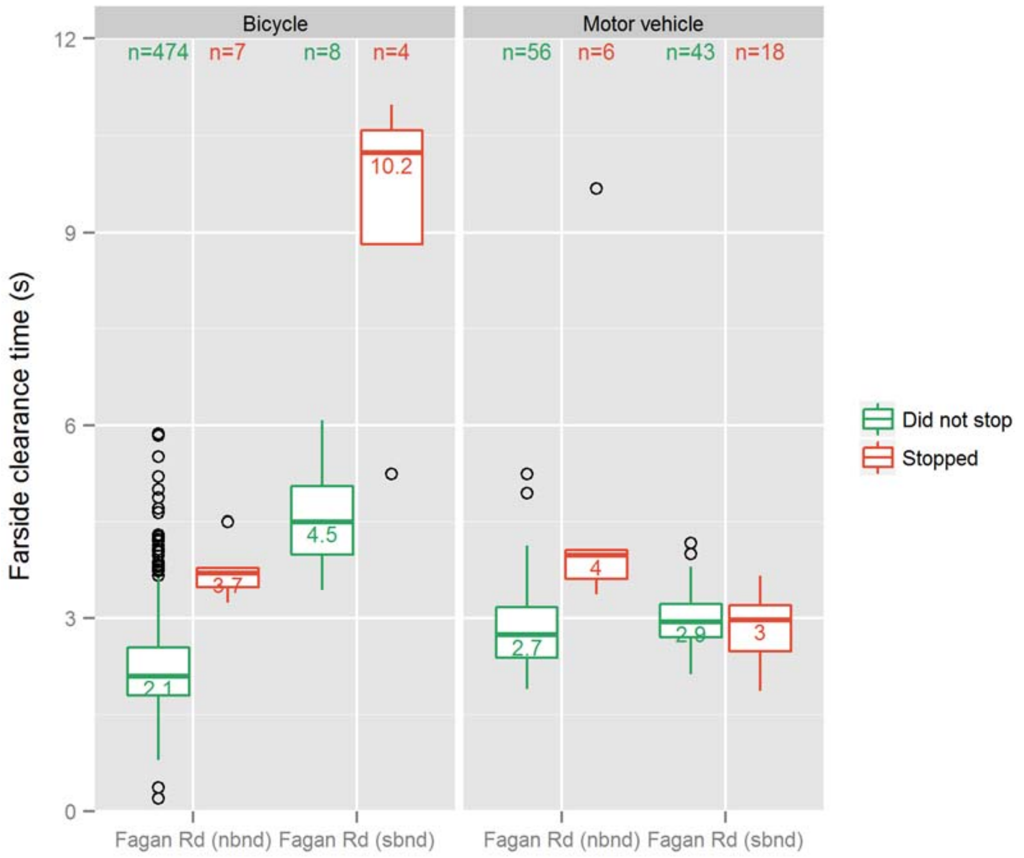
- Figure 2.19: Average and 85th percentile speeds for bicycle riders and motorists by stopping behaviour

Clearance times

The elapsed time from when a motorist or bicycle rider travelling straight ahead entered Butterfield Street and crossed to the farside of the street is illustrated in Figure 2.20 by mode, direction of travel and stopping condition. In interpreting this data the small sample sizes for bicycle riders and motorists stopping and travelling straight ahead should be noted, as well as the small number of observations of bicycle riders travelling southbound.[11] This comparison suggests the following:

[11] The camera position was such that bicycle riders or motorists travelling southbound towards Aberleigh Street could not be seen at the farside of the intersection if they tracked towards the left of the carriageway. This meant that the clearance times of most bicycle riders travelling in this direction could not be measured.

- Bicycle riders who stop take around twice the time to clear across Butterfield Street as those who do not; in the northbound direction (where sample sizes are largest) the median crossing time is 2.1 seconds for those who do not stop and 3.7 seconds for those who do (M=1.6 s, Z=3.97, p<0.00). Even in the southbound direction, where sample sizes are small, the observed effect is large enough to suggest the difference is significant (M=5.4 s, Z=2.55, p<0.00).
- For motorists the differences in clearance times between those who stop, and those who do not, are weaker. In the northbound direction the difference is statistically significant (M=1.2 s, Z=3.43, p<0.00) but not in the southbound direction (M=0.1 s, Z=0.41, p=0.68). This is not an unexpected finding, given the comparative ease with which a motorist can start from stop compared to a bicycle rider.
- Clearance times are fairly similar between bicycle riders and motorists in the northbound direction. Among those who did not stop motorists took a median of 2.7 seconds to cross compared to 2.1 seconds for bicycle riders. This difference is statistically significant at the 5% level (M=0.6 s, Z=6.36, p<0.00).



■ Figure 2.20: Farside clearance time by mode, direction of travel and stopping condition

2.9 Discussion

All three sites shared the following similarities in road user behaviour:

- non-compliance with the stop sign was very high for both motorists and bicycle riders (above 80% for motorists and more than 95% for bicycle riders),
- the presence of a stop sign (Fagan Road) does not appear to have significantly altered the likelihood a rider will stop compared to a give way sign (Aberleigh Road) once interactions with vehicles on the main road are controlled for,
- there were few interactions between road users on the minor road and road users on the major road (as the major road was comparatively quiet),
- compliance appears to be a function primarily of the presence of conflicting road user movements on the major road (which was rare at these sites),
- bicycle riders approach the intersections at a higher speed than motorists,
- there was a strong relationship between approach speed and clearance time across the intersection for bicycle riders, but not for motorists (observed at Ivory Lane), and
- bicycle riders and motorists who stopped took 50-100% longer to clear across the intersection than those who did not.

Our view as to the motivations for these behaviours, and their possible implications for safety and road design, are discussed next.

2.9.1 Effect of sign control on compliance

Ideally, in order to compare the change in compliance between a give way and stop sign control a before-after evaluation would occur at one or (better) multiple sites. However, tentative conclusions can be drawn from a cross-sectional comparison of stopping behaviour between southbound movements at Fagan Road (stop sign) and northbound movements along Aberleigh Road (give way sign). Clearly, there are significant confounding factors in making these comparisons, not least being the different sight lines and intersection geometries and the times of day at which road users are most likely to be present.[12]

Overall, the likelihood of riders stopping in the southbound direction (14.7%, Figure 2.14) is greater than in the northbound direction (1.6%, Figure 2.15). However, the difference in stopping behaviour appears to be largely motivated by the likelihood of encountering a conflicting movement along Butterfield Street. As shown in Table 2.4 around 9% of northbound riders encountered a road user on Butterfield Street compared to 24% in the southbound direction. When a conflicting movement was not present almost all riders heading southbound (96%) and all of those heading northbound did not stop. On the other hand, if the stop sign is having an effect on rider behaviour it may be in instances when an interaction is present; 19% of riders stopped heading northbound in such situations and 48% heading southbound. Alternative explanations are also possible, such as the direction of travel of the conflicting movement – if it is on the nearside of the intersection the rider is

[12] Riders will be far more prevalent heading southbound in the AM and northbound in the PM period.

(presumably) more likely to stop than if they are on the farside of the intersection. Irrespective, further investigation of this behaviour may be warranted to better understand what effect sign control has on rider stopping behaviour.

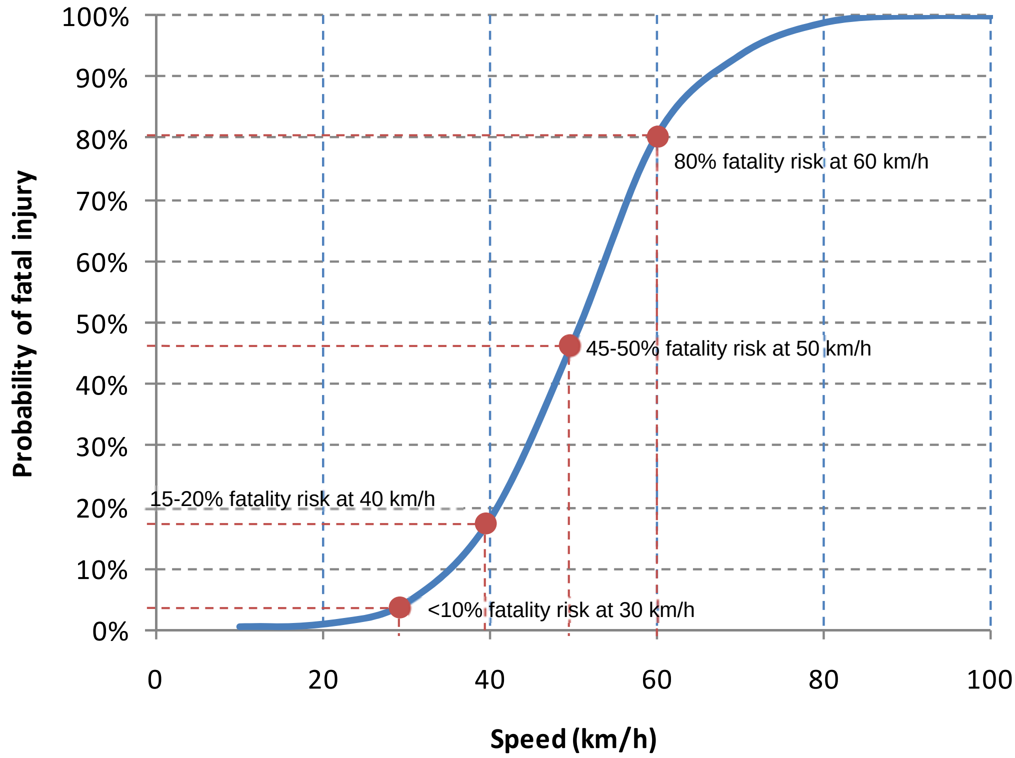
2.9.2 Compliance and safety

The compliance with the stop sign by both modes is very low, and is consistent with observational studies conducted elsewhere across a wide range of road types and locations (Section 2.6.2). It is then appropriate to ask whether (a) this is a problem, and (b) if so, what ought to be done about it.

Consider first whether non-compliance is having an adverse impact on road safety and mobility (these being two of the primary goals of road management). As noted in the literature review, there is incomplete and conflicting evidence on the relative safety of stop sign and give way sign controlled intersections. Furthermore, the practice of using sight distance as a criteria for determining when a stop sign is required, although intuitively reasonable, appears to have little empirical support. On this basis, there does not appear to be strong research evidence to support the hypothesis that this non-compliance is a problem.

Secondly, the three intersections in this study have a negligible crash history despite the observed non-compliance. However, this assessment is based on police recorded crash statistics. Such a dataset will very significantly under-report minor crashes. These minor crashes which involve only minor injuries or minor property damage are likely to make up the vast majority of crashes at these intersections given that they are low speed environments. Nonetheless, if these intersections had a particularly severe crash history we would expect there to be some evidence in the crash statistics. However, crashes are infrequent events and even if these sites had a comparatively high crash risk we may not detect this within the crash statistics as crashes would likely remain infrequent. This is particularly true given the low traffic volumes and very low likelihood of road users on the minor road encountering conflicting traffic on the major road.

Thirdly, the present study did not observe any physical collisions between road users, nor any interactions which could reasonably be considered as “near misses”. Indeed, in the vast majority of cases the motorists and bicycle riders emerging from the minor street were able to proceed across the major street without interacting with any vehicles on the major street. This is not surprising; the “major” streets at these intersections are all local streets with low volumes. Stated another way: the *likelihood* of an emerging road user conflicting with a motorist on the major street is low and the *consequences* of an interaction seem low given the low speed environment. This low speed environment significantly reduces the risk of incurring a serious injury, but also enables a more negotiated road environment where road users can interact and negotiate priority through visual cues (such as eye contact, nodding of heads or similar gestures). The likelihood of unprotected road users (pedestrians, bicycle riders) incurring a fatal injury in these low speed environments is minimal, as illustrated in Figure 2.21 based on numerous studies summarised in Richards (2010).



■ Figure 2.21: Relationship between motor vehicle speed and pedestrian fatality risk

However, we would caveat this commentary around speed and the consequences of a collision by noting the concerns expressed to Brisbane City Council by residents of motorist speeds on Butterfield Street at the intersection with Fagan Road. As noted in Figure 2.21, if the motorists on Butterfield Street comply with the posted speed limit of 50 km/h there is still a 45-50% chance of a collision resulting in a fatality. If, as has been suggested, motorists are exceeding the speed limit then the fatality risk is elevated. Assuming motorists are indeed travelling at these higher speeds there is a compelling safety case to introduce traffic calming as a means of reducing these speeds to levels more consistent with the local street environment. There is unlikely to be any mobility benefit to motorists in travelling at excessive speeds on this local road network, as travel times will be dictated by intersection delays rather than mid-block speeds. As such, the cost-benefit balance is clearly towards ensuring safe and equitable speeds for all road users.

Finally, consider the importance of exposure time in the intersection. It seems reasonable to argue that the less time a road user can spend crossing an intersection the safer they will be (assuming a road user has first appropriately looked for safe gaps in traffic). The fieldwork observations in this study suggest (unsurprisingly) that motorists and particularly bicycle riders who do not stop cross the roadway in around half the time of those who do. Furthermore, but somewhat surprisingly, bicycle riders who do not stop cross marginally faster than motorists.[13] One plausible explanation for this finding is the differences in the approach speeds; bicycle riders were observed to consistently approach the intersections at 3-5 km/h faster than motorists. Whether this increased exposure time has an effect on safety outcomes is much harder to determine. On one hand it could be argued the exposure time is largely irrelevant, and what is important is that the road user allocates sufficient time to look for conflicting traffic – and that stopping assists in doing this. On the other hand, it may be argued this act of stopping is unrelated to the judgement of safe gaps and may be counterproductive if the act of stopping and starting detracts from the primary objective of scanning for traffic. In our view this latter issue is more safety critical than exposure time *per se*. However, further research (ideally in a controlled environment of a driver simulator) would be required to better understand how motorists scan for conflicting traffic at intersections.

2.9.3 Mobility

It appears road users are disobeying the stop sign in order to maximise their mobility (by minimising their intersection delay) and perceive no loss of safety in doing so. Enforcing the stop sign compliance would be expected to have (minor) negative consequences for both motorists and road users by increasing travel times and, in the case of bicycle riders, requiring additional energy to be expended in starting from stationary.

2.9.4 Relative importance of stopping versus looking

There is evidence from US that in the majority of stop sign controlled intersection crashes most motorists claimed to have stopped first (Retting, Weinstein, and Solomon 2003; Stokes et al. 2000).[14] This suggests the issue is not with stopping compliance *per se* but rather a failure to correctly assess the presence of a gap in conflicting traffic. Intuitively it seems reasonable that the action of stopping is not what really matters. However, if stopping allows for road users to properly scan for conflicting traffic and to safely assess gaps in traffic then it is an *indicator* of improved safety outcomes. Given that the vast majority of motorists and bicycle riders did not stop at the observed sites, and there do not appear to be obvious safety repercussions for not having done so, we would err towards the notion that stopping itself is not a necessary prerequisite for adequate looking. However, stopping clearly can do no harm to the prospects of adequate scanning. What does hold some merit in our view though is the implications this act of stopping have on a riders' ability to clear across an intersection. The observational data clearly illustrates an increase in crossing time for riders who stop, usually around a doubling compared to those who give way. Reducing the crossing time will presumably have at least minor positive safety benefits. Moreover, the act of regaining balance and (where fitted) clipping into pedals will clearly increase the task burden and may take away from the primary objective of scanning for traffic. Furthermore, there will be more frequent acceptable gaps if the crossing time is reduced. This may reduce the likelihood riders will grow impatient and take unsafe gaps.

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[13] This finding is based on Fagan Road in the northbound direction only. Ideally, such a finding would need be observed elsewhere to consider it robust and a generalisable finding.

[14] There is an obvious risk of respondent bias here; respondents are likely to underreport they intentionally disobeyed a stop sign.

As such, there seems to be a reasonable case to argue for marginal benefits in allowing riders to give way.

It is argued by proponents of a rolling stop exemption for bicycle riders that they are positioned further forward on their vehicle than motorists and have (generally) a higher and less obstructed view of their surroundings. These advantages are clearly true, but what impact they have on safety is not demonstrated. Furthermore, as noted below, there may be some risk compensation at play if riders are approaching the intersections faster as a result.

2.9.5 Rider stop-starting effort

Proponents of a rolling stop exemption for bicycle riders argue that the retention of momentum and balance is critical to ensuring a high level of service for riders. The former, it is argued, allows riders to clear across an intersection more quickly (hence reducing risk). This study would appear to provide data to support this argument of reduced crossing time, which is roughly halved for riders who give way rather than stop. However, in our view the second argument around balance is more important. The issue of balance is concerned more with the task of having to regain balance from a stationary start and (where fitted) clipping into pedals. Clearly, these tasks add somewhat to the mental and physical task at a time when the safety implications are most critical – of emerging onto the main road. Riders will go to great lengths to retain their balance (so must assign a high level of service to doing so), and it seems reasonable that gaining balance is a significant cognitive task that distracts from other safety critical tasks. As such, all else being equal it seems that road designs that allow a rider to retain their balance will offer safety benefits.

2.9.6 Intersection approach speeds

One of the key findings from the observational study was that riders appear to approach the intersections faster than motorists. The difference cannot be explained by stopping compliance; at both Ivory Lane and Fagan Road bicycle riders approached the intersection faster both when they stopped and rolled through the intersection. At first glance this would appear to suggest riders are behaving less safely than motorists, as a faster approach speed implies less time for the rider to scan for safe gaps in traffic. However, we would hypothesise that riders may tend to approach at a higher speed because (a) they are located much closer to the front of their vehicle (about 0.5 m behind the front wheel reference used in this study) than motorists (who are around 2 m behind the front of their vehicle), and (b) riders have a higher and less obstructed view of their surroundings. There may be some form of risk compensation behaviour occurring whereby riders are cognisant of these comparative advantages and are travelling accordingly.

There may also be some difference in the braking performance of bicycles and motor vehicles at low speeds which allow riders to stop faster than motorists. However, the empirical data and models of braking performance generally do not consider these very low speed (<15 km/h) situations. In any case, both vehicles are likely to be able to stop over a very short distance once the brakes are applied at these speeds. What is more important is the reaction time of the rider or motorist; given the heightened awareness we would expect both road users to have approaching unsignalised intersections we would expect the reaction time to be less than the typical 1.5 – 2.5 seconds. As a rule of thumb, if riders are travelling on average at 15 km/h (4.2 m/s) between 3 and 5 m from intersections, and assuming a midpoint of 4 m for this speed, a rider would reach the stop line before commencing braking if the reaction time were one second. At these speeds we would expect a rider (or motorist) to be able to stop within 2-3 metres, which would result in a rider entering the conflicting roadway. Whether this is safety critical will depend on the intersection; in most cases we would expect motorists on the main road to track 1-2 m inside the kerb, providing a buffer. Nonetheless, it appears riders and motorists are making the decision whether to stop beyond 5 m back from the intersection; by travelling at 15 km/h within 5 m of the stop line they are committing to entering the roadway without stopping. Again, we can only speculate on what the safety implications of this behaviour may be.

2.9.7 Conclusion

Enforcement

In our view, there is no evidence to suggest that enforcing the stop sign compliance would improve safety outcomes (as the intersections appear relatively safe already), and the mobility impacts would only be negative. Furthermore, it is unclear whether enforcement could change the vast majority of road users' behaviours in a meaningful and sustained way. More useful would be targeted actions at sites where there is a clear causal link between crash risk and behaviour. For example, at Fagan Road this would imply greater enforcement of the speed limit on Butterfield Street rather than compliance with the stop sign.

While it is almost certainly true that, for example, the physical presence of police officers would increase compliance while present it is not clear that this improved compliance could be sustained over the longer term. Self-evidently, it would be an inefficient use of resources to regularly locate police officers at these specific intersections (let alone all similar intersections throughout Queensland) even if there were a compelling safety case for doing so. Instead, what is required is for occasional enforcement to have a direct behavioural impact on those who are caught and issued with an infringement notice and on those who are not, but see the police officers and are aware of the reason for their presence. We are not aware of any research that has been undertaken to determine the short-term and long-term impact of police enforcement on stopping compliance. [15]

At least two of the sites in this study have been subject to police enforcement over the preceding months (Ivory Lane and Fagan Street). As such, if this enforcement has had an effect it would be present within the observed compliance levels. As the compliance is so low, clearly this sporadic enforcement has not changed the behaviours of the vast majority of road users. This is not to say it has had no effect – clearly it is possible that at least some of the observed compliance is attributable to this enforcement. While our view is that enforcement is unlikely to be effective or an efficient use of resources, should enforcement be undertaken it is recommended that an observational before-after study be conducted to

[15] Furthermore, there appears to be little evidence on the effectiveness of similar enforcement activities such as for jaywalking.

detect any change in compliance levels. This seems a prudent course of action as a minimum in order to confirm or refute the effectiveness of enforcement.

Safety implications by road user group

The vast majority of motorists and the vast majority of bicycle riders did not stop at the three intersections in this study. While, as noted above, the implications for safety from this non-compliance appear to be weak the consequences of non-compliance will, presumably differ by mode. For bicycle riders who do not comply the risk is predominantly to themselves, at least in a collision with a motorist on the main road.[16] For a motorist the risk will be somewhat lower in a collision with another motorist, given their greater level of protection. However, failure to give way by motorists entering a major road at uncontrolled intersections is a major contributor to cyclist injuries. In this crash mode a motorist entering the main road fails to give way to a cyclist on the nearside of the main road. This crash type is attributed, in part, to a failure by motorists to "see" cyclists even though they may have "looked" (Herslund and Jørgensen 2003). In our view this is a far more safety critical issue to address – how to increase give way compliance among motorists turning across the path of oncoming bicycle riders.

Is non-compliance a "bad" thing?

A fundamental principle of traffic engineering and law enforcement is that compliance should be high for a road rule (or law) to be effective. It is desirable that a road rule be self-enforcing, perhaps by being self-evident to road users or by being a normative behaviour (that is, a socially acceptable and desirable behaviour – for which seat belt wearing is perhaps a good example). It seems reasonable to argue that widespread non-compliance risks devaluing other rules and, as argued in the current engineering guidance, the effectiveness of stop signs where they are considered necessary. There seems to be no data to support this assertion, although it appears reasonable. For this reason we would tend to agree that the widespread non-compliance with stop signs is a "bad" thing. This is not because there is evidence to suggest compliance would improve safety outcomes; the literature and the observations of very low levels of conflict in this study suggest such risks would be minimal. Rather, it is in support of the notion that rules, even where they are in themselves of limited value, should be followed so as not to devalue other more critical rules. If this argument is accepted, and it is also accepted that enforcement is unlikely to be cost effective, then the question arises as to what actions should be taken.

2.10 Recommendations

Our main conclusion from this analysis is that non-compliance with stop signs is widespread, has no measurable safety implications but tends to devalue the meaning of traffic controls more broadly. As such, it is desirable to redress the high level of non-compliance. Based on the above discussion, our recommendations are as follows:

- In the first instance TMR should work with councils to review stop sign controls with the intention of replacing stop signs with give way signs where practicable. In our

[16] This is a narrow representation of consequence; although the motorist is unlikely to be physically hurt they may well incur significant mental anguish should the rider suffer serious injuries.

view this action is far more important than whether riders should be exempted from stop sign compliance.

- The decision whether to allow a rolling stop for bicycle riders ought to rely on the subjective assessment of TMR of the impact any exemption may have on bicycle rider – motorist relations. An exemption for riders may, or may not, increase these tensions.
- Enforcement of the current road rule should be focused on those intersections where there is a demonstrated safety problem, and this safety problem is demonstrably related to stop non-compliance. Non-compliance in most situations is probably more an indicator of inappropriate sign usage than of a safety problem.

We reiterate that the level of non-compliance is high among both motorists and bicycle riders, and hence our view is that the most critical issue to address is the overuse of stop sign controls (as the safety justification for their use seems weak and non-compliance is so widespread).

Finally, we note that in our view none of these recommendations are likely to have any material impact on either (a) road user behaviour or (b) safety outcomes. Irrespective of what action is taken the majority of road users at stop sign controlled intersections will continue to treat them as give way controls, and this will (in most instances) not be a measurably unsafe behaviour.

3 Left turn on red signal

3.1 Introduction

The Parliamentary Committee's recommendation 20 states:

> *The Committee recommends that the Minister for Transport and Main Roads amend the Queensland road rules to allow a 'left turn on red permitted after stopping' rule for cyclists at red lights.*
>
> *(Transport, Housing and Local Government Committee, p. xviii)*

This recommendation would allow for cyclists approaching a signalised intersection to stop then proceed to turn left against the red signal. It would not affect straight ahead movements (which would need to continue to obey the signals) nor motorists (who would continue to comply with the existing rules).

3.2 Current road rules

The most relevant Queensland road rule states:

QRR section 56: Obeying traffic lights and traffic arrows

(1) A driver approaching or at traffic lights showing a red traffic light—

- *a. must stop—*
    - *i. if there is a stop line at or near the fraffic lights—as near as practicable to, but before reaching, the stop line; or*
    - *ii. if there is a stop here on red signal sign at or near the traffic lights, but no stop line—asnear as practicable to, but before reaching, the sign; or*
    - *iii. if there is no stop line or stop here on red signal sign at or near the traffic lights—as near as practicable to, but before reaching, the nearest or only traffic lights; and*
- *b. must not proceed until—*
    - *i. the traffic lights change to green or flashing yellow or show no traffic light; or*
    - *ii. a green or flashing yellow traffic arrow is showing, if the driver is turning in the direction indicated by the arrow.*

(1A) However, if the traffic lights are at an intersection with a left turn on red after stopping sign and the driver is turning left at the intersection, the driver may turn left after stopping.

(2) A driver approaching or at traffic arrows showing a red traffic arrow who is turning in the direction indicated by the arrow—

- *a. Must stop—*

   i. *If there is a stop line at or near the traffic arrows—as near as practicable to, but before reaching, the stop line; or*
   ii. *If there is a stop here on red arrow sign at or near the traffic arrows, but no stop line—as near as practicable to, but before reaching, the sign; or*
   iii. *If there is not stop line or stope here on red arrow sign at or near the traffic arrows—as near as practicable to, but before reaching, the nearest or only traffic arrows; and*

b. *Must not proceed until—*
   i. *The traffic arrows change to green or flashing yellow; or*
   ii. *The traffic lights show a green or flashing yellow traffic light and there is no red or yellow traffic arrow showing.*

Of most relevance to this recommendation is clause (1A) which allows left turning on red after stopping where signposted. This clause allows for the trials that have occurred on the Gold Coast at some intersections.

3.3 Advantages and disadvantages

The advantages usually cited for allowing riders to turn left on ride are as follows:

- Allows riders to clear through an intersection ahead of adjacent motorists. This may be particularly beneficial on uphill slopes, where riders will tend to accelerate more slowly (and are also more likely to wobble as they regain their balance).
- Allows riders to maintain their momentum and balance through the intersection, allowing them to focus more on the safety critical task of ensuring they have a safe gap into conflicting traffic.
- Reduces the risks of being caught next to left-turning motorists in their blind spot, particularly large vehicles (trucks and buses) – which present a significant threat of incurring serious injury.
- Reduces the likelihood riders will use the footpath to perform the left turning manoeuvre, so reduce conflict with pedestrians on the footpath. It would also reduce the risks associated with emerging into traffic from the footpath.
- Increases the relative attractiveness of riding by reducing delays.
- Formalises a behaviour which is already commonplace.

The potential disadvantages are:

- Increased rider crashes with motorists on the intersecting road where rider gap judgement is inadequate (or riders fail to look).
- Increased risk of injury, and general discomfort, for pedestrians on any adjacent pedestrian crossing.
- Increases tension with motorists who are not aware of the (proposed) road rule, who will perceive riders to be “law breakers”.

3.4 Precedents

Three European countries have partial exemptions for bicycle riders turning left[17] at signalised intersections (the Netherlands, Belgium and France). An exemption is usually only permitted where a traffic sign or signal lantern indicates as such. In these countries motor vehicles must obey the traffic signals. However, LTOR is permitted for all vehicles in much of the USA, and has been so since the mid-1970s. Most recently in 2003, Québec has adopted the LTOR rule except for the island of Montreal. A trial began at some intersections on the Gold Coast in 2013 and there are several intersections where LTOR is permitted in other Australian jurisdictions. The exact version of the road rule varies across localities between requiring road users to entirely stop before proceeding (equivalent to a stop sign control) or allowing a “rolling stop” (equivalent to a give way control; this variation is much less common).

3.5 Research evidence

Given that North America has had most experience allow LTOR at signalised intersections almost all research has been undertaken on this continent. However, this research has generally focussed on the implications of LTOR on turning motorist movements. This is rather different from the recommendation, which is for only bicycle riders to be allowed to undertake this manoeuvre. Nonetheless, some of this evidence is useful as context.

Much of the research on LTOR has focused on the safety repercussions, particularly for pedestrians on the adjacent crossings:

- Preusser et al. (1981) investigated six locations in the USA where the road rule change was introduced during the 1970s. They reported an increase in pedestrian accidents at the study sites from 43% to 107% for pedestrian crashes and from 72% to 123% for cyclist crashes. Over half of the crashes involving a left turning movement was during a red signal phase. However, the overall magnitude of these crashes was small – between 1% and 3% of pedestrian and cyclist crashes in the study areas.
- A cross-sectional study comparing six US states which introduced the LTOR rule during the 1970s and three that did not and found that crashes involving left turning movements at signalised intersections increased by 20% more in those states that introduced LTOR than those that did not, and that pedestrian crashes in urban areas experienced an increased of 79% (P. Zador, Moshman, and Marcus 1982; P. L. Zador 1984).

There is limited observational data on the prevalence of LTOR infringement by bicycle riders under the present road rules. Overall red light infringement rates by bicycle riders vary from 7% to 9% based on Australian observational studies (Daff and Barton 2005; Johnson et al. 2011). These rates of disobeying red lights are similar to motorists. In a study of multiple intersections in Melbourne a left turning rider had 28 times the odds of red light non-compliance than straight ahead movements (Johnson et al. 2011). In addition to

[17] Throughout this discussion we refer to left turn on red, even though much of the research from overseas refers to their equivalent – namely, right turn on red.

these rider observations Johnson et al. (2013) conducted a survey of Australian bicycle riders where 37% reported they had ridden through a red light, of which the main reason (32% of this subset) was to turn left. The proportion of police reported crashes involving cyclists where the rider was recorded as having disobeyed a red light is around 6.4% in Queensland (Schramm, Rakotonirainy, and Haworth 2010).

3.6 Observational study method

3.6.1 Measurements

Three sites were observed to identify:

- the proportion of left turning riders and motorists who disobeyed the traffic signal,
- the proportion of riders and motorists who disobeyed the traffic signal who stopped before proceeding (illegally) through the signal, and
- the proportion of riders who either rode entirely on the footpath around the corner, or left the roadway at the intersection onto the footpath.

3.6.2 Method

The sites were recorded over multiple days from 6 am to 7 pm from a position that allowed observation of crossing riders and pedestrians, and motorists on the intersecting roadway. All motorists and bicycle riders making the left turn of interest were examined, irrespective of which cycle in the signal phase they arrived.

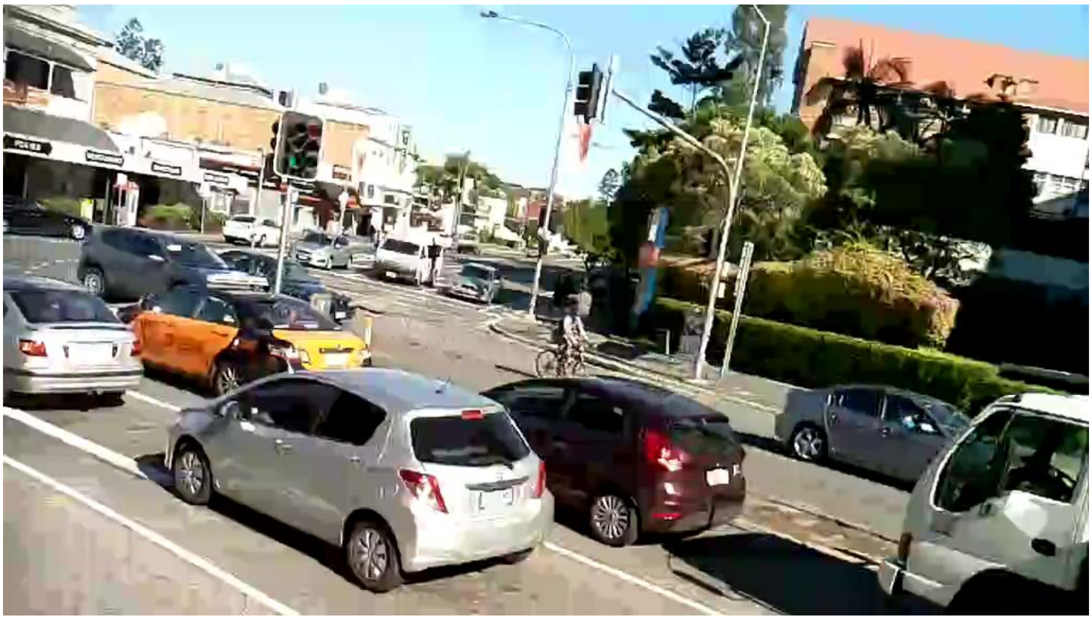
3.6.3 Site selection

One of the main challenges in selecting sites was to obtain sites where there was a reasonable likelihood of having a sufficient number of rider observations. Many prospective sites with traffic signals and a reasonable number of bicycle riders also had slip lanes, which precluded them from this study. Video snapshots from the three sites are shown in Figure 4.3. The sites have the following main characteristics:

- Mollison Street / Boundary Street (West End):
    - Left turn from Mollison Street into Boundary Street
    - Dedicated left turn signal phase and traffic lane
    - Green coloured bicycle lane along kerb leading to stop line.
- Annerley Road / Stanley Street (South Brisbane):
    - Left turn from Annerley Road into Stanley Street
    - Dedicated left turn signal phase and traffic lane
    - Green coloured bicycle lane along kerb leading to stop line
    - Signal call button located on kerb for riders to trigger pedestrian phase.
- Agnew Street / Wynnum Road (Norman Park):
    - Left turn from Agnew Street into Wynnum Road
    - Dedicated left turn lane, no bicycle provision.

- Figure 3.1: Left turn on red sites
- (a) Mollison Street / Boundary Street (West End)

- (b) Annerley Road / Stanley Street (South Brisbane)



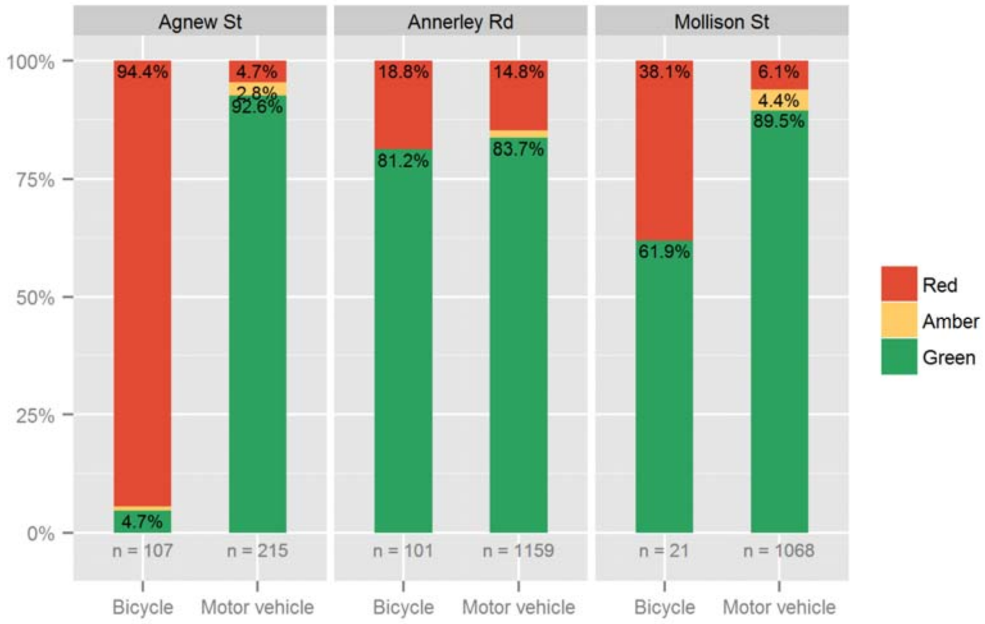
- (c) Agnew Street / Wynnum Road (Norman Park)

3.7 Fieldwork results

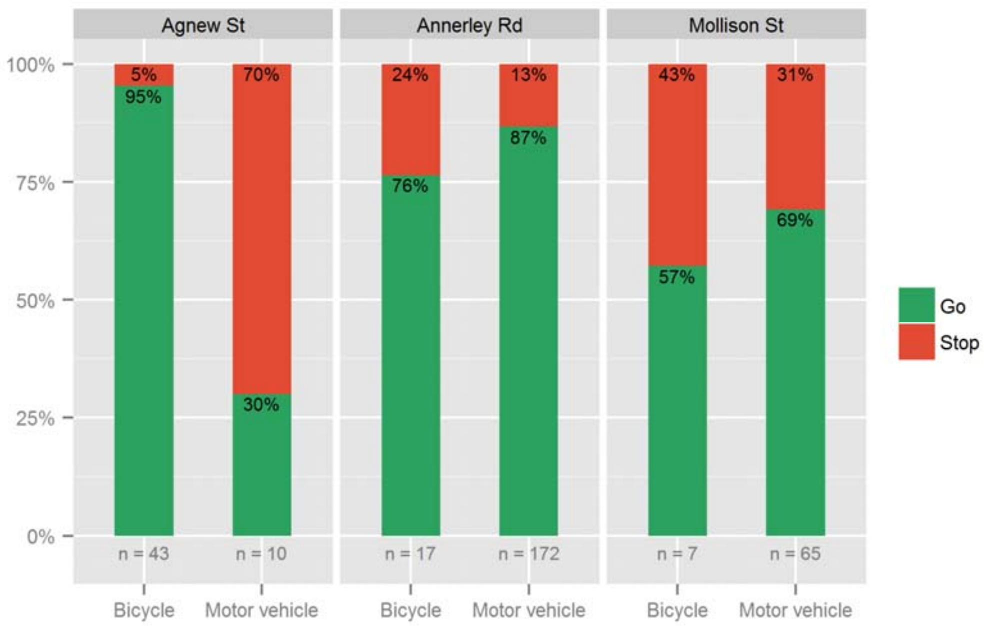
3.7.1 Compliance

Compliance with the signal varied significantly across the three sites, and between the modes. Non-compliance was very high among bicycle riders at Agnew Street, where almost 95% of riders did not obey the red signal.[18] Almost none of these riders stopped, instead they tended to slow and look for conflicting traffic before proceeding through the red signal (Figure 3.3). The proportion of left turning riders who did not obey the signal at Annerley Road (28%) and Mollison Street (38%) was significantly lower, but still common. This at least partially reflects the higher green cycle time at these sites compared with Agnew Street, such that a rider is more likely to encounter a green signal on arrival at the former two sites (and so be defined as "compliant"). It should be noted that the sample size of rider observations at Mollison Street is low (n=21). In most instances where a bicycle rider or motorist was observed to pass through the red signal they did so without stopping, except at Agnew Street for motorists (Figure 3.3). Apart from Agnew Street where motorists passed through the red signal they usually did so at the end of the amber phase. By contrast, riders would tend to pass through the red signal whenever they arrived in the cycle.

[18] Non-compliance here is only considered for bicycle riders who approach the intersection on the road and either (a) remain on the road when they enter the intersecting street, or (b) turn onto the footpath at the pedestrian crossing (and cross the stop line in doing so).



■ Figure 3.2: Signal compliance by site and mode



■ Figure 3.3: Stopping behaviour among those who did not obey the traffic signal

3.7.2 Gap acceptance

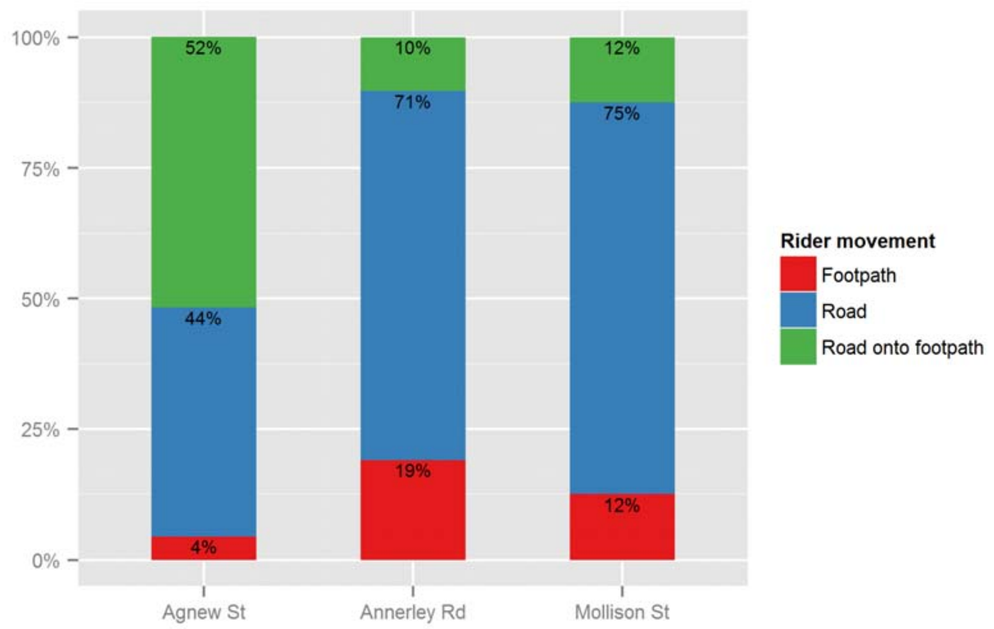
In most instances riders or motorists who proceeded through a red signal had a substantial gap ahead of conflicting traffic on the main road (Table 3.1). Nonetheless, there were instances where riders in particular appeared to accept small gaps to conflicting traffic. Nonetheless, there was no sign that any road user had to take evasive action as a result in order to avoid a crash. At Agnew Street, the presence of a wide shoulder on Wynnum Road meant that riders could turn onto Wynnum Road while remaining clear of traffic in the kerbside lane. Similarly, turning left from Annerley Road into Stanley Street there is an additional kerbside lane on Stanley Street into which riders appear to travel, so avoiding traffic in the two farside lanes.

■ Table 3.1: Gap to conflicting traffic of road users who disobeyed traffic signal

	Agnew St		Annerley Rd		Mollison St	
	Bicycle	Motor vehicle	Bicycle	Motor vehicle	Bicycle	Motor vehicle
No. obs.	43	8	6	15	7	56
Average (s)	7.9	109.9	8.2	7.6	53.6	29.0
Median(s)	4.6	16.3	1.4	8.6	58.5	20.5
5^{th} percentile (s)	2.4	6.1	0.4	2.8	0.3	9.7
Minimum (s)	0.9	4.2	0.1	7.9	0.1	7.9

3.7.3 Footpath cycling

The proportion of riders who approached the intersection on the road and turned left onto the main road varied from 44% at Agnew Street to 71% at Annerley Road and 75% at Mollison Street (Figure 3.4). The most significant difference between the sites was the high proportion (52%) of riders at Agnew Street who road onto the footpath at the intersection.



■ Figure 3.4: Location of bicycle riders during left turn

3.8 Discussion

In comparison to the other situations examined in the present study, motorist and bicycle rider compliance with traffic signals is (generally) fairly high. However, bicycle riders tend to be less compliant than motorists. This is particularly true at Agnew Street, where the vast majority of riders (95%) did not obey the signal. It is speculated that the long cycle times at this intersection, and the opportunity to turn onto the footpath, contributes to this high non-compliance. It is also possible that detection loops at this site (if present) are inadequately tuned to detect riders, such that regular riders are aware of this and so ignore the signal. It is noted that although non-compliance among riders was very high, just over half (52%) of non-compliant riders did not enter Wynnum Road but rather diverted onto the footpath.

Another key difference in the behaviour of motorists and bicycle riders who disobeyed the signal at the three sites was the tendency, in general, for riders to proceed through without stopping whereas most motorists stopped before proceeding against the red signal. As for rolling stops (Section 2) it is not necessarily true that stopping is the safest option for riders who disobey the signal. While stopping would presumably increase the likelihood of carefully scanning for conflicting movements it would increase the time to enter the roadway and position oneself in traffic. Irrespective, clearly the safest course of action would be to comply with the signal.

While no near misses were observed from the video observations there were a number of gaps to conflicting traffic that leave little margin for error. Given motorist speeds on many of the joining roads (at least 50 km/h) the consequences of a rider misjudging a safe gap could be catastrophic.

No conflicts were observed between turning bicycle riders or motorists and pedestrians on the adjacent pedestrian crossing at Mollison Street.[19] As noted in the literature however, there does appear to be an elevated risk of injury to pedestrians in allowing LTOR for motorists. Presumably a similar risk may apply if riders were exempted.

3.9 Recommendations

In our view allowing for a general exemption for bicycle riders to turn left at traffic signals would be unwise given the potential safety repercussions. It could be argued at specific sites that an exemption is warranted (such as with the use of signs) if sightlines are good and signal cycle times are so long that riders are otherwise unlikely to obey the signal in any case. However, even in these circumstances there remains the prospect that the credibility of signal control is diminished. This would be highly undesirable given the critical importance of this type of intersection control to safety and mobility on the road network. Given these concerns, in our view this proposed road rule change should not be adopted.

Instead of adopting this rule, it is suggested that where riders are observed to disobey signals (such as at Agnew Street) further investigation is warranted into the motivation for doing so, and in providing safer alternatives. Possible measures may include:

- Improve signal timing (cycle times) so as to reduce delay to riders (and motorists) turning left.
- Where detection is present ensure inductive loops are positioned such that riders will travel over them when approaching the intersection, and they are tuned such that they will detect bicycles.
- Provide off-road bypass routes, such as angled kerb ramps onto footpaths to allow riders to safely avoid signals while maximising level of service.

Enforcement may be warranted in certain situations, although our view is that providing design solutions that reduce the likelihood of non-compliance are likely to produce superior safety outcomes (and at lower cost).

[19] We note there was no pedestrian crossing to the left of the intersection of Agnew Street and Wynnum Road, nor at Stanley Street and Annerley Road.

4 Pedestrian Crossings

4.1 Introduction

The Parliamentary Committee's recommendation 20 states:

> *The Committee recommends that the Minister for Transport and Main Roads amend the Queensland road rule section 248 to permit cyclists to ride on a pedestrian crossing (Zebra) or children's crossing provided the cyclist approaching the crossing:*
>
> *a) First slows down, as near as practicable to, but before reaching,the stop line at the crossing; and where required for safety, stop, and*
>
> *b) Proceeds slowly and safety; and*
>
> *c) Gives way to any pedestrian on the crossing; and*
>
> *d) Keeps to the left of any oncoming rider of a bicycle or person who is using a personal mobility device.*
>
> *The Committee also recommends that the Minister amend Queensland road rule section 81 so that a driver must give way to cyclists using a pedestrian crossing or children's crossing.*
>
> *(Transport, Housing and Local Government Committee, p. xviii)*

This recommendation would allow for cyclists to ride across pedestrian and school crossings, and would be consistent with the Queensland road rules insofar as riders of all ages are allowed to ride on footpaths (unless specifically prohibited). The current road rule prohibiting riding on pedestrian and school crossings is consistent across Australia, although riding on footpaths for those aged over 12 (when not accompanying children under 12) is present only in Queensland and Tasmania.

In this section we refer to zebra crossings as a colloquial term to cover both pedestrian and school crossings.[20]

4.2 Current road rules

The relevant Queensland road rule states:

> ***QRR section 248: No riding across a road on particular crossings***
>
> *(1) The rider of a bicycle must not ride across a road, or a part of a road, on a children's crossing or a pedestrian crossing.*
>
> *(2) The rider of a bicycle must not ride across a road, or a part of a road, on a marked foot crossing, unless—*
>
> *(a) if there are bicycle crossing lights at the crossing—*
>
> *(i) the rider is, under this regulation, permitted to ride on the crossing; and*

[20] Clearly, there are distinct characteristics of school crossings from pedestrian (zebra) crossings, most notably the different pavement markings and signs and also the part-time status of school crossings.

(ii) the rider—

(A) proceeds slowly and safely; and

(B) gives way to any pedestrian on the crossing; and

(C) keeps to the left of any oncoming rider of a bicycle or person who is using a personal mobility device.

QRR section 81: Giving way at a pedestrian crossing

(1) A driver approaching a pedestrian crossing must drive at a speed which the driver can, if necessary, stop safely before the crossing.

(2) A driver must give way to any pedestrian on a pedestrian crossing.

(3) A ***pedestrian crossing*** is an area of a road **–**

(a) At a place with white stripes on the road surface that—

i. Run lengthwise along the road; and

ii. Are of approximately the same length; and

iii. Are in a row that extends completely, or partly, across the road; and

(b) With or without either or both of the following—

i. A pedestrian crossing sign;

ii. Alternative flashing twin yellow lights.

Importantly, the wording within rule 81(2) is that a driver must give way to any pedestrian **on** a pedestrian crossing. By implication, the driver does not have to give way to a pedestrian waiting on the footpath. This is not widely understood by Australian road users (Hatfield et al. 2007).

Queensland, along with Tasmania, allow bicycle riders of any age to ride on footpaths. Outside these states only children aged under 12 can ride on footpaths, or older riders if they are accompanying a rider under this age.

4.3 Advantages and disadvantages

The advantages commonly used to support the recommendation proposed by the committee are as follows:

- Riding across pedestrian crossings would reduce the crossing time compared to walking, which would reduce the exposure of a rider to potential conflicts.
- Riding across pedestrian crossings would reduce the crossing time and hence also reduce delays for waiting motorists.
- Would improve the consistency of the road rules by treating bicycle riders as pedestrians on pedestrian crossings, just as on footpaths and at signalised intersections.[21]

[21] The Queensland Road Rules were amended in 2013 to permit riders to ride across pedestrian crossings at signalised intersections. Previously they could only do so where there was a dedicated bicycle lantern.

- Reduces the physical and mental workload on riders to have to dismount.
- Non-compliance with the current road rule is widespread, which will tend to devalue other rules which are more safety critical.
- The risks of injury are predominantly with the rider, so providing a strong incentive for them to be cautious.
- Riding across on a zebra crossing is likely to be safer, and certainly perceived as more predictable, to other road users than crossing on the roadway in the near vicinity of a zebra crossing (which is legal).

The main disadvantages cited for such a rule are as follows:

- Riders travel at a faster speed than pedestrians, and so make it more difficult for a motorist to see and stop a rider approaching a zebra crossing from a footpath.
- Cyclists travelling along the left of the road may suddenly veer out onto the zebra crossing into the path of motor vehicles.
- There is a risk that rides will collide with pedestrians on the crossing, leading to potential injury to pedestrians (and particularly elderly pedestrians).
- Reduces the sense of comfort felt by pedestrians, who may be anxious about their safety having to interact with riders on a crossing.

4.4 Engineering guidance

MUTCD Part 10 (Department of Transport and Main Roads 2013b) provides the engineering guidance for the installation of pedestrian crossings (zebras) and children's crossings in Queensland. The guidance requires the following conditions be met for the installation of a zebra crossing:

- No more than one lane of moving traffic in any one direction.
- Adequate sight distance between approaching vehicles and pedestrians about to use the crossing for the former to be able to stop in time to give way to the latter.
- The speed limit on approach to the crossing shall be 50 km/h or lower and the 85th percentile speed shall not exceed 60 km/h.
- Crossings shall not be used on arterial roads.

Further advice on the appropriateness of particular types of pedestrian crossings are provided in TRUM 3.13.

The MUTCD guidance requires no kerbside parking within 20 m of the crossings in order to maintain adequate sight distance. The sight distance requirements are articulated in more detail in the AGRD Part 4A (Austroads 2009). The crossing sight distance (CSD) is the sight distance for motorists to be able to see and react to the presence of a pedestrian (or rider) on the kerb at the crossing. This distance is inversely related to the speed of the pedestrian (or rider); for a typical zebra crossing length of 10 m, 85th percentile speed of 50 km/h and pedestrian speed of 5 km/h the CSD is 100 m. By contrast, for a rider travelling at a (slow) speed of 10 km/h the CSD would be reduced to 50 m. However, this is probably not the critical sight criterion for riders approaching crossings as it calculates the sight distance only to the edge of the kerb. Rather, the motorist would need to be able to see the rider approaching the crossing for some distance back in much the same way that the sae intersection sight distance is used in the guides. What distance back is required would, presumably, need to be based on observations of rider speeds approaching zebra crossings.

4.5 Precedents

Most countries have some form of unsignalised pedestrian priority crossing design for mid-block locations. Most of these designs also require that riders dismount and cross as pedestrians. Among the few countries where riders are allowed to ride on zebra crossings are Austria and the US state of Washington (ViaStrada 2008). In most European countries where a significant number of riders are expected to use a crossing it is commonplace to provide a designated cyclist priority crossing immediately next to a zebra (pedestrian only) crossing (Figure 4.1).

- Figure 4.1: Typical pedestrian and cyclist priority crossing treatments in Europe

- (a) Lund (Sweden)

- (b) Houten (Netherlands)

There has been substantial discussion in Australia about the merits of allowing bicycle riders to ride across zebra crossings. Some of this discussion from around 2008 is summarised by ViaStrada (2008), although to date no other Australian jurisdiction has changed their road rules to allow for riders on zebra crossings. However, in some jurisdictions instead of zebra crossings coloured pavements have been used to provide for shared path user priority across streets (Figure 4.2).

■ Figure 4.2: Path priority crossing (Anniversary Trail, Melbourne)

4.6 Research evidence

There is limited research of which we are aware examining the impact of safety or mobility on allowing bicycle riders to ride across zebra crossings. One study has examined the interaction between bicycle riders and pedestrians on zebra crossings. This study in the UK observed pedestrian, bicycle rider and motorist behaviour at six zebra crossings (Greenshields et al. 2006). That study found that the risk of conflict between bicycle riders and pedestrians was low and comparable to Toucan crossings[22]. They found that 88% of riders did not dismount at the zebra crossings. However, there was no observable difference in conflict with motorists between those riders who dismounted and those who did not. Around 0.8% of the 1,580 roadway crossings by bicycle riders (who did not dismount) were defined as "serious conflict", indicating one or both users needed to react quickly to avoid a collision. Overall, 2.9% of interactions were defined as "conflict". This compares with 5.1% of interactions at uncontrolled side streets, suggesting the risk on zebra crossings is lower than riding across side streets.

Another study in Sweden examined the impact of converting at-grade shared (cyclist and pedestrian) crossings to raised tables with distinctive coloured surfaces (Gårder, Leden, and Pulkkinen 1998). It was found that bicycle volumes increased by around 50% after the treatment, and that crash risk was reduced by around 30%. The safety improvements extended also to pedestrians and motorists, and were attributed to reduced motorist speeds in the vicinity of the crossing due to the presence of the vertical deflection.

Given the paucity of research related specifically to riders and zebra crossings it is useful to review the literature from two related areas:

- the safety implications of zebra crossings for pedestrians, and

[22] Toucan crossings are signalised crossings with both pedestrian and bicycle lanterns, such that cyclists can legally ride across these crossings.

- the research undertaken on pedestrians and cyclists riding on footpaths, and of cyclists emerging from footpaths onto roadways.

The evidence on the safety of zebra crossings for pedestrians is mixed:

- A meta-analysis of a large number of studies from North America and Europe found a best estimate of an 8% reduction in pedestrian injury crashes after installation of marked crossings[23] on two-lane roads, but this estimate was not statistically significant (Elvik et al. 2009). By contrast, on multilane roads the best estimate is an increase in crashes of 88% (although, again this estimate is statistically insignificant).
- The severity of pedestrian injury and speed of motorists is lower at zebra crossings than non-zebra locations, based on an examination of emergency department presentations in Switzerland (Pfortmueller et al. 2014).
- There is some misunderstanding about the give way requirement at zebra crossings between pedestrians and motorists. A survey of NSW residents found that (correctly) 96% of respondents felt a pedestrian had right of way over a nearside motorists when they were on the crossing, and 92% when they were on the farside of the crossing (Hatfield et al. 2007). However, when the pedestrian was located on the footpath adjacent to the crossing 71% of respondents still felt the pedestrian would have priority over a nearside motorist, even though strictly this is not the case.[24]

At some locations where LTOR is permitted, signs are used to warn turning traffic of their obligation to give way to pedestrians. A study of a "Turning traffic must yield to pedestrians" sign in Las Vegas did not detect a statistically significant change in motorist yielding to pedestrians. However, there was a significant reduction in the number of motorists blocking the crossing after the sign was installed and there was an increase in the proportion of motorists fully stopping before conducting an LTOR manoeuvre (Karkee, Pulugurtha, and Nambisan 2006)[25].

There is conflicting evidence about the relative safety of riding on footpaths compared to roads. The lack of consensus is probably related, at least in part, to the quality of the data – many crashes will be unreported and exposure data is very limited. For example, Wachtel and Lewiston (1994) report from data in California in the 1980s an 80% increase in crash risk on footpaths compared with roads, which they largely attributed to wrong way (compared to the adjacent traffic lane) movements. Similarly, Aultman-Hall and Adams (1998) found the crash rate to be 2.4 times greater on footpaths in Ottawa. However,

[23] Not all of these marked crossings will be zebra crossings.

[24] The road rules stipulate that the motorist must give way only when the pedestrian is on the crossing itself. Taken literally this means there is no need to adjust the sight distance requirements in the MUTCD to allow greater splays to approaching riders. This is because the rider does not have priority until they actually enter the roadway. In practice however, this ambiguity will probably not be well understood my road users.

[25] This study illustrates the importance of (a) critiquing published papers carefully, and (b) statistical tests to confirm observed differences are statistically significant, and to interpret these results correctly. The paper asserts there was an observed change in motorist yielding behaviour, but also notes these changes are insignificant (p=0.156). It cannot be both. All that can be concluded from this result is that no difference could be observed (in statistical language: the null hypothesis of no change cannot be rejected).

Victorian research in the 1980s suggested that riding on the road had 1.5 times greater risk of injury involvement than footpaths for children and up to 6.8 for adults on non-arterial roads (Drummond and Jee 1988). There is some evidence to suggest that riding on footpaths rather than roadways is less safe than on roadways, primarily because of the increased risk of injury when entering a roadway (e.g. crossing unsignalised side streets). While some cautions are appropriate in considering these crash rates (particularly that those using footpaths may be less confident and experienced riders) the most common crash mechanism appears to be riders entering or crossing roads from the footpath. This has direct implications for the proposed road rule, which would encourage riders to enter the roadway (albeit at a designated crossing) from adjoining footpaths.

Zebra crossings with high volumes of pedestrians distributed across the day will have significant adverse impacts on motor vehicle capacity on the roadway. How significant the effect on capacity will be will be heavily influenced by the user demand profiles and motorist compliance with the pedestrian priority. Simulations based on behaviours observed in Germany (where around two thirds of motorists were observed to give way to pedestrians at non-median zebra crossings) suggest that capacity halves with around 400 pedestrians per hour (Bak and Kiec 2012). These capacity losses on the roadway would need be balanced against the travel time benefits that would accrue to pedestrians as a result of a zebra crossing.

4.7 Observational study method

4.7.1 Measurements

Three sites were observed to identify:

- the proportion of riders who (in accordance with the road rules) dismounted and walked across the zebra crossings,
- whether a pedestrian was present on the crossing when the rider crossed,
- rider gender,
- interactions with motorists, and
- the length of time the rider was on the crossing.

4.7.2 Method

The sites were recorded over multiple days from 6 am to 7 pm from a position that allowed observation of crossing riders and pedestrians, and motorists on the roadway. Manual classification of each rider observation was undertaken for each of the measurements. The time on the crossing was measured to the nearest video frame; the video was recorded at 30 frames per second, such that times could be recorded to the nearest 0.033 seconds.

4.7.3 Site selection

One of the main challenges in selecting sites was to obtain sites where there was a reasonable likelihood of having a reasonable number of rider observations. Video snapshots from the three sites are shown in Figure 4.3. The sites have the following main characteristics:

- Bennetts Road / Agnew Street (Norman Park):
  - Immediately north of the intersection with Agnew Street, after a right angled turn on Bennetts Street
  - Narrow concrete median provides for a staged crossing for pedestrians (but is too narrow to hold a bicycle)
  - Width from kerb-to-kerb of approximately 12.4 m (including the central refuge)
  - Most rider demand travels eastbound on Agnew Street using the roadway, then crossing Bennetts Street using the zebra crossing to continue east along Bennetts Street.
- Moggill Road (North):
  - Zebra crossing of southbound slip lane to the east of Centenary Motorway for motorists exiting the Centenary Motorway southbound to Moggill Road eastbound
  - High rider volumes as this site is part of the Centenary Cycleway
  - The presence of the Moggill Road intersection around 10 m downstream from the zebra crossing will, presumably, be influencing motorist behaviours at the crossing.
  - Width from kerb-to-kerb of approximately 12 m
  - The site was under significant reconstruction at the time of observations, and was immediately prior to the installation of signal control at the site.
- Moggill Road (South):
  - Zebra crossing of southbound slip lane to the east of Centenary Motorway for motorists on Moggill Road westbound to Centenary Motorway southbound
  - High rider volumes as this site is part of the Centenary Cycleway
  - Width from kerb-to-kerb of approximately 8 m
  - The site was under significant reconstruction at the time of observations.

It is noted that soon after these observations were obtained both of the Moggill Road sites were converted to signal control.

- Figure 4.3: Zebra crossing sites
- (a) Bennetts Road / Agnew Street (Norman Park)

- (b) Moggill Road (north)

- (c) Moggill Road (south)

4.8 Fieldwork results

4.8.1 Compliance

The proportion of riders who complied with the road rule that required that they dismount before crossing at the zebra crossing was very low (Table 4.1). At the Bennetts Road site the proportion of riders who walked across the intersection was 5%, and no riders were observed to walk across at either of the Moggill Road sites.

- Table 4.1: Rider compliance at zebra crossing

	Bennetts Rd / Agnew St		Moggill Rd (north)		Moggill Rd (south)	
	n	%	n	%	n	%
Rode	10	94.9%	350	100.0%	394	100.0%
Walked	187	5.1%	0	0.0%	0	0.0%
Total	*197*	*100.0%*	*350*	*100.0%*	*394*	*100.0%*

4.8.2 Interactions with other road users

Pedestrians

Pedestrian volumes are fairly low at all sites; at the Bennetts Road site five riders crossed at the same time as pedestrians were present on the crossing (2.5% of the sample) and no pedestrian-rider interactions were observed at the Moggill Road sites. In three of the five cases where a pedestrian was present the rider walked across the road. In all three cases the pedestrian was accompanying the rider.

Motorists

The proportion of rider crossings where a motorist was present varied from around a third (Bennetts Road and Moggill Road (north)) to just over half (Moggill Road (south)). A motorist being present was defined as the motorist reaching the crossing within two seconds of the rider.

■ Table 4.2: Interactions with motorists

	Bennetts Rd / Agnew St		Moggill Rd (north)		Moggill Rd (south)	
	n	%	n	%	n	%
No car interaction	123	62.4%	231	66.0%	177	44.9%
Car interaction	74	37.6%	119	34.0%	217	55.1%
Total	*197*	*100.0%*	*350*	*100.0%*	*394*	*100.0%*

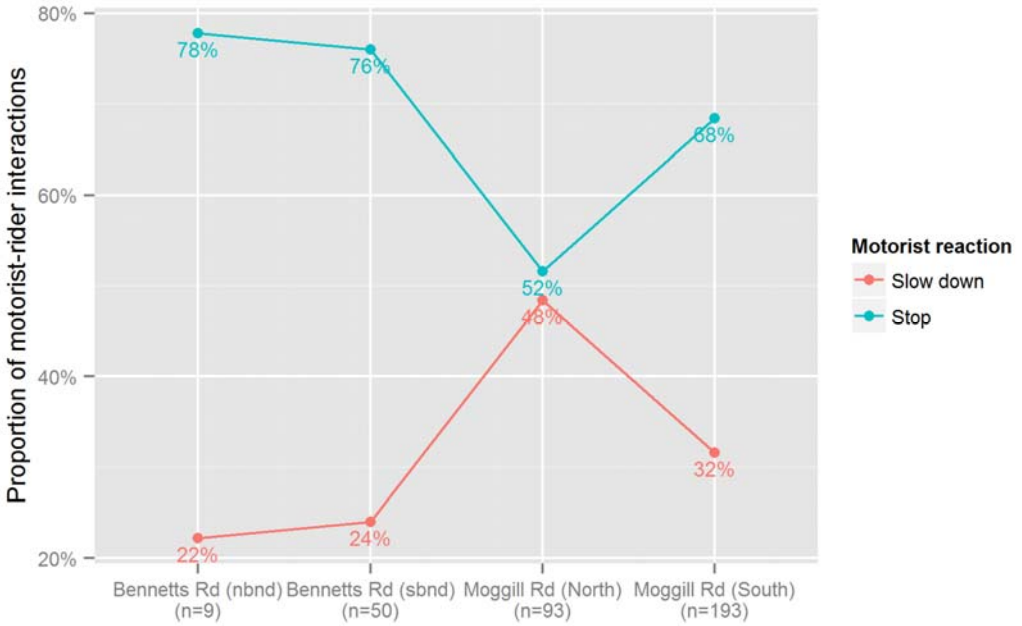
In at least 80% of cases where a motorist and rider was present the motorist gave way to the rider (Table 4.3).

■ Table 4.3: Motorist yielding behaviours

	Bennetts Rd / Agnew St		Moggill Rd (north)		Moggill Rd (south)	
	n	%	n	%	n	%
Motorist does not gives way	14	18.9%	24	20.2%	24	11.1%
Motorist gives way	60	81.1%	95	79.8%	193	88.9%
Total	*74*	*100.0%*	*119*	*100.0%*	*394*	*100.0%*

At the Bennetts Road site around three quarters of motorists who gave way came to a complete stop for the rider to cross the road (Figure 4.4). This proportion was similar at Moggill Road (south) but only around 50% at Moggill Road (north). The presence of the Moggill Road intersection immediately downstream of the zebra crossing is probably influencing this behaviour.

■ Figure 4.4: Motorist reaction to rider presence when giving way



All interactions were rated as having low risk; there were no incidents observed where riders and/or motorists appeared to react suddenly to avoid conflict at any of the sites.

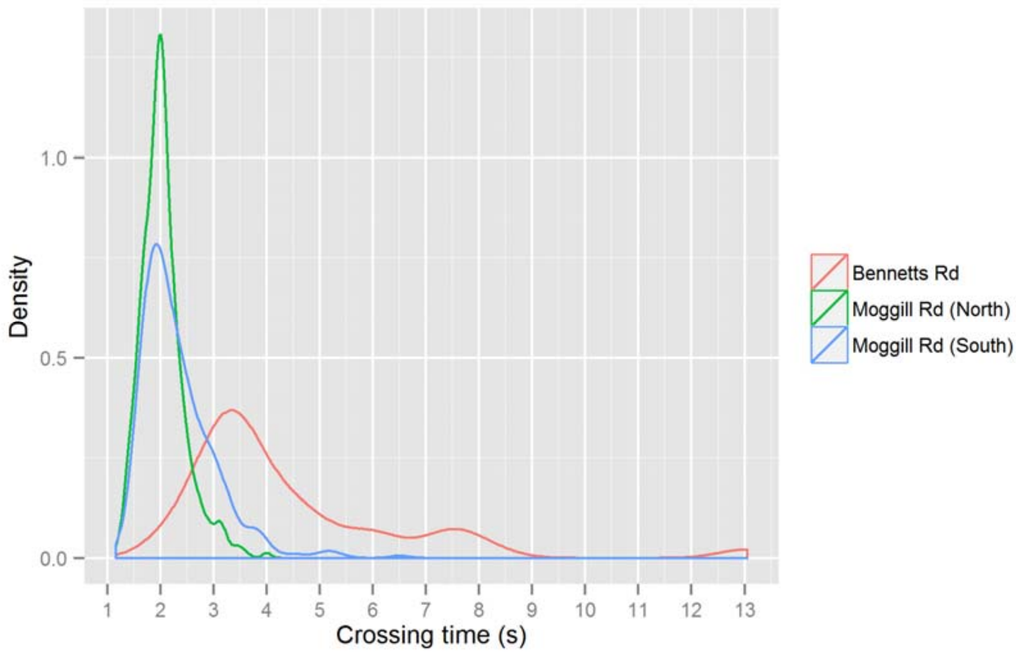
4.8.3 Crossing times

Crossing times were measured from the kerb lips, except on the western side of the Bennetts Road zebra crossing, where the outer edge of the zebra pavement marking was used as the reference. Summary statistics for the crossing times are provided in Table 4.4 and the time distribution estimated in Figure 4.5. The average crossing time at Bennetts Road was 4.4 seconds, compared with 2.0 seconds at Moggill Road (north) and 2.3 seconds at Moggill Road (south).

■ Table 4.4: Rider crossing times

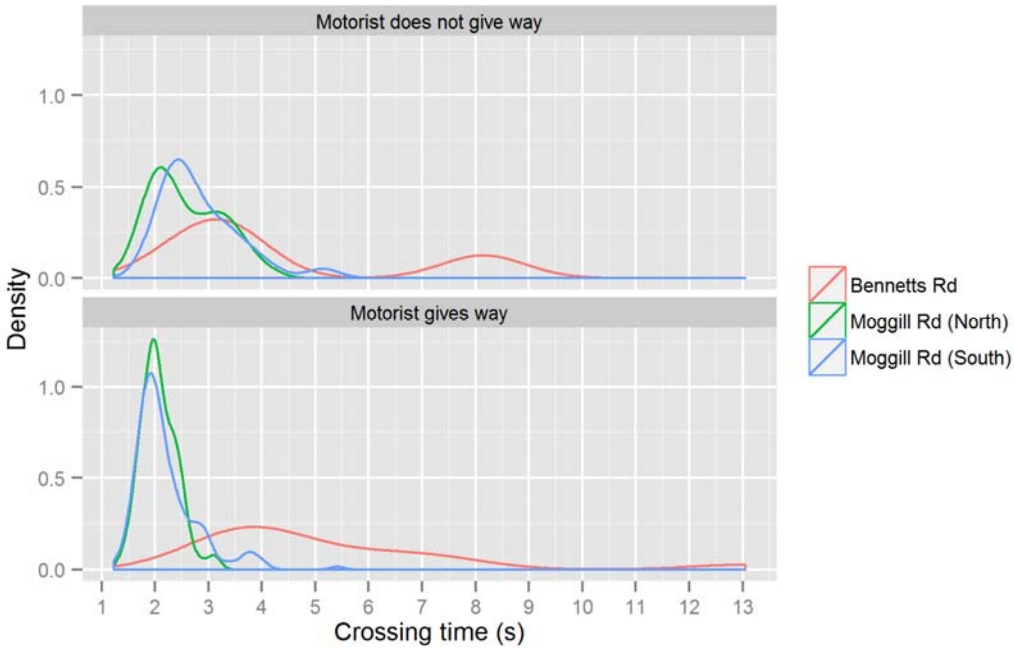
	Bennetts Rd / Agnew St	**Moggill Rd (north)**	**Moggill Rd (south)**
No. observations	197	350	394
Average	4.4 s	2.0 s	2.3 s
Minimum	2.0 s	1.2 s	1.2 s
Maximum	13.0 s	4.0 s	6.5 s
Std. dev.	2.1 s	0.4 s	0.7 s
85^{th} percentile	6.1 s	2.4 s	3.0 s

■ Figure 4.5: Crossing time distribution by site



The variation in crossing times was much greater at Bennetts Road, reflecting the longer crossing distance and the bi-directional traffic on this street which led to more frequent "negotiated" crossing behaviours where riders and motorists both slowed before (usually) the rider completed their crossing. This is reflected by the bi-modal distribution for Bennetts Road when motorists were present and did not give way (Figure 4.6). The distribution illustrates the crossing time for those who wait for a motorist to pass then proceed straight across (crossing times around two seconds) and for those who proceed slowly onto the crossing but wait for a motorist to pass on the farside lane (crossing times around 8 seconds).

■ Figure 4.6: Crossing time distribution by site and motorist give way behaviour



4.9 Discussion

The most robust conclusion from the primary research in this study at zebra crossings is the very widespread non-compliance with the road rule requiring riders to dismount and walk across zebra crossings. The non-compliance rate varied from 94% at Bennetts Road to 100% at both slip lanes on Moggill Road. These rates of non-compliance are somewhat higher than the 88% reported in the UK (Greenshields et al. 2006), but both studies point to a very high level of non-compliance.

The high non-compliance does not appear to result in high levels of risk to riders; none of the 941 observations were rated as requiring a rider or motorist to take evasive action to avoid a collision. To the contrary, riders in particular seemed to approach the intersections fairly slowly and look for conflicting movements before proceeding across the crossings. Furthermore, in around four fifths of cases a conflicting motorist gave way to the rider by either slowing or stopping. Strictly, the motorist is probably not required to do so given the rider is in breach of the road rules. However, it appears likely that motorists are unaware of this road rule (and quite possibly so too are many riders) and are treating riders as they would pedestrians on the crossings. Indeed, a sample of 40 pedestrian interactions with motorists at each intersection found a similar proportion of motorists giving way (85% pooled across both sites). This is broadly consistent with a review in the USA that found that on average 77% of motorists gave way to pedestrians at typical US pedestrian crossings (Turner et al. 2006).[26]

[26] Motorist compliance appears to vary greatly depending on the site; Turner et al. quoted a range of 44-97% compliance across 14 studies.

The very high level of non-compliance makes it impractical to compare compliant and non-compliant riders, as the sample size of compliant riders is very small (10 of 941 observations). However, assuming that dismounted riders would have the same crossing times as pedestrians we would expect, on average, crossing times to be about twice as long were riders to dismount. A sample of pedestrian observations at the Moggill Road (South) site found the average crossing time for pedestrians is around 5.1 seconds, compared with 2.3 seconds for riders. At the Moggill Road (north) site pedestrians took an average of 4.0 seconds to cross compared with 2.0 seconds for riders. Proponents of relaxing the road rule argue that this longer crossing time increases the exposure of riders to potential conflicts with motorists. This cannot be definitively supported or rejected; however, we would suggest the more relevant exposure measure is likely to be the number of crossings rather than the time spent on the crossings. For example, it seems plausible that a rider crossing three zebra crossings each with a crossing time of 3 seconds (i.e. a total time exposure of 9 seconds) is exposing themselves to greater risk than one crossing of 9 seconds. The action of looking for motorists, entering the roadway and expecting a motorist to give way seems to be the more relevant measure of exposure than time within the crossing itself. There may be an analogy here to the risks of footpath cycling; although riding on the footpath appears to be perceived to be safer than riding on the road overall (Haworth and Schramm 2011), there is an elevated risk of collisions when emerging onto (or crossing) roadways, particularly for teenage riders in comparison with riding on the road (Drummond and Jee 1988). Irrespective of the most appropriate exposure measure the data does not suggest the risk of riding across zebra crossings is very high.

4.10 Recommendations

There are, presumably, three main options in response to the recommendation:

- adopt the recommendation,
- reject the recommendation and do nothing, or
- reject the recommendation and seek to enforce the road rule.

In our view, the option of rejecting the recommendation and enforcing the rule is unlikely to be effective given the level of non-compliance and the practical difficulties of implementing a widespread and almost-continuous enforcement activity that would probably be required. Furthermore, even if enforcement of the scale required were implemented it is not clear that any measurable safety benefits to any road user group would occur.

Adopting the recommendation, or rejecting the recommendation and doing nothing further would, in our view, have largely identical safety outcomes – both would result in the majority of riders riding across zebra crossings as they do currently. In our view the issues are more around:

- whether the high level of non-compliance leads to less compliance for other road rules where the safety benefits are clearer, and
- whether the rule is sufficiently clear and consistent to road users that compliance can reasonably be expected.

In our view the first of these issues may have some minor impact, although this requires that road users understand the rule in the first place. This, in our view, is not altogether clear – leading to the second issue of clarity and consistency. Given that bicycle riders of all ages are permitted to ride on footpaths in Queensland, and that at some sites such as Moggill Road a cycleway connects to the zebra crossings, it appears to us that requiring riders to dismount at zebra crossings is unlikely to be widely understood, or at least seen by riders as inconsistent with other road rules. As such, in our view there is a reasonable argument that accepting this recommendation would lead to a more consistent set of road rules.

Given the high non-compliance with the rule currently we would not expect any material change in rider behaviour and hence no real change in safety outcomes as a result of changing the road rule. Instead, the change would simply bring the road rule in-line with observed rider behaviours. Any change in safety outcomes, be they for bicycle riders, pedestrians or motorists, are more likely to come from other changes – such as improving the visibility of existing zebra crossings and reducing motorist speeds in their vicinity (such as through the use of raised tables). In our view there is sufficient evidence to suggest that the rule should be altered to allow riding on zebra crossings, and that the relevant road authorities should consider the wider use of zebra crossings on raised tables as a means of improving safety for pedestrians and riders.

5 Conclusions

5.1 General

We suggest there are three general conclusions which come from this study into three particular conditions:

- The safety evidence for, or against, some traffic engineering treatments is limited and often inconclusive. In turn, the origins of the design guidance often appears to be based, at least in part, on professional judgement rather than empirical data.
- The three situations observed in this study all had very high levels of non-compliance with the current road rules. While not surprising, this raises important philosophical and practical questions as to (a) the effectiveness of certain road rules if they are widely ignored (or simply unknown), and (b) whether this non-compliance leads to lower compliance with other, safety critical road rules.
- The rate of non-compliance suggests that effective enforcement of the current road rules related to the three recommendations, would be very costly and time consuming (and may have no meaningful impact on crash reduction).
- Changing any or all of these road rules will have little impact on road user behaviour and so have minimal impacts on crash burden.

The first of these comments is not intended as a criticism of the traffic engineering profession. Instead it reflects the significant methodological difficulties in measuring the safety effect of treatments. Furthermore, it reflects the fact that all situations are different; no general rule will hold at all locations. This points to the need for common-sense risk assessments to be considered on a site-by-site basis.

Whether non-compliance for particular road rules leads to a weakening of other road rules (the “boy who cried wolf” theory) would be exceptionally difficult to prove, or disprove, empirically. We err to the view that widely ignored road rules should be avoided, but that to some extent they are inevitable. After all, it is highly unlikely road users fully understand the complexities within the road rules in any case. Far more likely is that road users respond to the road environment based on their experiences and with a peripheral understanding of the rules of behaviour.

Finally, resources dedicated to enforcement should (self-evidently) focus on those areas where the greatest safety benefit can be gained. Given the widespread non-compliance with the road rules pertinent in this study, and the seemingly low crash frequency resulting from this non-compliance, it is difficult to make a case to allocate resources to enforcement. Of course, this is a general statement – there may well be confined instances with a crash history where such enforcement is warranted. Nevertheless, we would suggest that non-compliance is so high, and in some cases for both riders and motorists (i.e. failing to stop at stop signs), that enforcement is only ever likely to have at best a short-term impact on behaviour. Far more effective would be engineering measures which provide the cues to road users as to the expected behaviour – or the adjustment of the road rules or site specific conditions to formalise the pre-existing behaviours.

5.2 Rolling stop

This study has identified very high levels of non-compliance with stop signs by both motorists and bicycle riders. In our view, this non-compliance is unlikely to be a major contribution to crashes, or at least is less important than factors such as speeds, sightlines and road users ensuring they carefully scan for conflicting traffic. Changing the road rule to allow bicycle riders to roll through stop signs would have negligible safety effects, as most riders already do so. While this would have the desirable effect of bringing road rules and behaviours into alignment it would not address motorist non-compliance. As such, our preference is to identify stop signs that do not conform to the current warrant condition and, unless there are strong merits for their retention, convert to give way control. Furthermore, there may be benefit in refining the MUTCD guidelines to be more explicit about the warrant requirements for stop signs.

5.3 Left turn on red

In our view allowing for a general exemption for bicycle riders to turn left at traffic signals would be unwise given the potential safety repercussions. It could be argued at specific sites that an exemption is warranted (such as with the use of signs) if sightlines are good and signal cycle times are so long that riders are otherwise unlikely to obey the signal in any case. However, even in these circumstances there remains the prospect that the credibility of signal control is diminished. This would be highly undesirable given the critical importance of this type of intersection control to safety and mobility on the road network. Given these concerns, in our view this proposed road rule change should not be adopted.

Instead of adopting this rule, it is suggested that where riders are observed to disobey signals (such as at Agnew Street) further investigation is warranted into the motivation for doing so, and in providing safer alternatives. Possible measures may include:

- Improve signal timing (cycle times) so as to reduce delay to riders (and motorists) turning left.
- Where detection is present ensure inductive loops are positioned such that riders will travel over them when approaching the intersection, and they are tuned such that they will detect bicycles.
- Provide off-road bypass routes, such as angled kerb ramps onto footpaths to allow riders to safely avoid signals while maximising level of service.

5.4 Riding across pedestrian crossings

Permitting bicycle riders to ride across pedestrian (zebra) and school crossings would, in our view, be consistent with existing rider behaviour and have negligible safety repercussions. The main safety issue will arise not with the rider on the crossing itself but rather approaching the crossing and ensuring sightlines are sufficient for them to see motorists and vice versa. One option may be to require riders to stop before proceeding to ride across these crossings. While this would clearly resolve this safety issue if riders were to do so, our view is that this is highly unlikely given the desirability of riders to maintain balance and momentum. Far better in our view would be to address the overall design of these crossings by seeking to reduce speeds between the conflicting movements to within safe limits.

There is good empirical evidence to suggest that the use of raised tables at pedestrian crossings improves safety for pedestrians. It seems reasonable that similar benefits would accrue to bicycle riders, as well as to motorists. In our view, the outcome that would maximise both safety and mobility would be to allow riders on pedestrian crossings and to prioritise the upgrading of crossings where significant numbers of riders are expected.

5.5 Further work

We suggest the following as potentially useful means of improving our understanding of the safety repercussions for these road rule recommendations:

- General:
  - Should one or more road rule recommendation be adopted, that crash statistics (ideally both police and hospital data) be reviewed a reasonable time after introduction (3-5 years) to ascertain what, if any, impact on safety the change may have had.
  - Should one or more road rule recommendation be adopted, that a before-after study of road user behaviours be undertaken to ascertain what, if any, change in road user behaviours has occurred so as to infer what safety outcomes may be expected.
  - Should enforcement be desired at one or more sites to evaluate the change in behaviour before and after the enforcement action is undertaken in order to determine its' effectiveness.
- Rolling stop:
  - Consider driver simulator-based trials with motorists at stop and give way sign controlled intersections to understand (a) whether motorists notice the sign control, and (b) if so, how their compliance, speed and visual scanning differs between the controls.
  - Conduct before-after observations at one or more intersections where a give way sign is replaced with a stop sign (or vice versa) in order to determine what effect the sign control is having on road user behaviour.
- Left turn on red:
  - It was difficult in this study to identify signalised intersections without slip lanes where there was a reasonable number of left turning riders and pedestrians on the adjacent crossing. If such a site is identified it may be warranted to conduct observations at the site to better understand the interactions that occur between riders who turn left (both compliant and against the signals) across the path of pedestrians.

- Pedestrian crossings:
    - Consider driver simulator-based trials with motorists, or perhaps real-world trials, to ascertain the ability of motorists to detect riders approaching a zebra crossing and the visibility splays that may be warranted in engineering guidance.

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