OPPORTUNITIES TO IMPROVE CYCLIST SAFETY IN BUS LANES

Author/Presenter: Daniel Newcombe, MEngSt (Transportation), BPlan, MNZPI

Senior Transport Planner, Auckland Transport

daniel.newcombe@aucklandtransport.govt.nz

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ABSTRACT

Given the trend towards increased use of cycling and public transport as travel modes, this study follows on from previous work which identified the road safety risks to cyclists (and motorcyclists) using bus lanes. The role of queuing behaviour and visibility into gaps within traffic queues is assessed and opportunities for an effective low cost measure to reduce the hazard to cyclists, motorcyclists and other road users is then analysed and discussed. The results of recent bus lane surveys are used to discuss the likely benefits of certain treatments, along with further research underway. The research will provide useful information to road safety advocates, transport planners and road designers, and assist in safely designing future bus lane routes.

INTRODUCTION

This study follows on from a previous investigation (Newcombe, Wilson 2010) into whether the implementation of bus lanes created new types of hazards for cyclists and motorcyclists. That study found no discernable increase in cycle or motorcycle crashes along bus lane routes in general following the implementation of bus lanes, indicating overall that the implementation of bus lanes do not reduce the safety of cyclists or motorcyclists.

It was found, however, that bus lane widths affected cyclist crash rates, with more generous bus lane widths (up to the recommended design standard of 4.5m) resulting in a lower than predicted cyclist crash rate, whereas a narrower than standard bus lane width (down to 3.0m) resulted in a higher than predicted cyclist crash rate. Another area where bus lanes were found to create a change in the pattern of cycle or motorcycle crashes was in relation to the location. The results showed a consistent increase in the proportion of cycle or motorcycle crashes occurring at intersections.

This study further investigates that issue by examining opportunities to resolve conflict between cyclists or motorcyclists using the bus lane and turning vehicles at side streets. Observations show that queued motorists tend to courteously leave a gap in the queue for turning vehicles at side streets, and turning motorists tend to quickly take the opportunity provided but have reduced visibility into the bus lane due to the queued vehicles.

Cyclists and motorcyclists, who may legally use the bus lane, then come into potential conflict with turning vehicles (refer to Figure 1). Motorcyclists are particularly at risk, due to their higher speeds. Drivers of turning vehicles are 'looking for buses' and visibility into bus lane is affected by the size of the gap left in the traffic queue.

Figure 1 – Burnley Terrace/Dominion Rd – Right-turning vehicle with limited visibility has come close to colliding with oncoming motorcyclist in bus lane

Analysis of this situation is warranted due to the increasing use of passenger transport and cycling as travel modes, and hence the increasing presence of both bus lanes and cyclists on Auckland roads. This study specifically considers bus lane routes. It is noted that in multi-lane arterial roads without bus lanes, traffic queues tend to be equally split between both lanes and right turn movements can only occur when queued motorists in both lanes leave a gap – hence there is less chance of conflict with an obscured kerbside vehicle approaching at speed.

CYCLING ISSUES CONTEXT

Auckland Transport and NZTA's most recent analysis of cycle crashes (November 2010) showed that the Auckland and Canterbury Regions had the highest number of cycle crashes and the highest number of fatal and serious crashes. In the five-year period of 2005-2009, Auckland Region recorded 1044 reported cycle crashes, resulting in 5 fatalities and 172 cyclists with serious injuries. 885 cyclists received minor injuries. The total social cost of those reported cycle crashes in the Auckland Region is estimated at $196.1m (in 2010 dollars). Figure 2 shows the location of those crashes within the former Auckland City geographical area.

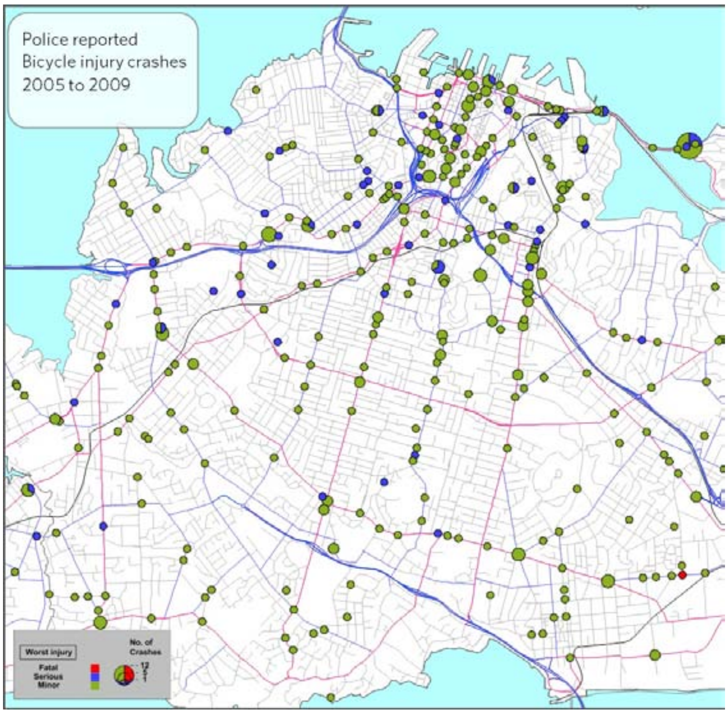

Figure 2- Auckland city injury crashes involving cyclists 2005-2009

Figure 2 indicates that most crashes occur on major arterial routes, particularly close to the CBD. Such locations are also commonly were bus lanes are found. Of the 1044 cycle crashes in the 2005-2009 period, 58% occurred at intersections, 95% on urban roads, 86% in daytime, with the worst month being March and with the worst period being 3pm to 6pm. This strongly suggests commuter cyclists make up the majority of casualties.

As with most crashes, cyclist crashes are usually the result of multiple factors, with an average of 2.1 factors identified per crash. The two most common causes of cycle crashes were "Poor observation" and "Failed to Give Way/Stop", which are both relevant to this study's area of investigation. In over 80% of these crashes the driver was at fault, indicating that there is a real problem with motorists not checking properly for approaching cyclists when turning into or out of a side street.

Most recent census results (2006) show that cyclists made up only 1-2% of the total Auckland City commuters, a level which has remained relatively steady over the last decade (Auckland City Council, 2008). However this figure excludes cycling for any other trip purpose, such as to school, university or for shopping or recreation, so underrepresents the number of cyclists on Auckland roads.

Auckland Transport undertakes an annual cycle count at a total of 84 sites across the Auckland Region during the morning and evening peaks. In 2010, a total of 12,625 cyclist movements were recorded, an increase of 27% over 2009. The cyclist volumes are noticeably higher in dense urban locations, again indicating that a large proportion of those cyclists are commuters. Comparing this to cycle injury crashes grouped by the same geographical areas, there is clearly a correlation between commuter cyclist volumes and cycle crash injuries (see Figure 3).

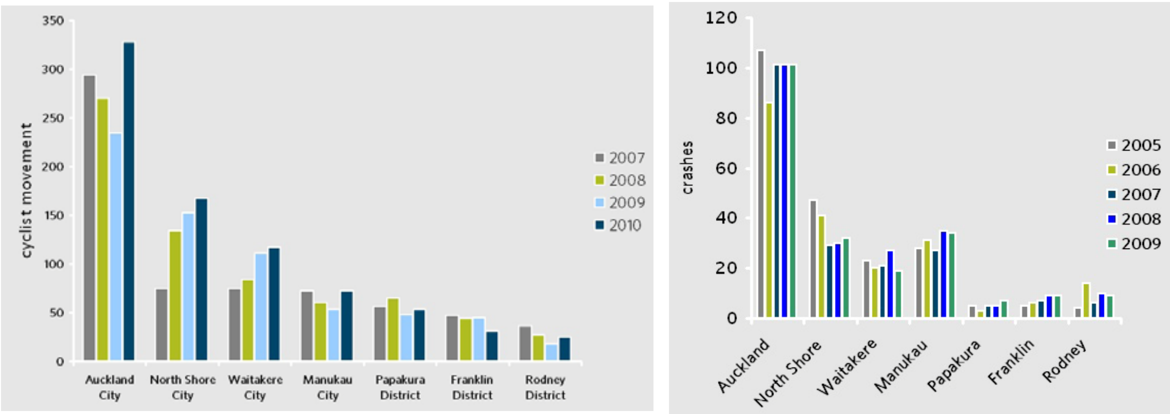

Figure 3 – Average total cyclist peak period movements and injury crashes involving cyclists by (former) local body (2007-2010)

Of particular relevance to this study, the Auckland Region's most common crash type is "other party turns right in front of cyclist travelling straight ahead", commonly at intersections (21% of all crashes). The highest number of crashes occur at T-intersections (380 out of 602 intersection crashes).

Analysing the "movement" types classified within the Ministry of Transport's Crash Analysis System (CAS), the most common injury crash types for both major and minor urban roads tend to involve vehicles turning from or into side streets. Figure 4 shows the top three crash types for major urban routes, and cyclists are almost always represented by the bold arrow in the diagram. From left to right, these movement types accounted for 167, 79 and 61 cycle crashes respectively, in the 2005-2009 crash data.

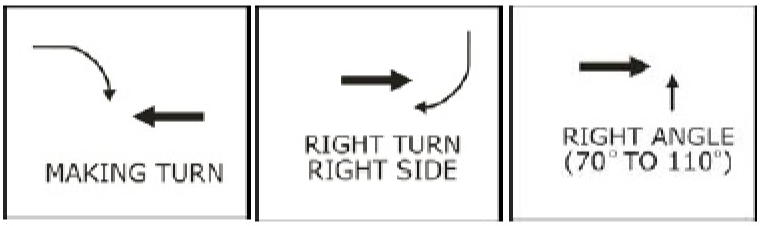

Figure 4 – Auckland's 3 most common cycle crash "movement" types for major urban roads

In a GIS clustering study of Auckland cycle crashes, Horspool found that over 90% occurred within 20m of an intersection and the number drops off exponentially as that distance is increased. Crash frequency was at the greatest density in the CBD, as would be expected, due to the greatest vehicle exposure, with the other main risk area being at busy intersections near shops.

Turner (2006) found that cycling has a higher crash risk than motorised modes of transport, and that the causes tend to be different from those of motor-vehicle crashes. Turner (2006) also found that most reported cyclist crashes occur at intersections and 60-75% involved motor vehicles. Koorey (2005) found that 59% of reported urban cycle crashes are at intersections.

Looking specifically at studies on bus lane routes, Ragland (2008) found that many vehicles failed to give way to pedestrians and cyclists. On-road cyclists were noted as having difficulty navigating among vehicles during lane changes, something not necessarily peculiar to bus lane corridors.

INITIAL DATA COLLECTION

This study follows on from previous analysis which examined the five year periods before and after the installation date of four typical urban bus lanes, with multiple side streets and generally consisting of two bus lanes and two traffic lanes. For comparison purposes, a ‘control’ route (New North Rd) without a bus lane was also selected. Crash data was obtained from the CAS database for every recorded crash involving a ‘cycle’, ‘moped’ or ‘motorcycle’. The small data sample is acknowledged and is the result of the low number of bus lanes installed long enough ago to have a sufficient post-implementation crash record (only 4 out of 22 bus lanes).

Table 1- Selected bus lane routes and details

Bus Lane Route and Location	**Year installed**	**Approximate Length (km)**	**Typical bus lane width**
Dominion Rd – Memorial Ave to View Rd	1998	3.7	3.0m
Mt Eden Rd – Wairiki Rd to Symonds St	1998	3.1	3.25m
Sandringham Rd – Grove Rd to New North Rd	1999	2.0	3.25m
Great North Rd – Pt Chevalier Rd to Newton Rd	2000	4.2	4.5m
New North Rd – Symonds St to Kitenui Rd **‘Assumed’ year of implementation to allow useful comparison to bus lane data*	2000*	3.9	3.3m

The results of the assessment showed that in general, there was no increase in cycle or motorcycle crashes along bus lane routes following the implementation of bus lanes, with the sole exception of Dominion Rd – where a large increase was recorded. This would indicate that there are specific circumstances along Dominion Rd which have led to this increase, and those circumstances do not apply to the remaining studied routes.

As can be seen in Figure 5 below, the number of crashes in the years following the introduction of bus lanes along Dominion Rd rose by over 30%, whereas each of the other routes experienced a reduction or slight increase (which, given traffic volume increases, is effectively a reduction). These results would indicate that the implementation of bus lanes on these routes had little, if any, overall effect on the safety of cyclists or motorcyclists – pending the identification of the factors contributing to the Dominion Rd crash increase.

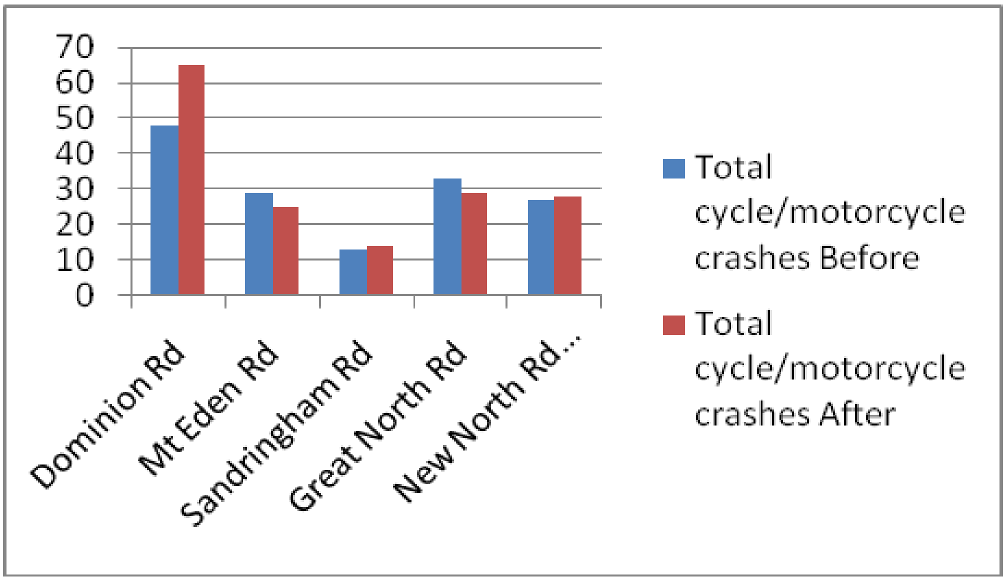

Figure 5 - Total cycle/motorcycle crashes before and after bus lane implementation

Whilst the small sample size limits the ability to apply the findings far, one issue where the previous study found that those bus lanes created a change was in relation to the crash location. The results showed a consistent increase in cycle or motorcycle crashes at intersections after bus lanes had been installed (refer Figure 6). In comparison, the control route of New North Rd experienced a substantial decrease in such crashes. A reason for this may be the reduction in conflicting interaction between cyclists or motor-cyclists and general traffic along midblock locations, where bus lanes are more typically present.

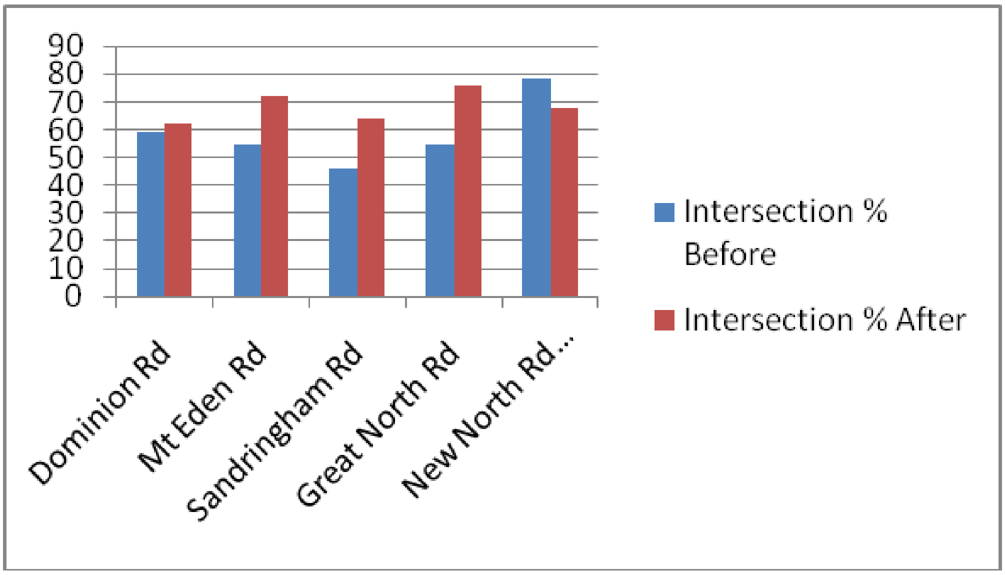

Figure 6 - Percentage of cycle or motorcycle crashes occurring at intersections before and after bus lane implementation

A further assessment of the previous study involved the relative cycle crash rates of the routes, using NZTA's Economic Evaluation Manual (Appendix A6, 2009). As two routes did not record cyclist data, these were excluded from the analysis, as such data is necessary to determine typical crash rates.

After calculating the existing ("Actual") crash rates, the previous study then determined the expected or typical crash rates for these routes. Midblock and intersection results were combined into a representation of the typical annual crash rates for cyclists on these routes ("Combined results"). These were then compared to the actual crash rates (see Table 2).

Table 2 - Expected cyclist crash rates per annum compared to actual

Route	Typical midblk. rates	Typical int. results	Combined results	Actual rates	Ratio actual/typical
Dominion Rd	2.158	0.114	2.272	4.98	2.19 ≈ 2.2
Great North Rd	2.590	0.199	2.789	1.49	0.53 ≈ 0.5
New North Rd	1.319	0.128	1.447	1.49	1.03 ≈ 1.0

These results showed that Dominion Rd has more than double the expected cycle crashes, whilst Great North Rd has around half the expected cycle crashes. Interestingly New North Road, the control route, has almost exactly the expected number of cycle crashes.

A likely explanation is that the Dominion Rd bus lanes are 3.0m wide, whereas the Great North Rd bus lanes are typically closer to the 4.5m recommended standard width. The New North Rd traffic lanes vary in width but are typically 3.25-3.5m. T

his would seem to indicate that the more generous bus lane widths (up to the recommended widths) result in a lower cyclist crash rate, whereas a narrower than standard bus lane width can increase the cyclist crash rate. There seems to be little else to differentiate the routes from each other in a way that aligns with the ratio of actual versus typical crash rates.

FURTHER ANALYSIS

The results of the previous study raised a range of issues, in particular in relation to whether the increase in intersection crashes was related to queuing in the general traffic lane. Visibility for turning vehicles is affected by the size of any gap left in that queue, and this may increase the risk to cyclists or motorcyclists using the bus lane.

A road safety treatment of the side street intersections on bus lane - one that better provided for a consistent and sufficiently 'large' gap - would appear to have merit.

In mid-2011, an initial survey was undertaken at four Dominion Rd side street sites - one with a holding line ahead of a side street, one with holding lines on both sides of a side street (see Figure 7) and two with no treatment.

247 peak period queuing incidents were observed and assessed in terms of whether a gap was provided at a holding line (or at equivalent where none was present), a sufficient other gap was provided (beyond where a holding line was or would have been), or whether an insufficient gap was provided (including no gap at all).

Figure 7 – Wiremu St/Dominion Rd intersection, showing holding lines to encourage better queuing behaviour

The survey found that where a holding line was present, an average of 57% of drivers observed it, and where no holding line was present an average of 33% of drivers observed the equivalent location (see Figure 8).

Figure 8 – King Edward St/Dominion Rd intersection - Example of a vehicle observing a holding line and providing a sufficient gap at a side street

Conversely, where a holding line was present, an average of 22% of drivers blocked the side street, and where no holding line was present, an average of 51% of drivers blocked the side street (see Figure 9). This indicates that if a holding line is present, more vehicles will queue in a position to provide turning side street vehicles with visibility and, without a holding line, more queuing vehicles will block the side street to turning drivers.

Figure 9 – Bellwood Ave/Dominion Rd intersection - Example of queued vehicles blocking a side street

It is the author's suggestion that greater visibility into and out of a bus lane provides greater safety for on-coming cyclists and motorcyclists, so there appears to be merit in considering a treatment such as holding lines.

It is noted that a holding line only indicates where vehicles should (not must) stop and has no legal significance, as it is not associated with any other traffic controlling features (e.g. a stop sign, pedestrian crossing, etc.). However, the application of a holding line suits the purpose under consideration in this study.

In particular, as noted in Section 3, cyclist volumes are highest on major arterial routes during peak commuter periods, which is also when the greatest traffic queues occur. So the highest number of potential crash victims are using the routes when the risky behaviour – the inconsistent provision of sufficient visibility by queued vehicles – is at its most frequent.

DISCUSSION OF IMPROVING QUEUING BEHAVIOUR

Whilst there are a range of possible treatments for encouraging better queuing behaviour, many of these have costs or impacts that may holding their implementation. Holding lines, as tested in the survey, are a fairly common treatment which appears to be reasonably effective. It is suggested that these would be best applied to both the arrival and departure side of a side street (as shown in Figure 7 above), to clearly mark the start and end of what may be considered an appropriately sized gap.

Holding lines, which need only be installed across the general traffic lane, have the advantage of being cheap to install and maintain, with minimal impact upon street amenity (although this may result in them not always being perceived by motorists).

Alternatively, the application of a yellow hatched area is often used in high risk locations or sites with significant queuing issues and is likely to be effective at side streets. However, there is a higher installation and maintenance cost, a higher impact upon street amenity and as Figure 10 shows, hatching is not always effective in preventing poor queuing behaviour.

Figure 10 – Queued vehicles upon yellow hatched area

'Keep clear' markings are known to be effective if fully visible, but are not as effective if partially obscured and are not suitable to be applied across two lanes. The repeated wording may also have a higher impact upon street amenity.

Green surfacing could also be considered as it has an association with the presence of both cyclists and buses, however green surfacing signifies a bus lane and/or cycle lane but gives no guidance for queuing behaviour. Such a treatment is also likely to be too expensive to be widely applied and may have a higher impact upon street amenity.

Warning signs at side streets are unlikely to be perceived – due to street clutter – but, more importantly, it may be difficult to clearly identify their intended purpose (e.g. a PW35 warning sign does not indicate the specific hazard, just the presence of cyclists).

Given the treatment options, it is the author's recommendation that holding lines be applied before and after side streets at bus lane locations where queues are known to regularly occur (there being little reason to install a treatment where queues rarely or never occur).

Holding lines appear to be an effective low-cost treatment to create a sufficient and consistent gap to provide turning vehicles with visibility of cyclists and motorcyclists in bus lanes

Having considered this recommendation, Auckland Transport's Road Safety team has sought additional investigation into the appropriate application of holding lines (i.e. those factors determining situations where holding lines should be installed). Trials are currently under development to determine any application issues and the likely safety benefits.

The author is currently undertaking the 'before' assessment of queuing behaviour at a range of urban bus lane intersections, utilising Auckland Transport's CCTV cameras. It is intended that holding lines will be added in the near future, to enable post-implementation monitoring (see Figure 11 for example).

Figure 11 – Example of CCTV image from current trial site – before (left) and after proposed treatment (right)

Once an appropriate period of monitoring has occurred, these results will be reported upon. If the trials result in better queuing behaviour and/or improved road safety, Auckland Transport have indicated a willingness to add holding lines to the bus lane marking standards.

Although this treatment was initially considered to address cycle and motorcycle crashes, the Road Safety team considers that improved queuing behaviour and greater visibility for turning vehicles may also result in reductions in other vehicle-versus-vehicle crashes.

Whilst the trials are still at an early stage, with the assistance of the Road Safety team, further analysis has been undertaken into the specific locations of relevant crashes. The author created a list of every non-signalised intersection on urban bus lane routes within the Auckland Region, and identified those where regular traffic queuing is known to occur. Typically these locations are closer to the city centre or ahead of major signalised intersections. Intersections with recent road safety or other engineering interventions (which meant an uninterrupted five-year crash history was not available) were excluded.

The Road Safety team then provided 2006-2010 CAS data for those sites, in all cases for only the time period during which the bus lane was operational and crashes in the direction of that bus lane. The information sought was for those crash types which were considered to be likely to be affected by queuing behaviour (for instance, rear-end and turning crashes – where unexpected stopping or starting can be a factor) but excluded those crash types unlikely to be related to queues (such as loss of control or head-on crashes).

It is the author's proposition that improved adherence to a 'safe' gap in traffic queues at side street intersections – through the introduction of some kind of treatment, such as holding lines – will reduce the occurrence of the former crash types generally, but not the latter.

This analysis produced information on side street crash types and plans showed clustering at particular intersections. This indicated that every bus lane route has different characteristics, each with a varying mixture and frequency of crash types, however the plans are useful in highlighting those intersections (and, to a lesser extent, routes) with particular crash trends.

Figure 12 shows crashes at non-signalised intersections for northbound vehicles on Dominion Rd between 2006-2010 during the 7-9AM peak period. This shows a high proportion of right turn crashes and rear-end crashes.

Although this plan includes all vehicle types, half of the crashes (9 out of 18) involve cyclists or motorcyclists, which appears unusually high, given that cyclists would typically make up 1-2% of road users. The circles highlight the areas where traffic queuing is known regularly occur during this peak period, and it would appear that these locations correlate to where crashes are occuring.

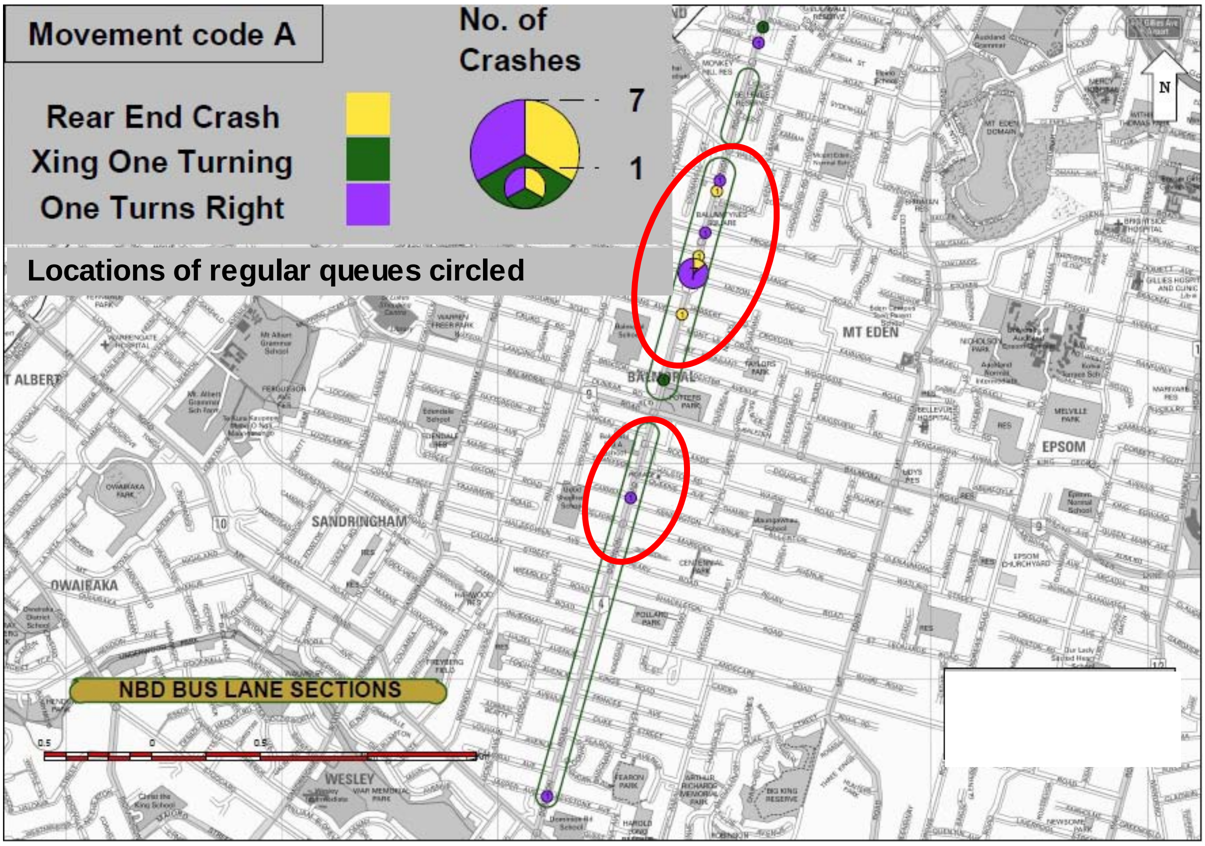

Figure 12 – Crashes at non-signalised intersections for northbound vehicles on Dominion Rd between 2006-2010 during the 7-9AM peak period

It is intended that the data on each of the bus lane routes will be further assessed and combined with the results of the holding line trials so that a programme of road safety treatments and a list of relevant criteria can be developed for consideration by the Road Safety team.

It is also intended that this be compared to routes where comprehensive treatments have been implemented (such as repeated 'Keep Clear' markings installed at intersections along the Onewa Rd bus/HOV lane) to determine any potential learnings from those treatments. As this analysis will require sufficient time for 'after' surveys, the results cannot be included in this study, however these will be reported upon in the future, as the third stage to this line of inquiry.

CONCLUSIONS

The study has shown that:

a) If a holding line is present at a non-signalised intersection on a bus lane route, more vehicles will queue in a position to provide turning vehicles with sufficient visibility.

Conversely, without a holding line, queuing vehicles are more likely to block the side street to turning drivers. So, a holding line improves queuing behaviour.

b) It is the author's suggestion that greater visibility into and out of a bus lane from a side street provides greater safety for on-coming cyclists and motorcyclists, and treatments and implementation criteria should be assessed further for the likely benefits this may create. It is considered that benefits will extend to other crash types not involving cyclists or motorcyclists.

c) Holding lines appear to be an effective low-cost treatment to create a sufficient and consistent gap to provide turning vehicles with visibility of cyclists and motorcyclists (and other vehicles). It is suggested that these be applied before and after side streets at bus lane locations where queues are known to regularly occur.

It is recommended that the current trials and assessments underway be reported upon once completed, so that preferred treatments, likely benefits and implementation criteria can be shared across the road safety and transport profession.

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