THE SAFETY PERFORMAMCE OF PRIORITY THREE LEG INTERSECTIONS – SEAGULLS AND LEFT TURN SLIP LANES

Dr Shane Turner, National Specialist – Road Safety

MWH New Zealand Ltd, 6 Hazeldean Road, Hazeldean Business Park, Christchurch

E-Mail: shane.a.turner@mwhglobal.com

Professor Graham Wood, Statistician

Research Consultant, Dunedin, New Zealand

E-Mail: graham.wood2014@gmail.com

Umesh Padcham Transport Engineer

BE Civil Engineering, University of Canterbury

MWH New Zealand Ltd, 6 Hazeldean Road, Hazeldean Business Park, Christchurch

Email: umesh.easwarapadcham@mwhglobal.com

Shaun Bosher, Transport Engineer

BE (Hons) Civil, Dublin Institute of Technology, Ireland

MWH New Zealand Ltd, 6 Hazeldean Road, Hazeldean Business Park, Christchurch

Email: shaun.bosher@mwhglobal.com

ABSTRACT

A number of priority intersection enhancements are used to reduce traffic delays and improve road safety. This includes various types of seagull intersection layouts and the additions of right turn (right turn bays) and left-turn slip lanes (LTSL). There are however safety concerns with some seagull intersections and LTSL. The purpose of this research was to identify those features of priority intersections incorporating either seagull layouts and/or LTSLs, which impact on safe intersection performance. Seagull intersections are an alternative to traffic signals and roundabouts at congested priority intersections, as they can reduce right-turn out delays without impeding main road through traffic flow. However some poorly designed seagull intersections experience high crash rates. This research outlines the safety analysis undertaken on a sample of urban and rural priority T-intersections, with and without seagull intersection treatments and LTSL. It presents the different types of rural LTSL present on road networks and the various types of urban and rural seagull intersections, including varying levels of painted and solid channelisation. The assessment identified a number of intersection layouts that sit between a ‘standard’ priority intersection and a full seagull intersection. Most notably, those intersections which provide a waiting area for right turning vehicles (within a solid median), but do not provide the acceleration lane (a feature of seagull intersections). A variety of statistical analysis methods have been used to explore the relationship between crashes and various features, including crash prediction modelling.

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INTRODUCTION

A high proportion of both urban (low speed) and especially rural (high speed) intersections have priority control; either stop or give-way control. Of the priority controlled intersections the majority have three legs. National data indicates that 64% rural intersection and 43% urban intersection injury crashes occur at three leg priority intersections in New Zealand. This shows that crashes at these intersections are a relatively large proportion of all intersection crashes even if the number of crashes at each intersection is generally lower than other forms of intersection control. The data also shows that 64% rural intersection and 52% urban intersection serious injury and fatal crashes occur at three leg priority intersections. The crash severity factors in the New Zealand Crash Compendium (NZTA, 2015) also show that almost a third of crashes at rural priority T-junctions are serious injury or fatal. This compares with 18% and 20% at rural roundabouts and three arm traffic signals respectively.

While the size of the road safety problem is relatively large the high number of intersections out on the network makes targeting these crashes with safety improvement treatments difficult. Most road controlling authorities use standards/guidelines and warrants to manage the design and safety of such intersections. RCA's rely on a combination of markings and signage to manage safety. Warrants are used to determine if left and right turning lanes or localised widening are required at such intersections. Recent work by Sullivan and Arndt (2014) has developed new warrants for right turn and left turn bays at priority intersections. Only a small number of such intersections receive attention in crash reduction studies or traffic capacity upgrades, especially in rural areas. Its predominately higher volume intersections that get this attention.

This research looks at the priority intersections that have been designed or upgraded to improve capacity of the intersection and/or road safety. The two most common upgrades at priority three leg intersections are the installation of right turn bays and left turn slip lanes. In this study we have focused left turn slip lanes (LTSL) at rural (high speed) intersections. The primary benefit of these lanes is to provide room for left turning vehicles to partially or fully decelerate when turning into a side-road. Hence they are installed to reduce the likelihood of rear-end crashes which are relatively rare, compared to other crash types, and typically have a low level of crash severity; rarely cause a serious injury or fatal crash. Of particular concern, and the reason for looking at this treatment, are situations where the design of the left turn facility reduces the visibility of right turn out traffic to through traffic, i.e. where the left turn in traffic block visibility lines to through vehicles. The concern here is that the crash type that involves right turn out versus through vehicle from the right is a more frequent crash type and more likely to cause serious injury or fatalities due to the side collision with the driver's door. The various designs of left turn lanes and the situations where visibility may be restricted are examined in this paper.

The research also looks at the safety performance of both urban and rural channelised intersections, and specially the 'seagull' layout. In the 'seagull' layout the right turn out of side-road vehicle crosses first the right to left through traffic to a protected central median before merging, via an acceleration lane, with traffic traveling left to right at the intersection. While the break-down of the right turn out into two movements on the surface has both traffic efficiency and road safety benefits compared with having to cross the two-direction main road traffic, the experience across New Zealand and Australia is that these intersections have a poor road safety record. Some seagulls have had very high crash rates, most likely due to poor design. This research examines (through the use of crash models and other analysis methods) whether well designed seagull have a similar, better or worse road safety performance compared with other high volume three leg priority intersections, in urban and rural areas. For those 'seagull' intersections that have a poor crash history the research attempts to isolate the design or other factors that cause this outcome.

The first section of the paper looks at the limited research available on the safety performance of seagulls and the safety issues associated with LTSL. The next section looks at the various types of three leg priority intersections, and specially the various types of LTSL treatments and the various channelised intersection options that fall between a standard priority intersection with a right turn bay and a fully channelised (solid median) seagull layout. The following section presents the sites that were selected for analysis and variables that were collected for each intersection. The last section before the conclusion/summary presents the selective results of the preliminary analysis and crash prediction modelling and a discussion on these findings. Crash modelling in this study is ongoing.

SEAGULL INTERSECTION AND LEFT-TURN SLIP LANE RESEARCH

The literature review focused on research of priority controlled seagull intersections and priority intersections that have LTSLs (particularly from the main road into a side-road). Across New Zealand there are a variety of existing types of seagull intersections. Figure 1 shows a typical example of a rural seagull layout. Seagull intersections have three key characteristics, 1) a seagull shaped 'splitter' island between through and right turning traffic on main road, 2) a merge lane with acceleration taper for right turn traffic turning out of side road and 3) at least one bypass lane for traffic traveling straight through from left to right. Figure 1 also shows two left turn slip lanes (LTSL) into and out of the side-road. There are a variety of different layouts, from small painted islands up to large solid left turn island (as shown at this site).

Figure 1: Typical Seagull intersection (with LTSL) in New Zealand

There is limited research available on seagull layouts (called chanelised layouts in other parts of the world). Tang and Levett (2009) identified that two major crash types (right-near and right-through) were predominant in all crashes at seagull intersections in New South Wales (refer to Figure 2). The multivariate study of potential crash causing factors provided very little evidence on why these crashes were occurring. The study did show that young female drivers and older (≥ 67 years old) male drivers were over-represented in the two main crash types. A potential explanation for the older age group demographic was the diminishing cognitive ability of older drivers, which may be causing them to misjudge appropriate gaps in the traffic.

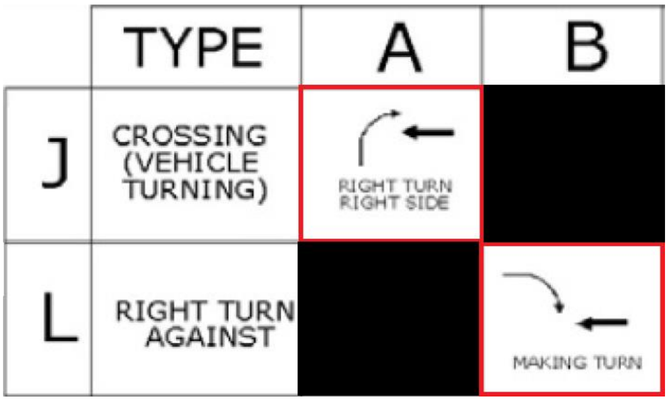


Figure 2: The two most common crash types at seagull intersections (NZ crash coding)

Radalj, et al., (2006) analysed the crash data and the design, of 76 seagull intersections in Perth, Western Australia. The study identified that seagull intersections installed as per the recommended guidelines, do not result in any significant (positive or negative) change in the type or number of crashes. However, where the intersection angle did not conform to the recommended guidance, the crash numbers and severity increased, especially the latter. The authors recommended that seagull islands should not be considered as an intersection safety treatment (as they had been in the past), as at best they tend to have a similar safety record as a standard T-intersection, and at worse can have a much worse safety record.

Elvik, et al., (2009) based on several international studies has concluded that the safety effect of chanelised passing lanes at T-junctions (seagull equivalent) is to increase the crash risk by 26%. However, opinion regarding the assignment of a crash reduction factor to a seagull intersection treatment generally appeared to be divided, given the wide range of research results found in various studies.

Summersgill, et al., (1996) investigated the frequency and character of crashes in relation to traffic flow, road features, layout, geometry, land-use, and other variables in the UK. They produced crash prediction models for various traffic movements at different junction and link types. For some of the movements the models also included the effect of channelisation. The found an increase in ‘JA’ crashes of 50%.

Harper, et al., (2011) researched the safety performance of three design variations of a seagull intersection design for the A1 Highway / Island Point Road intersection in New South Wales, Australia. After the seagull intersection was constructed a number of ‘right near’ (JA) type crashes began to occur. The intersection was subsequently modified to include a short left turn splay that included a small raised concrete splitter island and priority control. However, this did not effectively address the ‘right-near’ crashes, and consequently right-through (LB) type crashes began to occur more frequently. A final modification increased separation between the left-turn deceleration lane and the straight through lane of the major road (as in Figure 3). After which the crashes reduced appreciably. The authors concluded that the two main design issues were; the connection of the left-turn lane with the minor road, and the lack of clear sight lines for vehicles waiting to turn right onto the minor road.

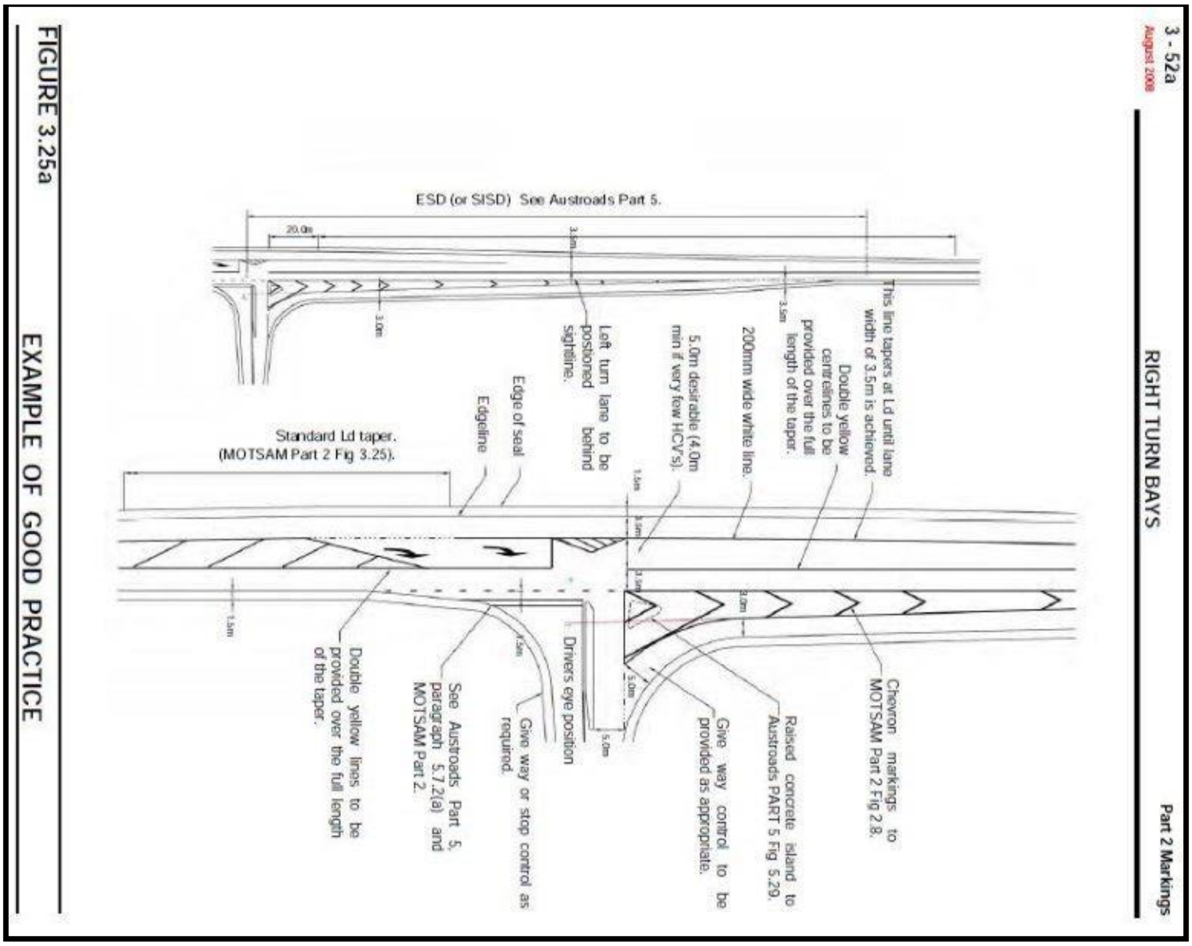


Figure 3 – Seagull with well-designed Left Turn Slip Lane (as in Austroads)

The main reasons for installing left turn slip lanes (LTSL or left turn chanelisation), as identified by Lake (1996), were; 1) when left turning traffic volumes are significant (>100–200 veh/h during the peak hour) and 2) the side road intersects at an acute angle and results in a large area of open pavement and an unacceptable corner radius. The typical standards used for installation of a left turn treatment in Australia and New Zealand are set out in Austroads (2010). Key factors include traffic volume, vehicle type, speed, site constraints and the provision for cyclists and pedestrians.

Research undertaken by Ale et al (2013) identified that the provision of left turn lanes reduces the incidence of rear-end crashes, the crash severity and the associated economic costs. The relationship between vehicle speed and the safety for various left turn treatments was analysed by Fitzpatrick et al (2006). Several left turn designs were explored, including lane line pavement markings, free flowing left turns, channelisation of a free flowing left turn and a left turn lane with a dedicated downstream lane. One of the most serious safety concerns was that large radii curves on LTSL act to increase vehicle speeds, which consequently has a negative impact upon the severity of pedestrian-vehicle crashes in urban areas. Notwithstanding this, it was argued that higher vehicle speeds may result in smaller speed differentials with following vehicles, and as such less severe rear-end conflicts.

Potts et al (2013) built upon the research of Fitzpatrick et al (2006) and identified that intersection approaches with channelised left turn lanes are more likely to reduce the likeliness of crashes when compared to conventional left turn lanes. Potts et al (2013) also identified that intersection approaches with channelised left turns delivered a similar pedestrian safety performance to approaches with shared through and left turn lanes.

Furthermore, intersection approaches with conventional left turn lanes had significantly more pedestrian crashes than channelised approaches.

While the functions and use of left turn lanes are reasonably well documented, the safety benefits and dis-benefits have recently been questioned, particularly in rural/high speed areas. Crashes involving left turn movements were found to be relatively rare (8.5% of all multi-vehicle crashes) compared with other crash types and especially near-side (JA) crashes. Concerns have been raised by safety specialists that at intersections with a lot of right turning out of side-road traffic that poorly designed left turn lanes may lead to an increased risk of near-side (JA) crashes.

Elvik et al (2009) identified from several studies that the provision of left turn lanes at T-junctions acts to increase the number of injury crashes by 12%. Elvik et al (2009) reasoned that left turn lanes may create blind spots where a vehicle turning left can obscure approaching through traffic for road users who are coming from the right side of the road. Elvik et al (2009) also added that large scale intersection channelisation can complicate the road layout, which may increase driver error. Of particular concern is that the more common near-side (JA) crashes tend to be more severe (with collision into drivers car door at speed) than rear-end crashes.

Research by Oh, et al., (2003) (to independently validate statistical models and algorithms in the USA IHSDM crash modelling tool) looked at validating five proposed types of rural intersection crash models used in the USA. The internal validation results indicated the crash models were potentially suffering from; omitted safety related variables, site selection and countermeasure selection bias and poorly measured variables. The external validation indicated the inability of models to perform on par with model estimation performance. Of particular concern is the performance of various types of left turn slip lanes. While the USA Highway Safety Manual (AASHTO, 2013) currently indicates a safety benefit for the installation of left turn slip lanes, some of the studies do indicate that the reverse has been observed; a deterioration in safety. This being a topic that needs considerable more research.

PRIORITY INTERSECTION CLASSIFICATIONS

Priority intersections come in a variety of different layouts. The more basic intersections have a single stop or give-way sign on the left hand side of the side-road and a stop line and associated side-road centre-line. On low volume side-roads it is fairly common to have no right turn bay, even on relatively high volume main roads and highways. As the main road volume increases often shoulder widening is provided at the top of the tee so through vehicles can pass slowly to the left of any right turners waiting to turn into the side-road.

Figure 4 shows and example of a higher volume side-road with right turn bay (from New Zealand Manual of Traffic Signs and Marking, MOTSAM). Notice how there appears to be an area where drivers turning right out of the side-road might be able to wait in the centre of the road. In some cases the line between the right turn-in and through traffic lane does extend quite a distance downstream of the intersection. This in some cases, especially when traffic lanes are wide, may encourage some drivers to wait in the centre of the road when turning right out of the side-road. In-between this design and the full seagull there are many intersections, especially when there is a solid median island, where a proportion of drivers do see an areas they can wait in before merging with through traffic. These are not classified as full seagulls unless there is a proper lane for them to turn into with a tapered acceleration area.

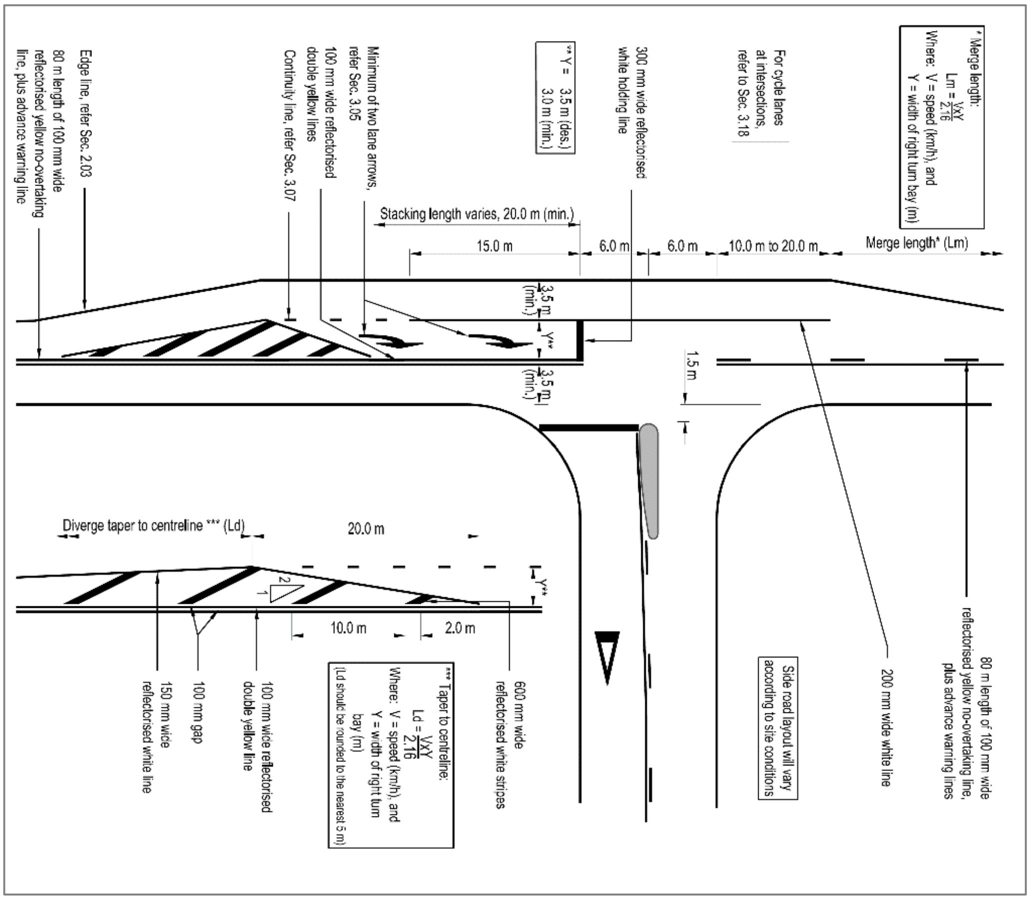
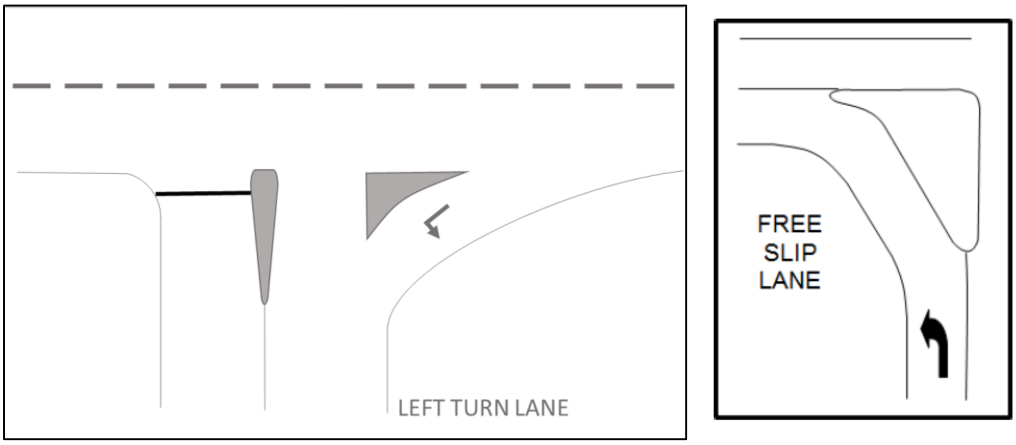


Figure 4: Standard T-intersection with a minor side road (Source: MOTSAM Part 2, NZTA)

Other enhancements that are made to higher volume side-roads include left turn slip lanes. Figure 5 shows the various types of left turn lanes that are commonly used in New Zealand. Median islands are also used as a safety countermeasure at higher volume and high speed priority intersections. This also allows a second stop sign, so that the stop signs are gated on the side-road approach. Median islands are also used in urban areas, where they not only split the directions of travel but also assist pedestrians to cross the side-road. In urban areas left turn slip lanes raised islands can also assist pedestrians when crossing the road.



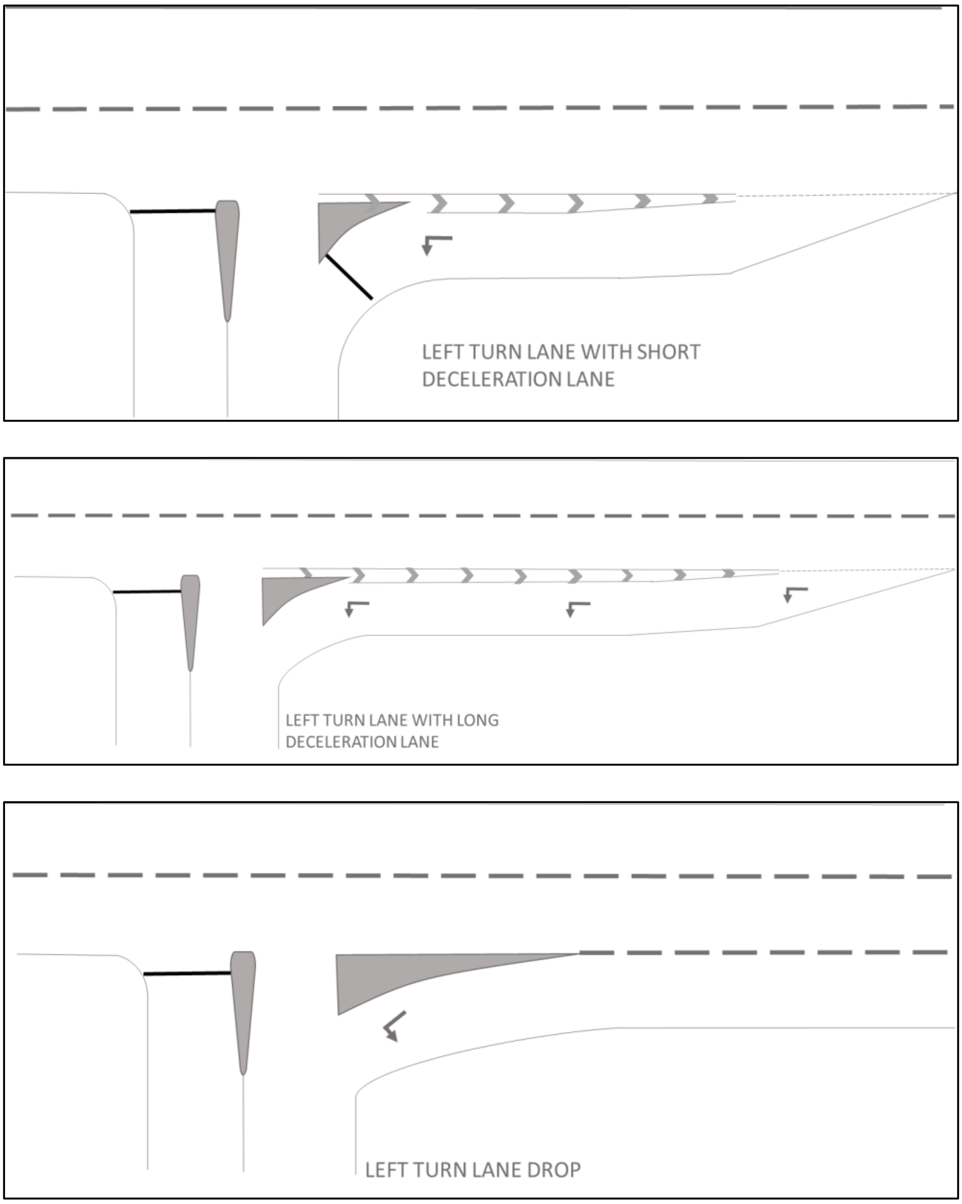


Figure 5: Various Left Turn Slip Lane examples

Seagull Intersections

As mentioned previously there are three characteristics of a seagull intersection, including the seagull island, bypass lane and acceleration lane for vehicles turning right from side-road into the median. This distinguishes a seagull from other priority intersection forms that have a right turn bay and an area vehicles can wait in the median. There is also a variety of different layouts from a full painted to fully chanelised seagull as shown in Figure 6. There are seagulls which have hit posts on lane lines instead of painted islands. The painted options tend to be used in urban areas with lower speeds. The chanelised options tend to be used more in rural areas, although there are also seagulls that have a mix of these island types. For the research each of the median and splitter islands have been classified and used in the safety analysis.

Figure 6: Example of Painted and Raised Island Seagull Intersection

SITE SELECTION AND DATA COLLECTION

Data has previously been collected for standard three-arm urban and rural priority T-intersections (Turner 2001 and Turner & Roozenberg 2007). In both studies data was collected for around 100 intersections. Some of the rural and urban intersections had LTSL. These data sets were reanalysed using additional layout data to provide a reference point for the safety of the standard priority T-intersections at different traffic flows and with particular layout characteristics.

In this study the data collection focused on collecting data for urban and rural seagulls and rural intersections with left turn slip lanes. This included data collection across both islands of New Zealand and in multiple cities and rural areas, especially for seagulls, which are a fairly rare intersection layout. In total turning traffic volumes and layout data was collected for over 70 new intersections. Table 1 shows a summary of the number of urban and rural seagulls and rural intersections with LTSLs.

Intersection Type	Urban	Rural
Seagulls	17	12
LTSL only	10	37

Table 1 - Sample size of seagull and LTSL sites used in the study

In addition to typical daily traffic volumes (six turning counts per intersections) and crash data by type (LB and JA were the focus), data was collected on speed limit and a large number of layout variables. This includes the geometry of the intersections (e g. whether on curve or grade), the layout (width and length) and type (solid, painted and hit posts) of islands, number of traffic lanes and the distance to nearest upstream and downstream feature and type of feature (e g. another side-road, parking, bus bay). For standard T-intersection there were 25 variables. For intersection with LTSLs this increased to 51 variables. While for seagulls there were 63 variables.

STATISTICAL ANALYSIS

To date the statistical analysis has modelled the ‘near side crossing’ crashes (JA type), for both rural and urban speed environments for standard intersections and seagulls. The ‘right-turn against' crashes (LB type) have also been modelled for urban standard intersections and seagulls. At the time of writing this paper, analysis was ongoing on 'JA' crashes at rural intersections with LTSL.

Both the traffic flows involved in each crash conflict and the speed limit were selected for the crash modelling based on previous research that showed that they are important predictor variables. Crashes were adjusted for flows and speed using regression and the adjusted values regressed separately against all potential predictors. Those with highest correlation were the key geometric predictors of crashes for each dataset. Table 2 and 3 shows the key variables identified for 'JA' and 'LB' crashes at standard urban and rural intersections respectively. There were three key predictors for 'JA' crashes at rural intersections (from a short list of nine variables), five predictors for 'LB' crashes at urban intersections (from short list of ten variables) and seven predictors for 'JA' crashes at urban intersections (from a short list of eight). A model was not developed for 'LB' crashes on rural roads as there were very few of these crashes occurring. The key geometric/layout variables have been coded to a common scale and so that high values correspond to higher unsafety. They were then combined into design indexes (RJADI and TULBDI), for inclusion in the crash prediction modelling.

Table 2: Key Predictors in Rural and Urban Priority Intersections – 'JA' Crashes

Key Predictor – Rural		**Included**	**Key Predictor – Urban**		**Included**
1	Near Side Upstream Feature	No	**1**	Near Side Through Lanes	Yes
2	Right Turn Bay	No	**2**	Main Road Median Width	Yes
3	Far Side Downstream Feature	No	**3**	Side Road Median Island	Yes
4	Distance to Far Side Downstream Feature	No	**4**	Gradient Main Road, Right Side	Yes
5	Distance to Far Side Upstream Feature	Yes	**5**	Side Road No. Exit Lanes (Left Turn)	Yes
6	Street Lighting	No	**6**	Distance to Far Side Upstream Feature	Yes
7	Far Side – Number of Through Lanes	Yes	**7**	Distance to Near Side Downstream Feature	Yes
8	Side Road – Number of Through Lanes, Left	No	**8**	Gradient of Main Road, Left Side	No
9	Gradient of Side Road Approach	Yes			

Table 3: Key Predictors in Urban Priority Intersections – 'LB' Crashes

Key Predictor – Urban		**Included**			
1	Street Lighting	No	**7**	Side Road No. Lanes	Yes
2	Chevron Board at top of Tee	No	**8**	Near Side Number Lanes	Yes
3	Distance to Near Side Upstream Feature	No	**9**	Distance to Far Side Downstream Feature	Yes

4	Side Road Median Width	Yes	**10**	Curvature Main Road at Centreline of Side Road	No
5	Side Road Median Island (Y/N)	No			
6	Far Side No. Through Lanes	Yes			

Table 4 shows the crash prediction models that were developed for standard T-junctions (they predict the number of crashes expected every five years). The sample sets for these models were around 90 intersections. In addition to the design index the models included the speed limit on the main road (MRSL) and the daily turning traffic volumes. Q1 is the right turn out of the side-road, Q3 is right turn into side-road and Q5 is the through movement right-to-left from the side-road.

Table 4: Models for JA and LB crashes at Standard T-intersections (five years)

Speed Environment & Crash Movement	**Fitted Model**
Rural JA crashes	$Y_{JA,R} = e^{-39}.Q1^{0.85}.Q5^{0.48}.MRSL^{3.38}.RJADI^{5.5}$
Urban JA crashes	$Y_{JA,U} = e^{-26}.Q1^{0.19}.Q5^{0.33}.MRSL^{3.8}.RJADI^{2.9}$
Urban LB crashes	$Y_{LB,U} = e^{-4.35}.\ Q3^{0.34}.\ Q5^{0.26}.\ MRSL^{-1.15}.TULBDI^{2.10}$

The speed limit and design index are important variables in the occurrence of JA crashes at both urban and rural intersections. As might be expected poor design is expected to have a greater impact on 'JA' crashes at rural intersections. Interestingly increasing traffic flows, especially the right turn out, has a greater impact on crashes at rural intersections, compared with urban intersections, where there is a safety in numbers effect going on.

Crash prediction models have also been developed for urban seagulls. See Figure 7 for the location of some of the seagull layout variables.

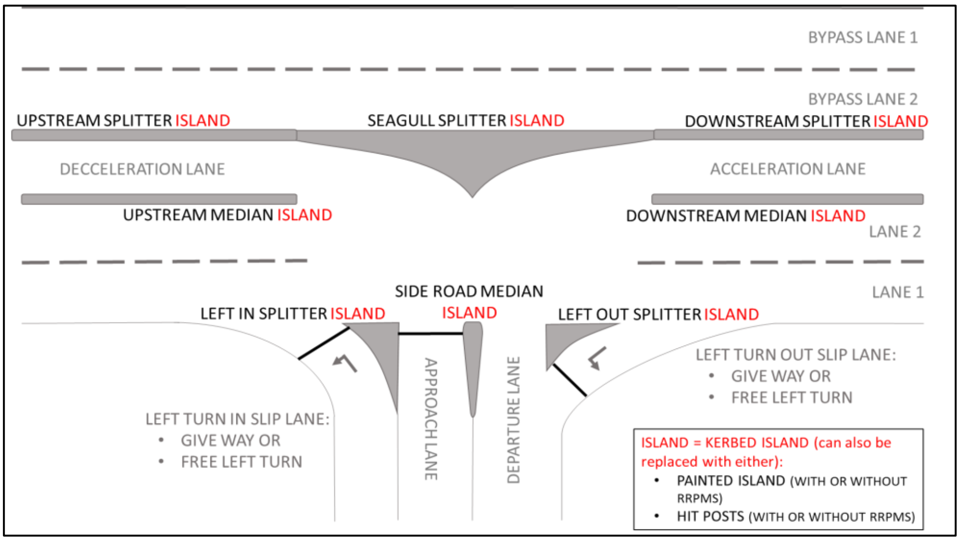


Figure 7 – Seagull Layout Variable - Island Types

Table 5 shows the key variables identified for ‘JA’ and ‘LB’ crashes at priority intersections with seagull layout. There were seven key predictors for ‘JA’ crashes and five predictors for ‘LB’ crashes (from a short list of 9) at urban seagull intersections. As before the ‘geometric/layout variables have been combined into design indexes (RJADI and SULBDI), for inclusion in the crash prediction models.

Table 5: Key Predictors in Urban Priority Seagulls – ‘JA’ and ‘LB’ Crashes

Key Predictor – Urban JA		Included	Key Predictor – Urban LB		Included
1	Near Side Through Lanes	Yes	**1**	Far Side Upstream Splitter Island Length	Yes
2	Main Road Median Width	Yes	**2**	Far Side Downstream Splitter Island Width	No
3	Side Road Median Island (Y/N)	Yes	**3**	Far Side Downstream Splitter Island Type	No
4	Gradient Main Road Right Side	Yes	**4**	Far Side Upstream Splitter Island Width	No
5	Side Road No. Lanes	Yes	**5**	LTSL into Main Road Type	Yes
6	Distance to Far Side Upstream Feature	Yes	**6**	Side Road Number of Lanes	Yes
7	Distance to Near Side Downstream Feature	Yes	**7**	Far Side Upstream Feature	No
8	Upstream Median Island Type (painted/solid)	No	**8**	Distance from Centre-line Side Road to end LTSL	Yes
9	Far Side Downstream Splitter Island Width	No	**9**	Near Side Number through Lanes	Yes

Table 6 shows the crash prediction models that were developed for urban seagulls. The sample sets for these models were 17 intersections. In addition to the design index the models included the speed limit on the main road (MRSL) and the daily turning traffic volumes. Q1 is the right turn out of the side-road, Q3 is right turn into side-road and Q5 is the through movement right-to-left from the side-road.

Table 6: Models for JA and LB crashes at Urban Seagull T-intersections (five years)

Speed Environment & Crash Movement	Fitted Model
Urban JA crashes	$Y_{JA,U} = e^{-26}.Q1^{1.55}.Q5^{1.17}.MRSL^{0.76}.RJADI^{1.65}$
Urban LB crashes	$Y_{LB,U} = e^{-52}.Q3^{2.95}.Q5^{0.30}.MRSL^{5.9}.SULBDI^{1.0}$

Speed limit shows out as an important variable for LB crashes but not for JA crashes. The design index seems to be less important predictor than was the case with standard T-intersections. The exponents on the traffic flows are in the normal range except for the right turn in flow (Q3) for LB crashes which has a major effect on crash rates as the right turn flow increases.

Crash prediction models are still being developed for rural intersections with Left Turn Slip Lanes (LTSLs). These models will be reporting on in a follow-up paper.

Example use of the Models

Let's consider the major crash type at urban T-intersections which is near side or JA crashes. The intersection has a right turn out flow (Q1) of 1000 vehicles per day and a through movement (left to right, Q5) of 5000 vehicles per day. The main road speed limit (MRSL) is 50km/h and the design index (UJADI) is 8.0. The expected number of JA crashes every five years is given by the following equation:

$$Y_{JA,U} = e^{-26}.Q1^{0.19}.Q5^{0.33}.MRSL^{3.8}.RJADI^{2.9}$$

= exp(-25.72)*1000^0.191*5000^0.33*50^3.8*8^2.85

= 0.45 crashes every five years

The crash rate at this intersection can be reduced to 0.2 crashes every five years by improving the design of the standard T-intersection so the design index (RJADI) reduces to 6.02 or by installing a well-designed Seagull with design index of 1.58. The calculation for the latter follows.

$$Y_{JA,U} = e^{-26}.Q1^{1.55}.Q5^{1.17}.MRSL^{0.76}.RJADI^{1.65}$$

= exp(-25.99)*1000^1.55*5000^1.17*50^0.75*1.58^1.65

= 0.20 crashes every five years

FINAL REMARKS/SUMMARY

The overseas research on the safety of various urban and rural priority T-intersection designs is limited, especially when considering the intersection layout. The research that is available tends to indicate that well designed seagull intersections have a similar crash performance to standard priority T-intersections. The safety of the seagull intersection, and in particular the severity of crashes, can be poor when design deficiencies are present. The safety research on left turn slip lanes at rural priority intersections shows mixed results. Some studies show safety improvements (as reported in the Highway Safety Manual, AASHTO, 2013) and some show a deterioration in safety (as reported in the Handbook of Road Safety, Elvik et al, 2009).

This research has consider the impact on JA (near side crossing) and LB (right turn against) crashes at priority T-intersections of traffic volumes, speed limits and various design features, including intersections that are classified as seagulls. The research shows that traffic volumes are the key predictors of crash occurrence. As traffic volumes increase crashes increase. Speed limit was also found to be a key factor at standard T-intersections and for LB crashes at urban seagulls.

A number of design indices where developed for seagull and standard priority junctions, both urban and rural, and for JA and LB crashes alike. Key factors that were included in these design indices were type and distance to upstream and downstream features (like parking and side-road) on each side of the road, number of through lanes on near-side, presence of side road median island, number of lanes on side-road approach and types of left turn slip lanes into and out of the side-road. In most of the models the design index was an important variable, although rarely as important as the traffic volume.

REFERENCES

Ale G, Varma A, and Gage B. 2013. Safety Impacts of Right-Turn Lanes at Unsignalized Intersections and Driveways on Two-Lane Roadways: Crash Analysis. Journal of Transportation. USA

AASHTO. 2013. Highway Safety Manual, Washington DC, USA

Elvik, R., Høye, A., Vaa, T., & Sørensen, M. 2009. The Handbook of Road Safety Measures (2nd ed.). Bingley: Emerald.

Fitzpatrick, K., Schneider, W., & Park, E. 2006. Operation and safety of right-turn lane designs. Journal of Transportation Research Board, 55-64.

Harper, J., Smart, W., & De Roos, M. 2009). Seagull intersection layout, island point road: a case study. 2009 Australasian Road Safety Research, Policing and Education Conference. Perth, WA.

Lake, G. 1996. Performance and design of intersections. Clayton, VIC: Institute of Transport Studies, Monash University.

NZ Transport Agency, 2015. New Zealand Economic Evaluation Manula – Crash Estimation Manual. NZTA Wellington NZ

NZ Transport Agency, 2000. Manual Of Traffic Signas and Marking (MOTSAM), NZTA Wellington NZ

Oh, J., Lyon, C., Washington, S., Persaud, B., & Bared, J. 2003. Validation of FHWA crash models for rural intersections. Transportation Research Record 1840, 41-49.Potts 2013

Potts I.B, Bauer K.M, Torbic D.J, Ringert J.F. 2013. Safety of Channelized Right-Turn Lanes for Motor Vehicles and Pedestrians. Journal of the Transportation Research Board*,* No. 2398.

Radalj, T., Raymond, R., Syeda, S., & Johnston, D. 2006. Seagull island evaluation. Main Roads Western - Road Safety.

Sullivan D, and Ardnt O. 2014. Expanded Warrants for Unsignalised Intersection Turn Warrants. 26th ARRB Conference – Research driving efficiency, Sydney New South Wales.

Summersgill, I., Kennedy, J., & Baynes, D. 1996. Accidents at three-arm priority junctions on urban single-carriageway roads. Crowthorne, U.K: Department of Transport.

Tang, J., & Levett, S. 2009. Safety performance of T-junctions on high speed rural roads: stage 1 - seagull T-junctions. Australasian Road Safety Research, Policing and Education Conference. Sydney, NSW.

Turner, S. 2001. Accident Prediction Models. NZ Transport Agency Research Report 192,

Turner, S and Roozenburg, A. 2007. Crash Rates at Rural Intersections, Road Safety Trust Research Report, NZTA, Wellington, NZ