CENTRE FOR
AUTOMOTIVE
SAFETY RESEARCH

THE UNIVERSITY of ADELAIDE

Post impact trajectory of vehicles at rural intersections

SD Doecke, JRR Mackenzie, JE Woolley

CASR REPORT SERIES
CASR086
May 2013

Report documentation

REPORT NO.	DATE	PAGES	ISBN	ISSN
CASR086	May 2013	23	978 1 921645 23 5	1449-2237

TITLE

Post impact trajectory of vehicles at rural intersections

AUTHORS

SD Doecke, JRR Mackenzie, JE Woolley

PERFORMING ORGANISATION

Centre for Automotive Safety Research
The University of Adelaide
South Australia 5005
AUSTRALIA

SUPPORTED BY

Department of Planning, Transport and Infrastructure
GPO Box 1533
Adelaide SA 5001
AUSTRALIA

AVAILABLE FROM

Centre for Automotive Safety Research
http://casr.adelaide.edu.au/publications/researchreports

ABSTRACT

This report describes the path of vehicles following a collision with another vehicle at a rural intersection. Detailed information from in-depth investigations of 70 intersection crashes was analysed. Rear end crashes at intersections were excluded as were collisions involving a motorcycle. The vehicle which had right of way most commonly had an impact speed of between 80 and 99 km/h and the impact point was on the front of the vehicle. The vehicle which was required to give way most commonly had an impact speed of between zero and 20 km/h and was struck between the front of the vehicle and the B-pillar. After the vehicle to vehicle impact half the vehicles travelled more than 18 metres, 20% more than 34 metres and 10% more than 50 metres from the centre of the intersection. The most common direction of the vehicle following the initial impact was found to be between 15 and 29.9 degrees, where the original direction of travel of the through vehicle is at zero degrees. Intersection geometry, speed zone, impact point and mass ratio influence the nature of the post impact trajectory of the vehicles involved. As the results show a high number of vehicles travel a large distance at a shallow angle following an intersection collision, extending crash barriers on the through road (the road with right of way) right up to the intersection may have some benefit. Clear zones surrounding the intersection are also advisable and have an added benefit of increasing sight distance. Hazards can be assessed for removal or relocation by applying the results of this study.

KEYWORDS

Intersection, rural road, traffic accident

Summary

This report describes the path of vehicles following a collision with another vehicle at a rural intersection. The aim was to provide guidance to transport authorities on roadside design at intersections. The current Australian guidelines are not explicit on roadside design at intersections to protect vehicles from secondary impacts with roadside objects. The authors are not aware of prior research of this nature in relation to rural intersection design.

Detailed information concerning high speed rural road intersection crashes was obtained from the Centre for Automotive Research's (CASR) in-depth crash investigation database. Rural road crashes were investigated by CASR during two separate time periods; 1998 to 2000 and 2006 to 2010. For this study, any crash involving a vehicle-to-vehicle collision at a rural junction was sought and crashes were taken from both time periods. Rear end crashes at intersections were excluded as were collisions involving a motorcycle. In total, 40 intersection crashes were obtained from the period of 1998 to 2000, and 30 intersection crashes were obtained from the period of 2006 to 2010.

The vehicle which had right of way most commonly had an impact speed between 80 and 99 km/h and the impact point was on the front of the vehicle. The vehicle which was required to give way most commonly had an impact speed of between zero and 20 km/h and was struck between the front of the vehicle and the B-pillar.

After the vehicle-to-vehicle impact half the vehicles travelled more than 18 metres, 20% more than 34 metres and 10% more than 50 metres from the centre of the intersection. The most common direction of the vehicle following the initial impact was found to be between 15 and 29.9 degrees, where the original direction of travel of the through vehicle is at zero degrees. For both vehicles, collisions that occur at a cross road result in higher straight line distances and higher angles than collisions that occur at a T-junction. Speed zone, vehicle impact point and mass ratio influence the nature of the post impact trajectory of the vehicles involved.

Three of the 70 crashes resulted in a secondary collision that was more severe than the initial collision. Two of these secondary impacts with roadside hazards resulted in a vehicle occupant being fatally injured, and one resulted in serious injuries.

As the results show a high number of vehicles travel a large distance at a shallow angle following an intersection collision, extending crash barriers on the through road (the road with right of way) right up to the intersection may have some benefit. Clear zones surrounding the intersection would aid in creating a safe system providing they are of adequate size. Removing hazards around an intersection will have the added benefit of increasing sight distance. Hazards can be assessed for removal or relocation using the results of this study.

Contents

1 Introduction

This report describes the path of vehicles following a collision with another vehicle at a rural intersection. The aim was to provide guidance to transport authorities on roadside design at intersections. This research was prompted by anecdotal evidence from CASR's in-depth crash investigations which demonstrated that it is possible for a vehicle to strike a roadside hazard following a collision with another vehicle, and that this secondary impact can be more severe than the initial vehicle to vehicle collision.

The current Australian guidelines for road design are not explicit on roadside design at intersections to protect vehicles from secondary impacts with roadside objects. The Austroads Guide to Road Design Part 4 (Austroads, 2009a) briefly mentions that adequate clear zones should be provided around intersections because a significant number of off-road crashes occur at intersections. The reader is referred to the Austroads Guide to Road Design Part 6 (Austroads, 2009b), although this document makes no specific mention of clear zone requirements at intersections. It is therefore inferred that Austroads intended clear zones to be applied in the same manner at intersections as it recommends for mid-block sections of road. However, Austroads (2009b) states that the clear zone widths it recommends are only applicable to low angle departures. This suggests that different clear zone guidelines may be warranted at intersections as high departure angles are possible following a vehicle to vehicle collision.

A search of the literature was conducted but it appears that there has been no prior research of this nature. The majority of prior research into intersection crashes focuses on the pre-crash movements of the vehicles rather than the movement of the vehicle after the initial impact. The only study found that made reference to post impact trajectory of vehicles following an intersection crash only examined metropolitan crashes. This study found that 15 vehicles from a sample of 35 uncontrolled intersection crashes struck a roadside object after the initial collision (McLean et al, 1979).

The percentages of crashes that are either right turn or right angle crashes in South Australia since 1990 are shown in Figure 1.1. These percentages have been derived from the South Australian Traffic Accident Reporting System (TARS). Right turn and right angle crashes are the typical crash types at rural intersection between two vehicles. While rear end crashes are also associated with intersection crashes these are less common in rural areas and are generally less severe. Rear end crashes would also have quite different post impact trajectories than right turn or right angle crashes. Figure 1.1 shows that right turn and right angle crashes represent about 20% of rural crashes of all severities (including non-injury crashes) in South Australia and about 15 to 20% of casualty crashes. The percentage of serious crashes in rural areas that are right turn or right angle crashes varies between 10 and 19%, although from 1999 to 2009 this percentage remained within the 10 to 15% range. Note that crashes classified as serious include crashes where at least one occupant was admitted to hospital and crashes where at least one fatality occurred. It appears that, in general, right turn and right angle crashes are less likely to be serious crashes than other rural crashes.

Crashes involving motorcycles and pedestrians were not included in this study. Data from TARS revealed that 94% of all rural right turn and right angle crashes did not involve a motorcycle or pedestrian between 2005 and 2009. When considering casualty crashes this percentage is lowered to 91% and when serious crashes are considered this percentage is lowered further to 84%.

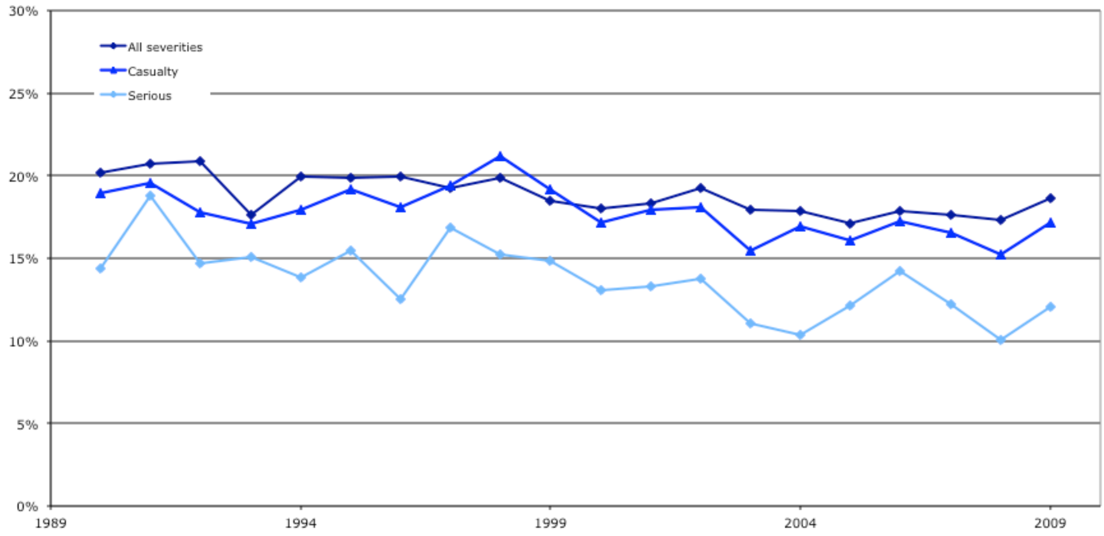

Figure 1.1
Percentage of crashes in rural South Australia
between 1990 and 2009 that are either right angle or right turn crashes

2 Method

Detailed information concerning high speed rural road intersection crashes was obtained from the Centre for Automotive Research's (CASR) in-depth crash investigation database.

The database consists of information collected through the in-depth investigation of crashes where any occupant of an involved vehicle is transported by ambulance to hospital, or suffers fatal injuries. Investigations begin with immediate attendance at the scene of the crash by a team of two personnel. The information collected for each crash includes: photographs/video of the crash scene and vehicles involved, examination of the road environment, a site plan of the crash scene and vehicle movements during the crash, examination and measurements of the vehicles involved, interviews with crash participants, interviews with witnesses, discussion with police, information from the official police report, information from Coroner's reports (where an occupant has suffered fatal injuries), and hospital injury data for the injured crash participants.

CASR staff were on call to attend crash scenes between 0900 and 1630 during weekdays. Fatal accidents that occurred at any time on any day were also investigated as evidence at the scene was preserved by the South Australian Police Force's Major Crash teams.

Rural road crashes were investigated by CASR during two separate time periods; 1998 to 2000 and 2006 to 2010. For this study, any crash involving a vehicle-to-vehicle collision at a rural junction was sought and crashes were taken from both time periods. Rear end crashes at intersections were excluded as were collisions involving a motorcycle. In total, 40 intersection crashes were obtained from the period of 1998 to 2000, and 30 intersection crashes were obtained for the period of 2006 to 2010.

There were four types of collisions identified as shown in Figure 2.1. Note that the use of a cross road is for illustration purposes and that crashes at T-junction type intersections were also considered. In all four collision types, one vehicle (designated unit 1) was travelling through the intersection with right of way, at which point a second vehicle (designated unit 2) entered the intersection and a collision occurred. In all cases, unit 2 disobeyed either a direct indication to yield (give way / stop sign), or an implied direction (give way to the right). The description used for the various configurations are based on the movement of the vehicle which was required to give way; they do not match the configuration descriptions used in the TARS database. Note that the straight and right turn configurations may also occur with unit 1 in the lane closest to unit 2 (travelling down the page). In this case the positive x axis shown in the diagrams would point down the page, as the positive x axis is normalised to the direction of travel of unit 1. The positive y axis is normalised to the initial direction of unit 2.

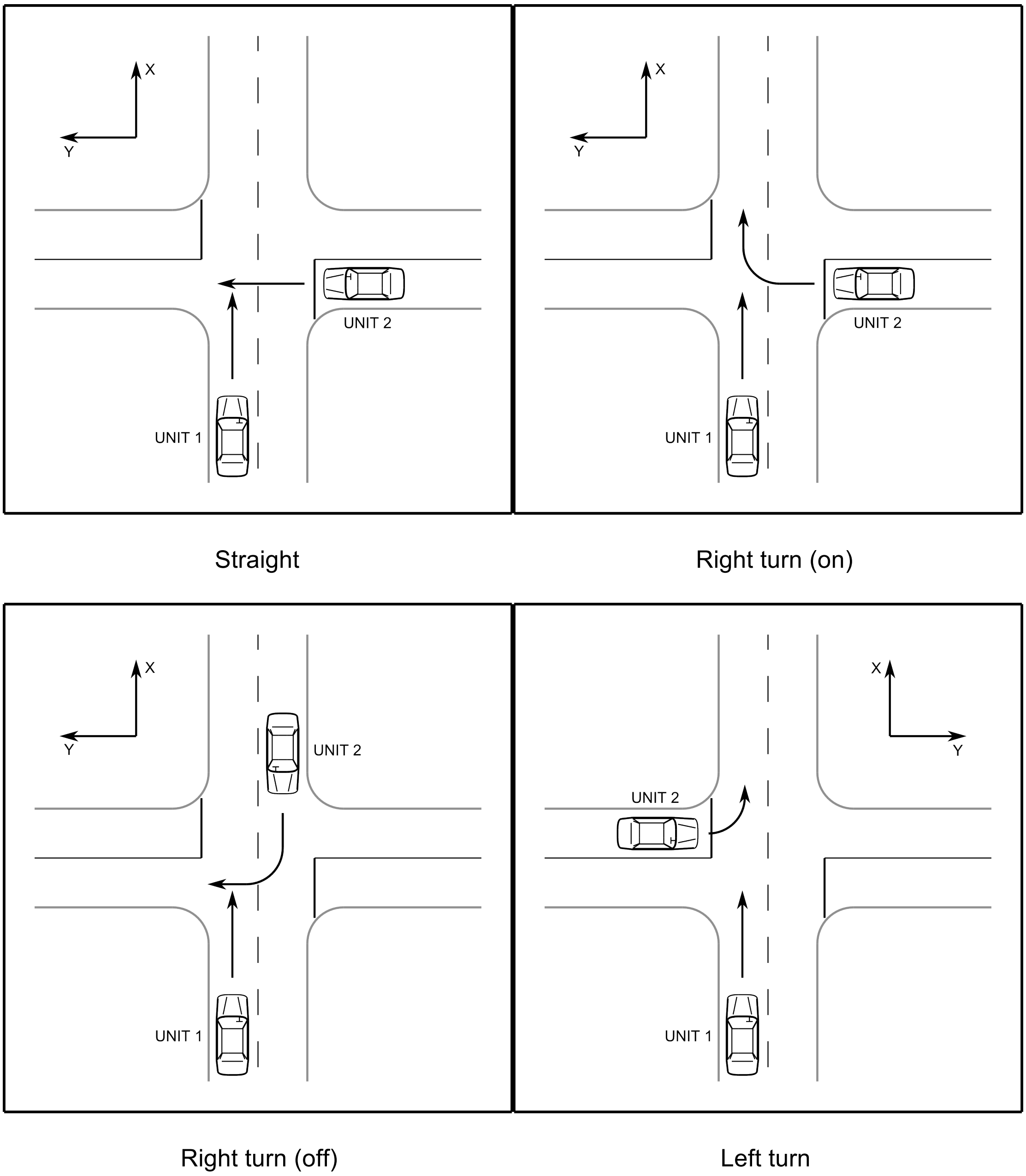

Figure 2.1
Intersection collision types included in the study

2.1 Crash and location based variables

For each crash variables pertaining to the crash and crash location were recorded. These variables are described below.

Road geometry

The type of intersection road geometry where the collision took place.

Traffic control

The type of traffic control at the intersection where the collision took place.

Most severe impact

The cause of the most severe impact to either of the vehicles during the crash sequence. The most severe impact may be due to the initial collision between unit 1 and unit 2, or may be due to a later collision when one of the units collides with a roadside object. The severity of impact is in terms of vehicle occupant injuries as opposed to vehicular damage (e.g. a side impact at 40 km/h may be deemed more severe than a frontal impact at 60 km/h).

2.2 Vehicle based variables

For each vehicle, or unit, involved in a crash specific variables were recorded. These variables are described below. It should be noted that some of the variables are measured relative to the centre point of the intersection. The centre point is determined by the intersection of the centre lines of both roads when they are extended into the intersection. This can be observed in Figure 2.2

Speed limit

The speed limit of the road on which the vehicle was initially travelling.

X distance

The distance, in the x direction, between the centre point of the intersection and the furthest point of the final position of the vehicle (see Figure 2.2). Note that the positive x direction is defined as the initial direction of travel of unit 1.

Y distance

The distance, in the y direction, between the centre point of the intersection and the furthest point of the final position of the vehicle (see Figure 2.2). Note that the positive y direction is defined as the initial direction of travel of unit 2.

Straight line distance

The straight line distance between the centre point of the intersection and the furthest points of the final position of the vehicle (see Figure 2.2).

Angle

The angle between the x axis and the line created by the straight line distance (see Figure 2.2).

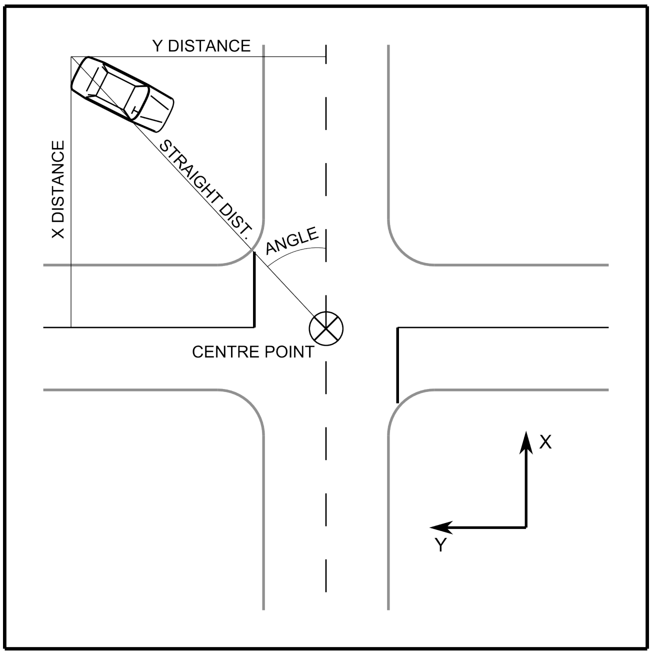

Figure 2.2
Measurement of post impact trajectory

Manoeuvre

The pre crash manoeuvre being conducted by the vehicle, as shown in Figure 2.1.

Impact point

The principle point of force upon the vehicle as a result of the collision with the other vehicle. This was divided into five possible points as shown in Figure 2.3.

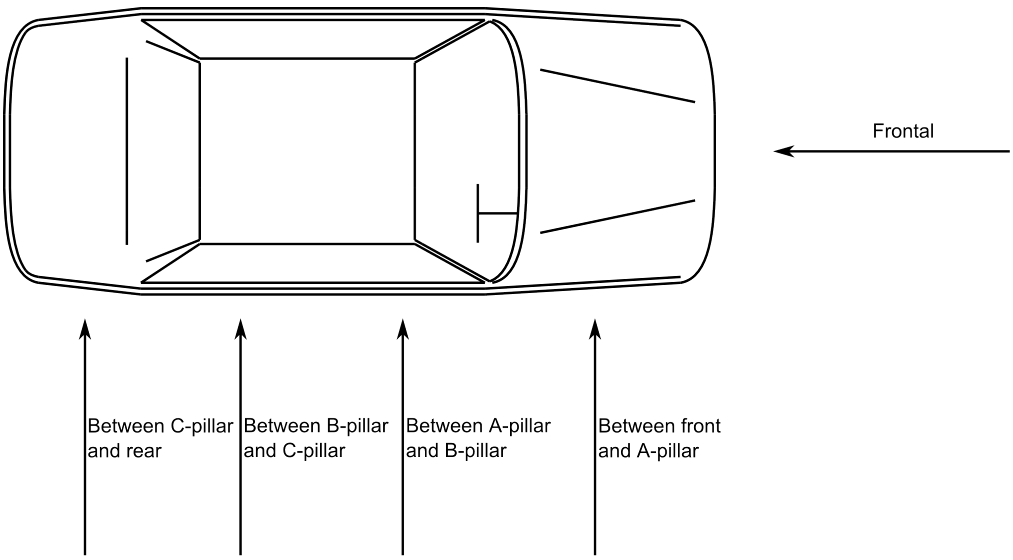

Figure 2.3
Impact points

Struck object

Any object that was struck after the initial collision between the two vehicles (if any).

Vehicle mass

The approximate mass of the vehicle.

Injury severity

The highest severity of injury sustained by one of the vehicle occupants.

3 Results

3.1 General

The number and percentage of each collision type (Figure 2.1) are shown in Table 3.1. Collisions where Unit 2 was travelling straight or turning right onto the road being travelled by Unit 1 made up the majority of the crashes.

Table 3.1
Rural intersection crashes by collision type

Collision type	Number	Percentage
Straight	28	40.0%
Right turn (on)	30	42.9%
Right turn (off)	11	15.7%
Left turn	1	1.4%
Total	70	100.0%

The crashes occurred at two different types of intersections, cross roads and T-junctions. Table 3.2 shows that there were marginally more crashes at cross roads than T-junctions.

Table 3.2
Rural intersection crashes by intersection geometry

Intersection geometry	Number	Percentage
Cross roads	37	52.9%
T-junction	33	47.1%
Total	70	100.0%

Table 3.3 shows the types of traffic control that were present at the intersections where the crashes occurred. No traffic control was most common. Which vehicle must give way to the other in such a situation is implied by either the geometry of the road (a T-junction requires vehicles on the terminating road to give way) or the give way to the right rule. Give way signs were less common than no traffic control but more than twice as common as stop signs.

Table 3.3
Rural intersection crashes by traffic control

Traffic control	Number	Percentage
None	32	45.7%
Give way sign	26	37.1%
Stop sign	12	17.1%
Total	70	100.0%

The injury severity for each unit is shown in Table 3.4. The occupants of vehicles classified as unit 2 (the vehicle which had to give way) had a much greater chance of being fatally injured. A vehicle occupant requiring, at worst, hospital treatment was the most likely outcome for either unit, although marginally so for unit 2. This is not surprising given the criterion of ambulance transport for a crash to be included in the in-depth crash investigations.

Table 3.4
Rural intersection crashes by injury severity and unit

Injury Severity	Unit 1		Unit 2	
	Number	Percent	Number	Percent
None	19	27.1%	15	21.4%
Treated	27	38.6%	21	30.0%
Admitted	19	27.1%	14	20.0%
Fatal	5	7.1%	20	28.6%

Table 3.5 shows the object struck in a secondary collision by each unit. Unit 1 and unit 2 were equally likely to have a secondary collision. While many of the objects struck can be considered frangible of greatest concern are the secondary collisions with trees and stobie poles.

Table 3.5
Rural intersection crashes by object struck in secondary collision and unit

Object struck in secondary collision	Unit 1		Unit 2	
	Number	Percent	Number	Percent
None	61	87.1%	61	87.1%
Total objects struck	9	12.9%	9	12.9%
Another vehicle	0		2	
Fence	1		2	
Guide post	2		1	
Post	1		0	
Stobie pole	2		0	
Sign	1		1	
Tree	2		2	
Hedge	0		1	

Table 3.6 shows that the most severe impact was almost always the impact with the other car, although on three occasions the most severe impact was a secondary impact with a roadside hazard. It should be noted that two of these secondary impacts with roadside hazards resulted in a vehicle occupant being fatally injured, and one resulting in serious injuries. Two of the vehicles in these crashes struck a stobie pole. The third struck a tree.

Table 3.6
Rural intersection crashes by most severe impact

Most severe impact	Number	Percentage
Car	67	94.4%
Roadside hazard	3	5.6%
Total	70	100.0%

The speed limits of the rural intersection crashes are shown in Table 3.7 by unit. It should be noted that in the older in-depth crash investigation study only the speed limit of unit 1 was recorded resulting in the large number of unknowns for unit 2. For unit 1 more than two thirds of the vehicles were travelling on a road with a speed limit of 100 km/h or higher. Speed zones of less than 80 km/h were rare, partly due to the more recent series of rural in-depth crash investigations requiring at least one road to have a speed limit of 80 km/h or more. The crashes included in this study can therefore be thought to predominately represent collisions at high speed rural intersections.

Table 3.7
Rural intersection crashes by speed limit and unit

Speed limit	Unit 1		Unit 2	
	Number	Percent	Number	Percent
50	1	1.4%	1	1.4%
60	5	7.1%	2	2.9%
70	1	1.4%	0	0.0%
80	14	20.0%	14	20.0%
90	1	1.4%	0	0.0%
100	28	40.0%	15	21.4%
110	20	28.6%	5	7.1%
Unknown	0	0.0%	33	47.1%

Many of the cases were reconstructed to determine the vehicles' travel and impact speeds. The impact speeds are shown in Table 3.8 grouped into bins of 20 km/h. The most common impact speed for unit 1 was between 80 and 99 km/h. For unit 2 the most common impact speed is between 0 and 19 km/h. Such low impact speeds for unit 2 most likely represent vehicles which have stopped at the intersection and have then driven into the path of unit 1.

Table 3.8
Rural intersection crashes by impact speed and unit

Impact speed	Unit 1		Unit 2	
	Number	Percent	Number	Percent
0-19	1	1.4%	16	22.9%
20-39	1	1.4%	12	17.1%
40-59	8	11.4%	8	11.4%
60-79	13	18.6%	6	8.6%
80-99	16	22.9%	0	0.0%
100-119	5	7.1%	1	1.4%
Unknown	26	37.1%	27	38.6%

The impact point by unit for the rural intersection crashes can be seen in Table 3.9. For unit 1 the most common impact point is the front of the vehicle. For unit 2 the most common impacts point is between the front of the vehicle and the A-pillar, though an impact between the A and B-pillars is almost as common.

Table 3.9
Rural intersection crashes by impact point and unit

Impact Point	Unit 1		Unit 2	
	Number	Percent	Number	Percent
Front	43	61.4%	16	22.9%
Between front and A-pillar	14	20.0%	22	31.4%
Between A and B-pillar	8	11.4%	20	28.6%
Between B and C-pillar	4	5.7%	10	14.3%
Between C-pillar and rear	1	1.4%	2	2.9%

The mass ratio was defined as the ratio of the mass of unit 1 to the mass of unit 2. The distribution of the mass ratios between discrete bins can be seen in Table 3.10. The most common mass ratios are between 0.75 and 1.24. A reasonable number of mass ratios are greater than two. A mass ratio of greater than two most often represents a collision between a truck (unit 1) and a light vehicle (unit 2) such as a car, although in some cases it could represent a collision between a large sports utility vehicle and a small car.

Table 3.10
Rural intersection crashes by traffic control

Mass ratio	Number	Percentage
< 0.50	5	7.1%
0.50 – 0.74	6	8.6%
0.75 – 0.99	14	20.0%
1.00 – 1.24	15	21.4%
1.25 – 1.49	11	15.7%
1.50 – 1.99	7	10.0%
> 2.00	12	17.1%
Total	70	100.0%

3.2 Trajectories

The final positions of vehicles involved in a crash at a high speed rural intersection are shown in Figure 3.1. Note that in some crashes investigated the final position of one of the vehicles could not be determined, therefore while there were 70 crashes investigated involving 140 vehicles the final positions of 11 vehicles were unknown. The majority of the final positions are clustered within 30 metres of the centre of the intersection, although some go well beyond that range. The vehicles which travel a large distance from the intersection appear to do so at a relatively shallow angle. These cases may represent cases where the mass ratio between unit 1 and unit 2 was particularly high, such as when unit 1 was a large truck and unit 2 a light vehicle. Figure 3.2 shows a zoomed view of Figure 3.1.

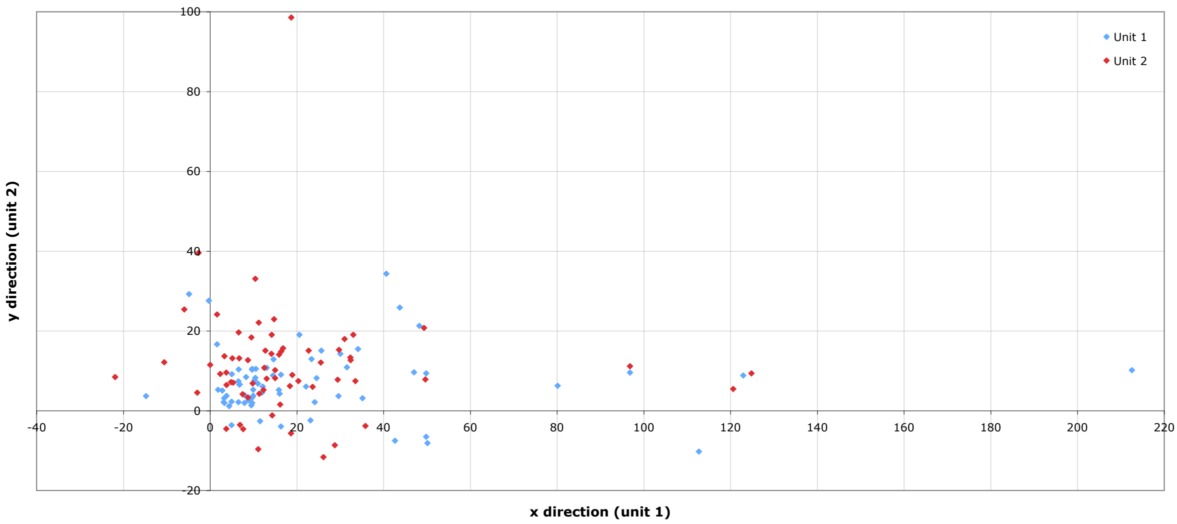

Figure 3.1
Final positions of crash involved vehicles at rural intersections (n=129)

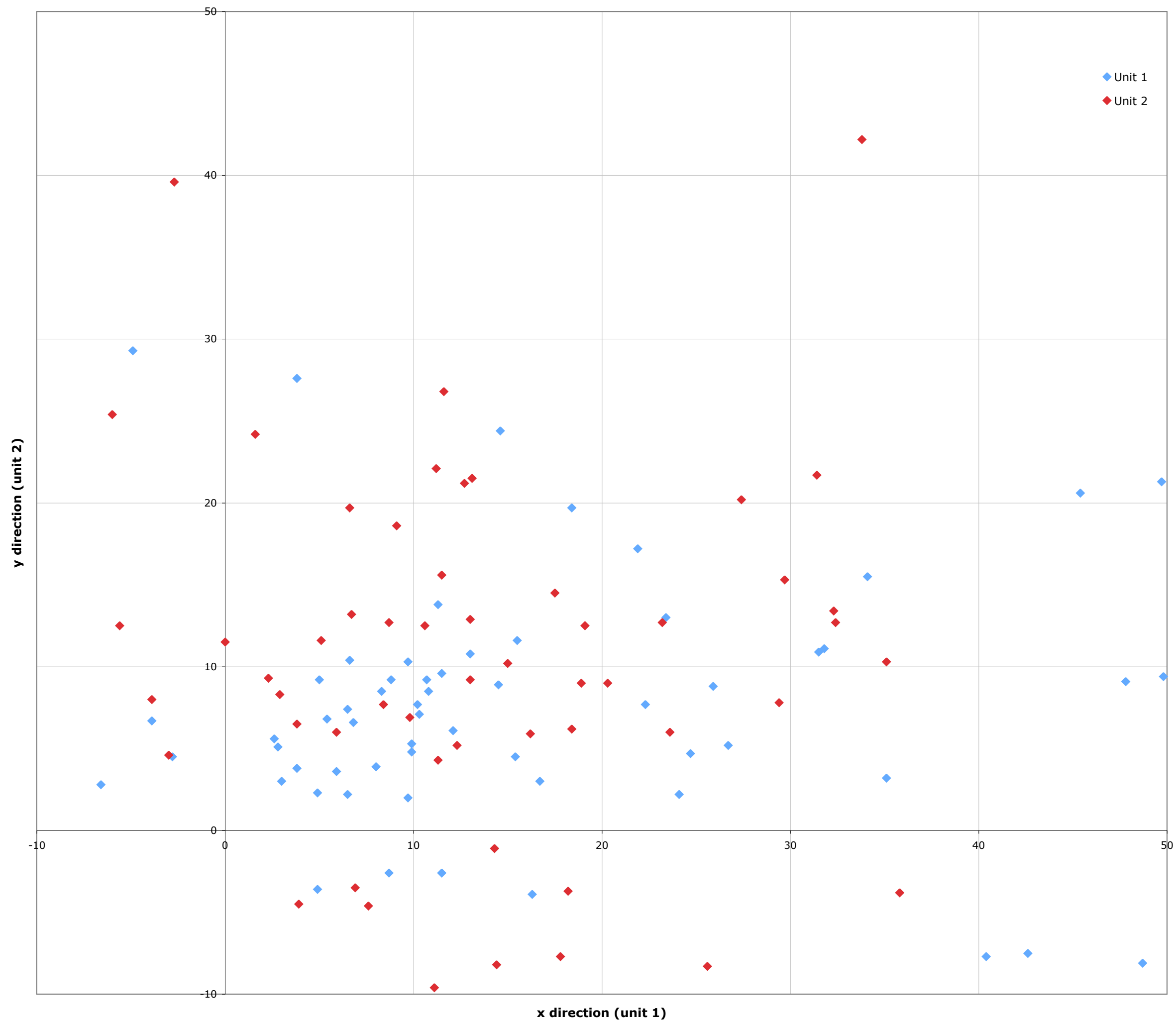

Figure 3.2
Zoomed view of positions of crash involved vehicles at rural intersections (n=115)

The cumulative distribution of the straight line distance between the centre point of the intersection and the vehicles final position is shown in Figure 3.3. Half the vehicles travelled more than 18 metres, 20% more than 34 metres and 10% more than 50 metres from the centre of the intersection following a collision.

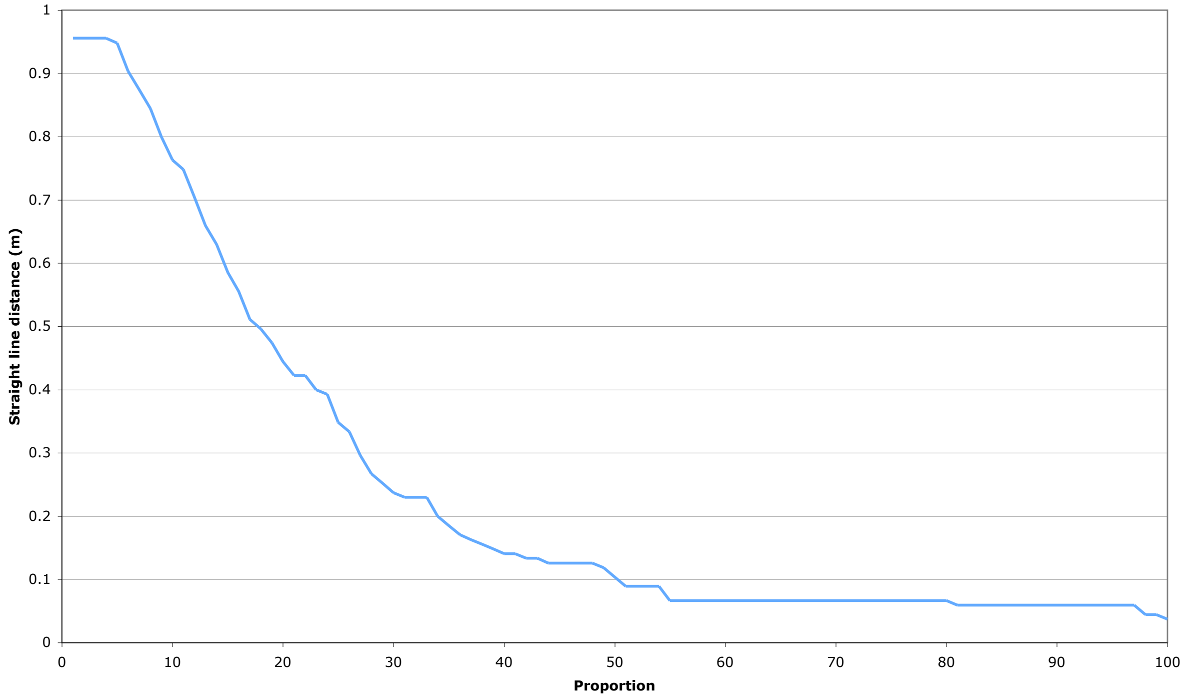

Figure 3.3
Cumulative distribution of straight line distance of a vehicle following a rural intersection collision

The distribution of the angles between the centre point of the intersection and final position of the vehicle are shown in Figure 3.4. The angles of the vehicles designated as unit 1 are centred around the 15 to 29.9 degree bin. The vehicles designated as unit 2 are more evenly spread over the range, although the greatest percentage is also found in the 15 to 29.9 degree bin.

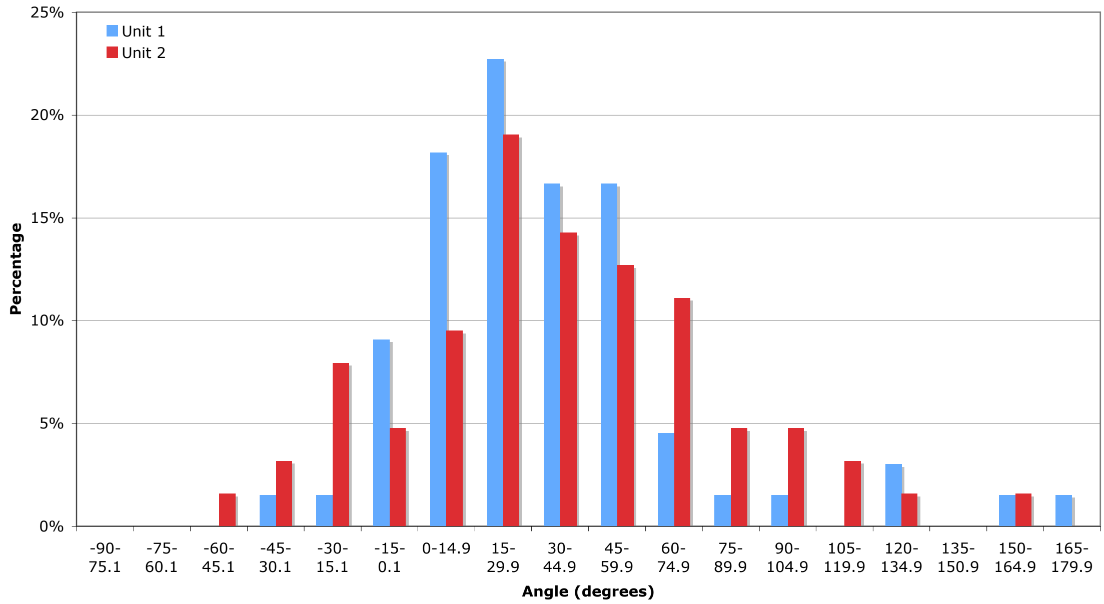

Figure 3.4
Distribution of the angle between the centre point of the road and the final position of the vehicle

Table 3.11 displays the straight line distance and angle of the rural intersections crashes by the geometry of the intersection. The median and the mean are displayed as the group does contain some outlying values. In general the median provides the more reliable point of comparison in the following tables. For both unit 1 and unit 2, collisions that occur at a cross road result in higher straight line distances and higher angles than collisions that occur at a T-junction.

Table 3.11
Straight line distance and angle of rural intersections crashes by intersection geometry

Intersection Geometry	Unit 1				Unit 2			
	Distance		Angle		Distance		Angle	
	Median	Mean	Median	Mean	Median	Mean	Median	Mean
Cross roads	17.8	27.3	38.1	37.5	24.3	28.6	35.1	35.3
T-junction	12.5	28.3	24.4	29.1	15.7	26.1	29.3	39.1

The straight line distance and angle by the speed zone of unit 1 are shown in Table 3.12. For unit 1 the straight line distance increases as the speed zone increases, while the angle decreases as the speed zone increases. Similar relationships between the straight line distance and angle and the speed zone of unit 1 appear to exist for unit 2 although the crashes in 80 or 90 km/h zones do not follow this trend.

Table 3.12
Straight line distance and angle of rural intersections crashes by speed zone of unit 1

Speed zone of unit 1	Unit 1				Unit 2			
	Distance		Angle		Distance		Angle	
	Median	Mean	Median	Mean	Median	Mean	Median	Mean
50 / 60 /70	12.7	13.8	46.3	61.8	18.3	20.6	44.8	47.0
80 /90	13.6	28.4	28.2	42.7	15.0	26.7	50.5	51.8
100	17.0	20.4	27.1	28.0	21.6	25.0	30.2	32.4
110	21.0	41.8	14.9	24.9	23.5	33.6	22.6	29.3

The straight line distance and angle of the rural intersection crashes by impact point are shown in Table 3.13. The distance that unit 1 typically travelled from the centre of the intersection increased as the impact moved further from the front of the vehicle, peaking at impacts between the B and C pillars and then reducing again for impacts between the C pillar and the rear of the vehicle. It should be noted that there are a very low number of impacts occurring between the C pillar and the rear of the vehicle in the crashes investigated. The angle for unit 1 is highest for impacts between the front of the vehicle and the A pillar. For unit 2 the distance travelled from the centre of the intersection increases for frontal impacts, peaking at impacts between the A and B pillars, before reducing again as the impact point moves towards the rear of the vehicle. Unit 2's angle is lowest when the impact is located between the front of the vehicle and the A pillar, increasing as the impact moves further towards the rear of the vehicle.

Table 3.13
Straight line distance and angle of rural intersections crashes by impact point

Impact Point	Unit 1				Unit 2			
	Distance		Angle		Distance		Angle	
	Median	Mean	Median	Mean	Median	Mean	Median	Mean
Front	12.3	26.8	25.1	30.3	18.6	25.0	49.7	35.4
Front to A pillar	15.9	21.2	40.3	51.1	19.4	22.4	18.6	12.6
A to B pillar	28.1	42.3	32.8	33.5	24.8	39.7	36.4	40.0
B to C pillar	39.3	33.8	7.2	7.6	19.8	19.9	64.8	69.2
C pillar to rear	16.0	16.0	16.3	16.3	13.2	13.2	90.2	90.2

Table 3.14 shows the straight line distance and the angle from the centre of the intersection to the final position of the vehicle by the ratio of the mass of unit 1 to the mass of unit 2. When the mass ratio is above two the straight line distance of both unit 1 and unit 2 is the greatest. This is most likely due to unit 1 being a heavy vehicle and therefore having a lot of momentum. This is also reflected in the low angles that are observed in collisions between a vehicle with a mass ratio greater than two. The angle was highest for crashes with a mass ratio of less than 0.50 for both unit 1 and unit 2. This may also be due to a heavy vehicle being involved in the collision, this time as unit 2.

Table 3.14
Straight line distance and angle of rural intersections crashes by mass ratio

Mass ratio	Unit 1				Unit 2			
	Distance		Angle		Distance		Angle	
	Median	Mean	Median	Mean	Median	Mean	Median	Mean
< 0.50	15.7	16.4	61.2	84.9	24.2	23.0	93.9	95.4
0.50 - 0.74	20.5	21.6	46.3	54.1	26.4	46.9	28.7	34.0
0.75 - 0.99	19.4	22.8	24.4	34.6	22.8	24.1	51.3	44.0
1.00 - 1.24	11.2	20.3	26.0	19.3	17.1	16.8	41.1	33.7
1.25 - 1.49	11.0	12.1	31.4	45.8	16.6	18.9	35.3	35.2
1.50 - 1.99	15.0	16.0	34.6	24.7	18.6	22.4	27.3	36.3
> 2.00	50.7	72.6	10.7	12.6	34.5	51.0	14.1	12.9

Figure 3.5 is a graphical representation of percentage of vehicles that travel through a given sector surrounding the centre point of the intersection. It can be interpreted practically as the chance of a vehicle striking a hazard within a given sector. For example a hazard located between 10 and 15 metres from the centre point of an intersection at an angle of between 15 and 30 degrees has a chance of between 15 and 20% of being struck by a vehicle involved in a collision at the intersection. Figure 3.5 reveals that the vehicles' most common post impact trajectory was between 15 and 30 degrees but more vehicles travelled beyond 40 metres of the centre point of the intersection at a shallow angle of between 0 and 15 degrees. When the angle was outside the range of 0 to 45 degrees less than 5% of vehicles travel further than 20 metres from the centre point of the intersection in any given sector.

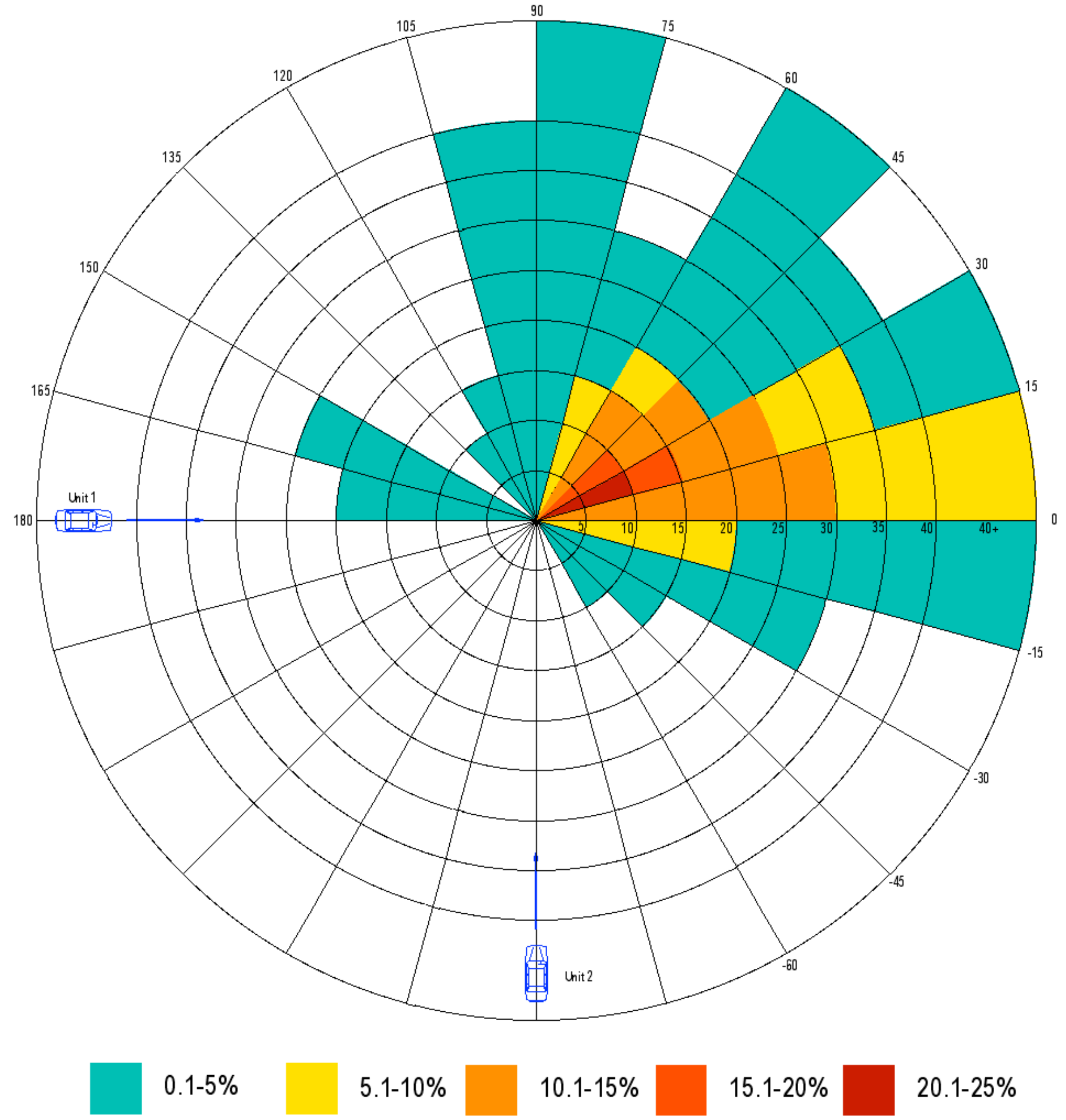

Figure 3.5
Percentage of vehicles that travel through a given sector surrounding the centre point of the intersection (n=70)

4 Discussion

A limitation of this study, in particular Figure 3.5, is that vehicle trajectories have been assumed to be linear from the centre point of the intersection to the final resting position of the vehicle. In real life the path the vehicle travelled may be curved. This mostly affects the sectors close to the centre of the intersection in Figure 3.5.

The greater straight line distances and angles observed at cross roads, as opposed to T-junctions, may be the result of higher impact speeds of unit 1, who's driver is not aware of either the intersection or their responsibility to give way. Such errors should be less likely at a T-junction where the requirement to give way is more explicitly implied in the road geometry and the presence of an intersection is indicated by the termination of the road unit 2 is travelling on. Cross roads should therefore be afforded more roadside clear of hazards.

It is interesting to note the effect that the impact point has on the post impact trajectory of a vehicle. For unit 1 the worst impact, in terms of post impact trajectory, is an impact between the B and C pillar of the vehicle. Such an impact would be behind the centre of gravity of a typical vehicle and would therefore induce an uncontrolled yaw into unit 1 without slowing it down significantly. While such an impact in it self may not be severe the subsequent high speed loss of control may result in a severe impact with a roadside hazard.

It should be noted that the crash sample is not representative of all crashes and is predominantly confined to weekday crashes during business hours involving ambulance transport. Therefore some care needs to be made in extrapolating the results however the principles associated with protecting road users from secondary collisions at intersections still apply and this research provides some guidance on the issue.

Other research has highlighted the benefits of barriers as opposed to clear zones or wide medians on rural high speed roads (Doecke & Woolley, in press a; Doecke & Woolley, in press b). Barriers are not typically recommended at intersections because the impact angle may be very high and the least aggressive barrier types, such as wire rope barriers, can not be used due to the small radii often required (Austroads, 2009b). Barriers are only recommended at intersections in specific locations, such as on an overpass, where the risk to all road users is particularly high if a vehicle is not contained (Austroads, 2009b). These results have shown that a high number of vehicles travel a large distance at a shallow angle following an intersection collision (Figure 3.5) therefore extending a barrier on the through road (the road with right of way) right up to the intersection may have some benefit.

Clear zones surrounding the intersection would aid in creating a safe system providing they are of adequate size. Removing hazards around an intersection will have the added benefit of increasing sight distance. Hazards can be assessed for removal or relocation by applying the diagram shown in Figure 3.5 to known traffic flows at the intersection.

Acknowledgements

This study was funded by the South Australian Department of Planning, Transport and Infrastructure (DPTI) through a Project Grant to the Centre for Automotive Safety Research. The DPTI Project Manager was Julie Holmes.

The Centre for Automotive Safety Research is supported by both the South Australian Department of Planning, Transport and Infrastructure and the South Australian Motor Accident Commission.

References

Austroads (2009a) Guide to Road Design Part 4: Intersections and crossings general, Sydney, Austroads

Austroads (2009b) Guide to Road Design Part 6: Roadside design safety and barriers, Sydney, Austroads

Doecke SD, Woolley JE (in press) Effective use of clear zones and barrier on rural roads. CASR085 Adelaide: Centre for Automotive Safety Research.

Doecke SD, Woolley JE (in press) Adequacy of barrier and median separation on rural roads. CASR087 Adelaide: Centre for Automotive Safety Research.

Mclean AJ, Offler WJ, Sandow BL (1979). Adelaide in-depth accident study 1975 – 1979. Part 7: road and traffic factors. Adelaide: Road Accident Research Unit, The University of Adelaide