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Abstract

Safe speeds are considered a key part of a safe transport system. Speeds in intersection crashes are of particular importance due to their commonality and the risks associated with the impact types that occur in intersection crashes. The aim of the research described in this report was to use EDR data from the CASR-EDR database to examine the travel and impact speed of vehicles involved in crashes at intersections. A further aim was to examine how certain intersection features may influence these speeds. The median and 85th percentile speeds were calculated by speed zone using EDR data from 104 striking vehicles. The risk of serious injury in an intersection crash at these impact speeds were also calculated. Crashes that occurred in 50 and 60 km/h speed zones (n=88) were further analysed by crash type, intersection type and traffic control. The risk of serious injury in intersections crashes was found to increase with speed limit. Initial outcomes of this study indicate that crashes occurring in intersections zoned at 70 km/h or less, limit the risk of serious injury of the median impact speed to below 1%. However, to limit the risk of serious injury to lower than 1% considering the 85th percentile impact speed, the speed limit through intersections must be 50 km/h or less. Roundabouts produce the lowest impact speeds of any intersection type or traffic control in 50 and 60 km/h zones, though this result should be confirmed with a larger sample.

Keywords

Event Data Recorder, Intersection, Speed, Speed limit, Roundabout, Traffic Control, Serious Injury

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Summary

Safe speeds are considered a key part of a safe transport system. Speeds in intersection crashes are of particular importance due to their frequency and the injury risks associated with the impact configurations that occur in intersection crashes. Event data recorders (EDRs) offer a new opportunity to examine the speeds of vehicles in crashes. The aim of the research presented in this report was to use EDR data to examine the travel and impact speeds of vehicles involved in crashes at intersections. A further aim was to examine how certain intersection features may influence these speeds.

The data source for the analysis was the CASR-EDR database. There were 104 cases that could be included in the analysis, with most of the cases occurring in 50 and 60 km/h zones. The median and 85th percentile speeds were calculated by speed zone, for all 104 crashes. The risk of serious injury in an intersection crash at these impact speeds were also calculated. Crashes that occurred in 50 and 60 km/h speed zones (n=88) were further analysed by crash type, intersection type and traffic control.

It was found that the serious injury risk at the median impact speed remained below 1% for speed limits of 70 km/h or less. For the 85th percentile impact speed, only crashes occurring in 50 km/h zones ensured the risk of serious injury remained below 1%. These speed limits could be considered the maximum speed limit for intersections that do not slow travel speeds through other means, though it is unclear what speed should be used for this application, the median or the 85th percentile. Furthermore, the lack of data for intersection crashes in speed zones above 60 km/h means that this result is best treated as a preliminary result that requires confirmation once a larger sample is available.

The data presented in this report revealed that in almost all instances the impact speeds in intersection crashes occurred below the speed limit. The exceptions to this, were cases where vehicles were travelling substantially above the speed limit. In general, the data suggests that, for planning purposes, the speed limit could be thought of as a maximum expected impact speed in 50 and 60 km/h zones. This may also hold true for other speed limits but would need to be confirmed with more data.

Roundabouts were found to be both the intersection type and traffic control type that had the lowest crash impact speeds. The ability of a roundabout to reduce and control impact speeds in intersection crashes was highlighted by the large differences in the 85th percentile impact speeds when comparing roundabouts and other intersection and traffic control types. This difference in 85th percentile impact speed ranged between 7 and 17 km/h, which represented at least a halving of the risk of serious injury in crashes at roundabouts compared to other intersection and traffic control types. This suggests that roundabouts could be considered as the safest intersection and traffic control type for vehicle-to-vehicle crashes without even considering the additional benefit of reduced impact angles in roundabout crashes. However, more data from roundabout crashes is necessary to confirm this.

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1. Introduction

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The data source for the analysis was the CASR-EDR database. There were 104 cases that could be included in the analysis, with most of the cases occurring in 50 and 60 km/h zones. The median and 85th percentile speeds were calculated by speed zone, for all 104 crashes. The risk of serious injury in an intersection crash at these impact speeds were also calculated. Crashes that occurred in 50 and 60 km/h speed zones (n=88) were further analysed by crash type, intersection type and traffic control.

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2. Method

The data source for the analysis was the CASR-EDR database. The CASR-EDR database includes the EDR data from vehicles involved in a crash in South Australia, information from the associated police report, and hospital injury data when available. The database contains crash data from 2017 onwards, with 100 to 200 cases added each year. The sample has been found to be reasonably representative of all police-reported crashes in South Australia in terms of injury severity, speed zone and crash type. For further detail on the CASR-EDR database see Elsegood, Doecke & Ponte (2021)

Figure 2.1 shows the process used to select cases for inclusion in the analysis. Some early versions of EDRs did not record speed, but only delta-v. Of those with speeds recorded, 264 cases in the CASR-EDR database occurred at an intersection. However, not all of these would be considered typical intersection crashes. Some were single-vehicle crashes that occurred at an intersection (n=18). Others were rear-end crashes that were coded as occurring at an intersection (n=9). While many rear-end crashes occur as a result of congestion related to intersections, these were not considered as intersection crashes for the purpose of this analysis. Several unusual types of two-vehicle turning collisions were also excluded. The analysis was limited to right angle, right turn – adjacent, and right turn -opposite crash types, which formed the vast majority of crashes at intersections (n=216). Each case in the CASR-EDR database typically only had EDR data from one of the involved vehicles. The speeds of interest were the travel speeds and impact speeds of the bullet, or striking, vehicles. This left 104 cases that could be included in the analysis. Initial analysis by speed zone highlighted that most of the crashes occurred in 50 and 60 km/h zones. While the initial plan included conducting further analyses by speed zone groupings, only the speed zone group of 50 and 60 km/h zones was sufficient in size (n=88) for further analysis.

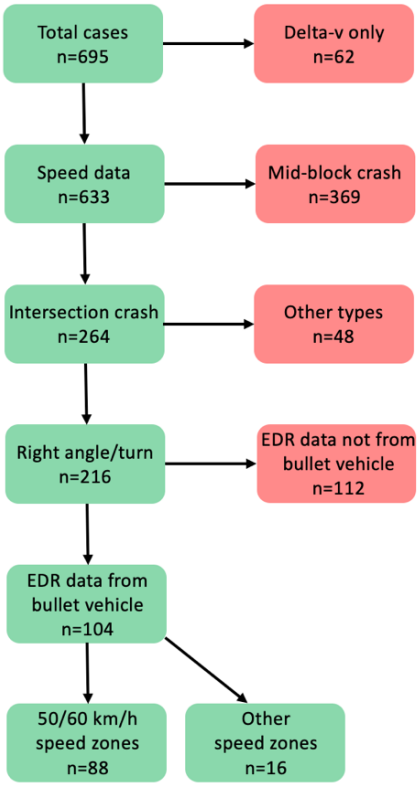

Figure 2.1
Cases selection for analysis

The definitions of travel speed and impact speed in the present study were taken from those used in the CASR-EDR database. Travel speed is defined in the CASR-EDR database as the maximum speed of the vehicle recorded in the EDR data, which generally records 4.5 to 5 seconds of pre-crash speed data. Impact speed is defined as the speed the vehicle was travelling when it first impacted the other vehicle.

The median and 85th percentile speeds were calculated by speed zone for all 104 crashes. The same was calculated for the sub-sample of cases occurring in 50 and 60 km/h speed zones, disaggregated by crash type, intersection type and traffic control. To provide meaningful comparison between crashes occurring in different speeds zones, the travel speed and impact speed were expressed as speeds relative to the speed limit, rather than the absolute speed. When considering speeds by crash types (right angle, right turn – opposite, right turn – adjacent), crashes that occurred at roundabouts were excluded from the analysis as a roundabout fundamentally changes the travel paths of vehicles through an intersection when compared to a regular crossroads or T-junction. The t-test was used to test the statistical significance of differences in median travel and impact speed noted in the analysis.

The risk of serious injury in an intersection crash at the median and 85th percentile impact speeds was also calculated. The equations presented in Doecke et al. (2020) were used. These equations give the probability of serious injury by a vehicle impact type relative to closing impact speed. In an intersection crash there are typically two impact types that occur in a single crash, a frontal impact for the striking vehicle, and a side impact for the struck vehicle. The closing impact speed is equal to the impact speed of the bullet vehicle in intersections crashes where the vehicles are travelling at right angles. Equations 1 and 2 taken from Doecke et al. (2020) were used to calculate the probability of serious injury for a frontal impact and side impact at a given impact speed. The overall risk of serious injury is then calculated by summing the probabilities using Equation 3. This probability can then be expressed as a percentage risk.

$$P_{front\ impact} = \frac{1}{1+e^{8.1231-0.0548(impact\ speed)}} \quad (1)$$

$$P_{side\ impact} = \frac{1}{1+e^{10.5583-0.1161(impact\ speed)}} \quad (2)$$

$$P_{intersection\ crash} = \left(P_{front\ impact} + P_{side\ impact}\right) - \left(P_{front\ impact} \times P_{side\ impact}\right) \quad (3)$$

The following is an example of how Equations 1 to 3 are used to calculate the risk of serious injury for an intersection crash with an impact speed of 60 km/h.

$$P_{front\ impact} = \frac{1}{1+e^{8.1231-0.0548(60)}} = 0.0079$$

$$P_{side\ impact} = \frac{1}{1+e^{10.5583-0.1161(60)}} = 0.0268$$

$$P_{intersection\ crash} = (0.0079 + 0.0268) - (0.0079 \times 0.0268) = 0.0345$$

The probability that an intersection crash with an impact speed of 60 km/h would result in serious injury is 0.0345, or 3.45%.

3. Results

3.1. All speed zones

The median and 85th percentile values of the travel and impact speeds of the bullet vehicles in the intersection crashes are shown in Table 3.1 by speed limit. The calculated serious injury risks for intersection crashes at the median and 85th percentile impact speeds are also shown. The median and 85th percentile speeds are only meaningful for the 50, 60 and 80 km/h speed zones, as all other speeds zones have very few cases. However, all speed zones are shown for completeness. It is interesting to note that while there is a 6 km/h difference in the median travel speeds in 50 and 60 km/h zones, this reduces to only 1 km/h at impact. However, the difference between the 85th percentile impact speeds for these two speed zones is much larger, at 5.1 km/h.

Table 3.1
Travel speed, impact speed and serious injury risk in intersection crashes, by speed limit

Speed limit	Number	Travel speed (km/h)		Impact speed (km/h)		Serious injury risk	
		Median	85th	Median	85th	Median	85th
25 km/h	1	38.0	NA	25.5	NA	0.2%	NA
40 km/h	1	34.0	NA	34.0	NA	0.3%	NA
50 km/h	19	48.0	51.3	38.0	46.3	0.5%	0.9%
60 km/h	69	54.0	60.0	39.0	51.4	0.5%	1.5%
70 km/h	3	66.0	95.4	41.0	73.9	0.6%	13.6%
80 km/h	6	65.5	73.3	55.0	68.0	2.1%	7.7%
90 km/h	1	86.0	NA	63.0	NA	4.7%	NA
100 km/h	2	94.5	95.6	60.3	70.9	3.5%	10.2%
110 km/h	2	110.5	113.0	92.5	101.3	56.6%	78.5%
Total	**104**	**54.0**	**64.0**	**40.0**	**53.6**	**0.5%**	**1.8%**

The full distribution of travel speeds and impact speeds in 60 km/h zones are shown in the histograms presented in Figure 3.1 and 3.2. While the travel speeds are varied, there is a clear peak in the distribution between 50 and 60 km/h. In contrast, the impact speeds have a much wider distribution, with a similar number of impact speeds being between 31-35, 36-40, 41 to 45 and 46 to 50 km/h. Only one of the 69 impacts occurred at a speed over the 60 km/h speed limit, and this was related to a vehicle that was travelling at 114 km/h.

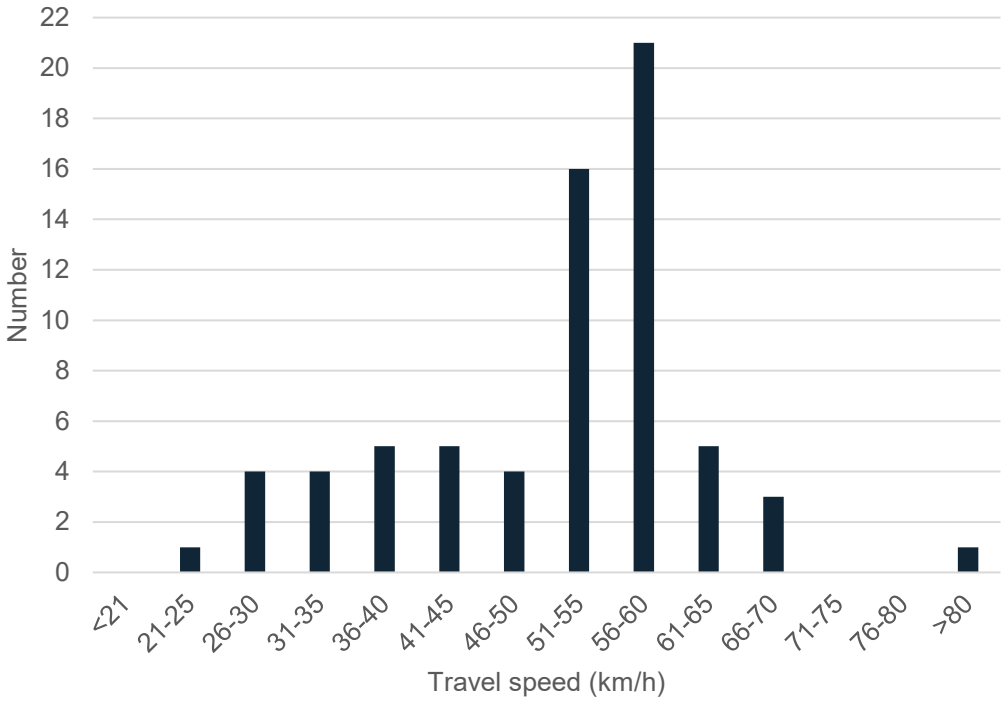

Figure 3.1
Travel speed of striking vehicles for intersection crashes in 60 km/h zones

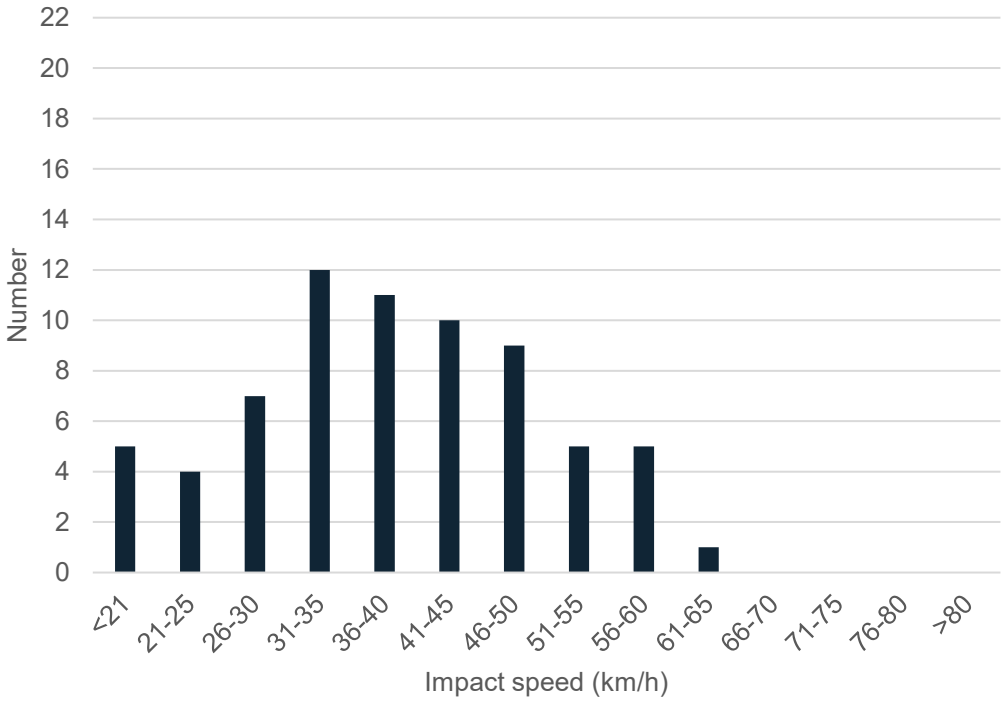

Figure 3.2
Impact speed of striking vehicles for intersection crashes in 60 km/h zones

3.2. 50 and 60 km/h speed zones only

The following results are based only on the intersection crashes that occurred in 50 and 60 km/h speed zones. In order to combine the data from both speed zones, travel and impact speeds are expressed relative to the speed limit.

The travel and impact speeds (relative to the speed limit) are shown by crash type in Table 3.2. The serious injury risks for the median and 85th percentile speeds in in 50 and 60 km/h zones are also shown. Note that crashes at roundabouts were excluded from the results in this table. Right angle crashes had a lower median travel and impact speed than the two different types of right turn crashes, but higher 85th percentile values. Right turn – opposite crashes had the lowest 85th percentile impact speed. The results indicate that the 85th percentile impact speeds in a 60 km/h zone would be 48.9 km/h for right turn – opposite crashes, 53 km/h for right turn – adjacent crashes and 54.5 km/h for right angle crashes. The serious injury risks are above 1% for the 85th-percentile speeds in 60 km/h zones, but are all below 1% in 50 km/h zones.

Table 3.2
Travel and impact speed relative to speed limit, and serious injury (SI) risk, for intersection crashes occurring in 50 and 60 km/h zones, by crash type

Crash type	Number	Travel speed relative to speed limit (km/h)		Impact speed relative to speed limit (km/h)		SI risk for 50 km/h zones		SI risk for 60 km/h zones	
		Median	85th	Median	85th	Median	85th	Median	85th
Right angle	20	-14.5	4.3	-24.0	-5.5	0.2%	0.8%	0.4%	2.0%
Right turn -adjacent	35	-4.0	1.0	-17.0	-7.0	0.3%	0.7%	0.7%	1.7%
Right turn - opposite	28	-4.5	0.0	-18.5	-11.1	0.3%	0.5%	0.6%	1.2%

Table 3.3 shows the travel and impact speeds (relative to speed limit), and the serious injury risks, by junction type, for the intersection crashes occurring in 50 and 60 km/h zones. A crash that occurred at a multi-leg junction and a crash that occurred at a Y-junction are not shown. Travel speeds in roundabout collisions were much lower than those at crossroads and T-junctions. The median impact speed was also lower at roundabouts than the other junction types, though the difference was not as great as for travel speed. However, the difference in the 85th percentile impact speed was similar in size to that for travel speed, being about 12 km/h less than at other junction types. The differences between the speeds at roundabouts compared to the other types of intersections was statistically significant for travel speed (p=0.001 to 0.047), but not for impact speed (p=0.087 to 0.198). For a 60 km/h zone, the 85th percentile impact speeds would be 53.2 km/h for crossroads, 53 km/h for T-junctions, and 40.8 km/h for roundabouts. Roundabouts were the only intersection type to have a serious injury risk of less than 1% for the 85th percentile impact speed in 60 km/h zones.

Table 3.3
Travel and impact speed relative to speed limit, and serious injury (SI) risk, for intersection crashes occurring in 50 and 60 km/h zones, by intersection type

Intersection type	Number	Travel speed relative to speed limit (km/h)		Impact speed relative to speed limit (km/h)		SI risk for 50 km/h zones		SI risk for 60 km/h zones	
		Median	85th	Median	85th	Median	85th	Median	85th
Crossroads	33	-5.0	1.4	-21.0	-6.8	0.2%	0.7%	0.5%	1.8%
T-junction	43	-4.0	1.0	-18.0	-7.0	0.3%	0.7%	0.6%	1.7%
Driveway	5	-7.0	-0.6	-19.0	-12.0	0.3%	0.5%	0.6%	1.1%
Roundabout	5	-23.0	-12.8	-25.0	-19.2	0.2%	0.3%	0.4%	0.6%

Table 3.4 shows the travel and impact speed (relative to speed limit), and the serious injury risk, by the type of traffic control, for crashes occurring at intersection in 50 and 60 km/h zones. Roundabouts were also included in Table 3.4 as they are considered both an intersection type, and a type of traffic control. Roundabouts had the lowest median and 85th percentile travel speeds, followed by traffic signals. Roundabouts also had the lowest impact speeds. Stop signs had the highest travel speeds, and the highest median impact speed, but the second lowest 85th percentile impact speed. Give Way signs had the highest 85th percentile impact speed and were the only traffic control at which the 85th percentile speed in a 50 km/h zone resulted in a serious injury risk above 1%. Conversely, roundabouts were the only traffic control to have a serious injury risk of less than 1% for their 85th percentile speed in 60 km/h zones. The differences in travel speed were found to be statistically significant between roundabouts and: uncontrolled intersections ($p=0.001$), give way signed intersections ($p=<0.001$), and stop sign controlled intersections ($p=0.007$), but not signalised intersections ($p=0.108$). The differences in impact speeds were also found to be statistically significant between roundabouts and give way and stop sign controlled intersections ($p=0.012$ and 0.023 respectively), but not between roundabouts and uncontrolled or signalised intersections ($p=0.140$ and 0.135 respectively).

Table 3.4
Travel and impact speed relative to speed limit, and serious injury (SI) risk, for intersection crashes occurring in 50 and 60 km/h zones, by traffic control

Traffic control	Number	Travel speed relative to speed limit (km/h)		Impact speed relative to speed limit (km/h)		SI risk for 50 km/h zones		SI risk for 60 km/h zones	
		Median	85th	Median	85th	Median	85th	Median	85th
Uncontrolled	41	-4.0	2.0	-19.0	-7.0	0.3%	0.7%	0.6%	1.7%
Traffic signals	29	-8.0	-2.0	-22.5	-11.2	0.2%	0.5%	0.4%	1.2%
Give Way Sign	7	-1.0	0.0	-17.0	-1.8	0.3%	1.1%	0.7%	2.9%
Stop Sign	6	0.0	3.8	-15.0	-11.5	0.4%	0.5%	0.8%	1.1%
Roundabout	5	-23.0	-12.8	-25.0	-19.2	0.2%	0.3%	0.4%	0.6%

4. Discussion

This study used EDR data from the CASR-EDR database to examine speeds in intersection crashes. EDR data has been shown to provide highly accurate speed data for crashes (Bortles, Biever, Carter & Smith, 2016). By using this new source of speed data, this study has provided insights into the speeds of vehicles in crashes at intersections. This included both the speed at which they were travelling at prior to the crash, and the speed at which they impacted the other vehicle.

Calculations of risk of serious injury for the intersection crashes showed that the risk of the median impact speed remained below 1% for speed limits of 70 km/h or less. For the 85th percentile impact speed, only 50 km/h zones ensured the risk of serious injury remained below 1%. These speed limits could be considered the maximum speed limit for intersections that do not slow travel speeds through other means, though it is unclear what speed should be used for this application, the median or the 85th percentile. Furthermore, the lack of data for intersection crashes above 60 km/h means that this result is best treated as a preliminary result that requires confirmation once a larger sample is available.

Roundabouts were found to be both the intersection type and traffic control with the lowest crash impact speeds. The ability of a roundabout to reduce and control impact speeds in intersection crashes is highlighted by the large differences in the 85th percentile impact speeds between roundabouts and other intersection and traffic control types. This difference in 85th percentile impact speed was between 7 and 17 km/h, which represented at least a halving of the risk of serious injury in crashes at roundabouts compared to other intersection and traffic control types. This suggests that roundabouts could be considered as the safest intersection and traffic control type for vehicle-to-vehicle crashes without even considering the additional benefit of reduced impact angles in roundabout crashes. However, more data from roundabout crashes is necessary to confirm this.

The data presented in this report revealed that in almost all instances the impact speeds in intersection crashes occurred below the speed limit. The exception to this were cases where vehicles were travelling substantially above the speed. In general, the data suggests that, for planning purposes, the speed limit could be thought of as a maximum expected impact speed in 50 and 60 km/h zones. This may also be true for other speed limits but would require validation with a larger dataset.

The calculation of the risk of serious injury performed in the analysis raises the question of acceptable risk. That is, what risk of serious injury is acceptable, and what risk of serious injury is unacceptably high? Doecke et al. (2020) points out that this is still an unanswered question but suggests it likely to be much smaller than the previously used 10%, and probably close to 1%. The acceptable risk should also consider not just the risk of serious injury if a crash occurs, but the frequency of the crashes.

5. Conclusions

The risk of serious injury in intersection crashes was found to increase with speed limit. Initial indications from this study are that speed limits of 70 km/h or less keep the risk of serious injury of the median impact speed below 1%. However, if the 85th percentile impact speed is considered, the speed limit must be 50 km/h or less to achieve a serious injury risk of less than 1%. Roundabouts produce the lowest impact speeds of any intersection type or traffic control in 50 and 60 km/h zones, though this result should also be confirmed with a larger sample.

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The views expressed in this report are those of the authors and do not necessarily represent those of the University of Adelaide or the funding organisations.

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