Injury Reduction Benefits of Roundabouts Evaluated Using Real-world Data and Simulation Software

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Abstract

Roundabout geometry inherently promotes favorable impact angles and reduced travel speeds, with casualty crash reductions of around 75% being found (Newstead et al., 2001). Using real-world crash and speed data, the benefits of a traditional roundabout were examined. We present a crash case-study and free-speed measurements from a conventional roundabout to highlight the safety performance of this design. While the conventional roundabout is a Safe System compliant intersection treatment, not all designs promote travel speeds that meet acceptable injury risk levels. Contemporary design issues are discussed briefly in this context.

Background:

Crashes that occur at cross-intersections can have major consequences, given they typically occur at high speeds and at 90-degree impact angles. This is exemplified by 45% of serious casualty crashes and 20-30% of road fatalities in Victoria occurring at intersections (Candappa et al., 2015).

Roundabouts are regarded as an intersection design solution that offers major safety benefits whilst achieving efficient traffic flow. An optimally designed roundabout, via the radii of its approach alignment achieves speed reductions, such that vehicles enter the roundabout at 50 km/h or lower before they reach the conflict area (Austroads, 2015). The horizontal deflection associated with the circular island achieves further speed reductions and the tangential approach optimises intersection performance by managing conflict angles and sight lines.

Given the importance of roundabouts as a Safe System solution for intersection-based road trauma, this study examines the impact speed and injury severity of a specific crash at a conventionally-designed roundabout, and presents vehicle speeds at entry and through the roundabout.

Methodology:

A crash case study was examined from the MUARC Enhanced Crash Investigation Study (ECIS), (refer to Fitzharris et al., 2015 for a detailed description of ECIS). ECIS includes a 'control component' where the ‘free speed’ (i.e., first vehicle in traffic) of drivers passing through the crash site without incident is recorded, on the same day of the week and within a 30 minute window either side of the known time of crash.

The case study crash occurred in a roundabout at the intersection of a high volume highway (100 km/h) and a regionally-significant road (100 km/h), in a semi-urban environment (Figure 1). The site was represented in Rhino V5 and imported into Human Vehicle Environment (Figure 1). Two simulation vehicles representing the real-world case-vehicle (a 2005 SUV, ANCAP 5) and the real-world B-vehicle (a large sedan, ANCAP 5) were used to simulate crash. The crash was validated against objective crash measures. The point of impact (POI) was the left front door of the A-vehicle (the struck vehicle) and the front right corner of the B-vehicle (the striking vehicle). The driver of the B-vehicle failed to yield. Airbags did not deploy in either vehicle. The case (A) vehicle driver first presented to a local GP and was then transferred to hospital by ambulance with cervical spine (neck) pain, lower back pain, and concussion (AIS1, minor injury). Both vehicles were towed from the scene with minor damage.

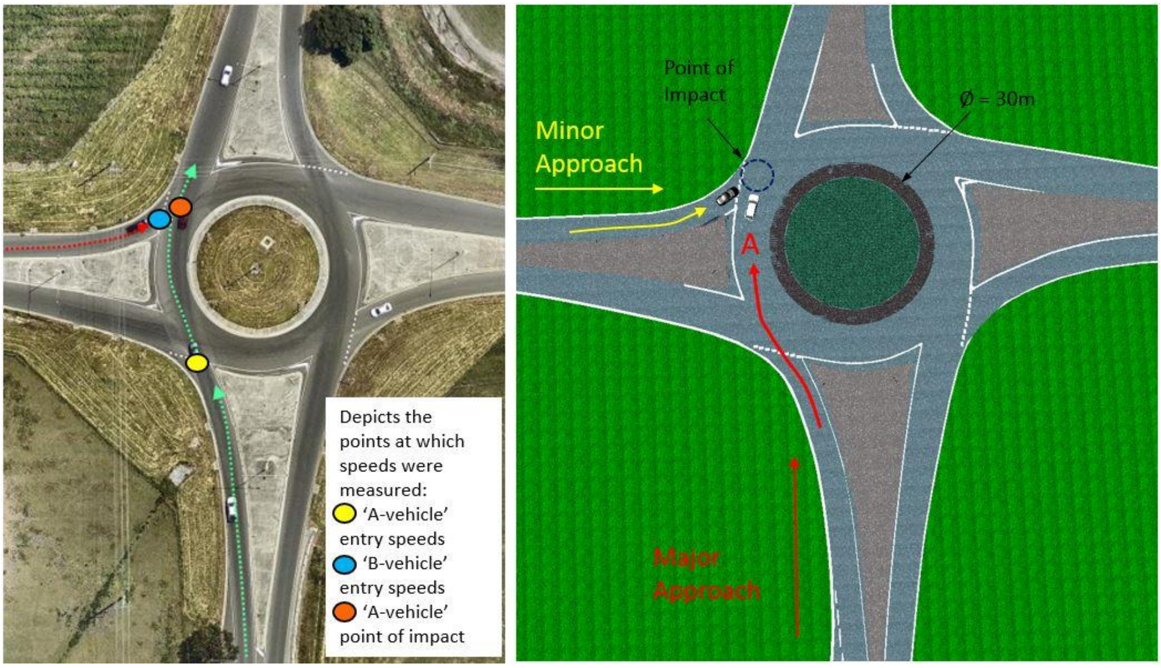

Figure 1. A graphic showing the actual site (Left) and that modelled in HVE (Right), showing the intended paths of the vehicles.

Results:

Simulation Outcomes: Simulation estimates suggest that the case-vehicle travelling on the major approach, entered the roundabout at 41 km/h and after braking, impacted at 35 km/h. The B-vehicle, travelling on the minor approach, entered the roundabout at 38 km/h and impacted the A-vehicle at approximately 29 km/h. Crash forces were estimated to be 24 kN. The angle between impacting vehicles was approximately 20 degrees. That the case (A) vehicle driver required hospitalisation for further assessment of their injuries is of concern, however, it is notable that the type of injury was classified a 'minor' using the Abbreviated Injury Scale (i.e., AIS1, AAAM 2005).

Free Speed Measures (Control): Speed for 27 vehicles travelling from the major approach at the entry to the roundabout and at the POI, and 30 vehicles on the minor approach, were measured using a laser camera (Table 1, see Figure 1 for measurement points). The speeds of all but one vehicle (96%) on the major approach at the POI were below 50 km/h (mean speed reduction: 8.8 km/h, $p<0.01$).

Table 1. Control Vehicle Free Speed (km/h) Measurements Statistical Summary

	Major Road, 100 km/h		Minor Road, 100 km/h
	Entry point	Point of Impact	Entry point
Mean Speed (km/h) (SD, km/h)	49 (13)	40 (6)	33 (8)
Median (km/h)	51	41	34
Lowest / Highest speed (km/h)	16 - 69	28 – 53	16 - 48
Traffic volume* (cars/min)	3	3	3

*Measurements obtained between 12.21pm and 1.35pm

Conclusion:

The study of this roundabout was precipitated by a crash where the driver was hospitalised but with low severity injury after being struck by another vehicle at an estimated 29 km/h. Based on the lower impact speed and commensurate low crash forces, the roundabout performed well and within Safe System design boundaries (i.e. lower impact speeds, more favorable geometry and both drivers were in ANCAP 5-star rated vehicles).

Examination of free-speeds requires a thorough assessment of roundabout geometry and other factors such as traffic volume, road function, the presence of other vehicles within the roundabout and sight lines. A thorough discussion of this will follow in a full length paper

Further work examining roundabouts with different design features including the effects of single or dual circulating lanes, across different times of the day using multiple speed measurement points, will be the subject of future research. In doing this, a comparison of the performance of traditional roundabout designs with innovative designs, including those featuring 'reverse curve' approach lanes, will be undertaken.

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ECIS Study team

In addition to those named in the author by-line, the ECIS team consists of: Tandy Pok Arundell, Prof C. Raymond Bingham, Caitlin Bishop, A/Prof Di Bowman, Samantha Buckis, Sarah Bullen, Samantha Cockfield, Rai Curry, Prof. Hampton. C. Gabler, Dr Jane Holden, Debra Judd, Prof. Mike Lenné, Lindsay Lorrain, Daniel Machell, Hayley McDonald, Prof. Andrew Morris, Michael Nieuwesteeg, Geoff Rayner, Marnie Reilly, Emily Robertson, Dr Amanda Stephens and Karen Vlok.

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