Local road mountable roundabouts – are there safety benefits?

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Abstract

Roundabouts are internationally accepted as being highly effective in improving safety at intersections. However, the installation of roundabouts at intersections is not always easy. Initiatives to improve safety at intersections include the use of mountable or mini-roundabouts on local roads. Similar in design to the traditional roundabouts, mini-roundabouts have the advantage of being more readily incorporated at restricted intersection geometries, the mountable central island allowing larger vehicles to mount the island to account for tight turning circles. Though not necessarily a new concept, little information is available on the design's efficacy. A case study of two such roundabouts suggests some safety benefits. When considering the overall kinetic energy at the subject sites, the levels of kinetic energy, in both vehicle and vulnerable road user-involved crashes, were far more favourable at the treated sites than those at the control site. A study using a larger dataset is recommended to validate results.

Background

Roundabouts are internationally accepted as being highly effective in improving safety at intersections. However, the installation of roundabouts at intersections is not always easy; the intersections often need to be widened to create the appropriate deflection and induce adequate reductions in approach speeds. Especially on local streets where intersection geometry is constrained by residential properties and budgets for improvement works are not large, traditional roundabout installation becomes problematic. An alternative option was needed.

Fully mountable "mini-roundabouts" have been in use in Melbourne in the recent past at local street intersections (AustRoads Ltd, 2013), as well as overseas, however, no evaluation of these has been completed, and little information exists on mini-roundabout effectiveness in general. Monash University Accident Research Centre (MUARC) was commissioned by the Transport Accident Commission (TAC) to complete a brief study to identify any quantifiable safety benefits associated with these roundabouts with respect to passenger vehicle and vulnerable road user, VRUs (pedestrian and cyclist) safety.

Mini-roundabout definition

Mini-roundabouts are essentially traditional roundabouts but with a smaller footprint and a traversable central island. The central island is adequately small in diameter such that the intersection does not require widening yet the island defines traffic movement at the intersection. Splitter islands are used to channel vehicles around the central island. Traffic operation at a mini-roundabout requires drivers to give way to vehicles circulating the central island (and vehicles approaching on the right in the event of potential conflict) and to travel around the island except where vehicle size impedes this (US Federal Highway Agency 2010, County Surveyors Society and Department for Transport, UK, 2011, Austroads, 2013). Typical defining features of a mini - roundabout include a traversable central island of diameter between 1 and 4 m, a dome of no more than 125 mm and a raised kerb of no more than 6 mm (AustRoads, 2013). The accompanying linemarking is typical of that at traditional roundabout designs.

Mini-roundabouts differ from traffic circles in two distinct ways – traffic circles at intersections operate as Give Way sign controlled intersections; and generally do not involve vehicle channelisation in to the circulatory roadway. That is, it appears to be used more as a traffic calming measure at the intersection than a traffic movement controlling measure. (County Surveyors, 2011)

Method

Two mini-roundabouts in line with the AustRoads prescribed definitions were identified as case studies to establish indicative effects of these treatments on intersection safety. A nearby local street intersection, governed by Give Way sign regulation, was identified as a control site. Key features of all three sites included 50 km/h posted speed limits, on-street parking and 2.5-3 metre traffic lanes. Vehicles along Road 1 of the control site were governed by a Give Way sign, vehicles in the east-west direction maintains right of way; vehicles along Road 1 and Road 2 of the treatment sites are governed by traditional roundabout rules. Covert measurements of the speeds of approaching vehicles were recorded over a two-day period via laser gun. Speed measurements were collected only for Road 1 of each treatment site and control site (the north-south direction). Speeds along Road 2 of the treatment sites (east-west direction) were assumed to have similar speeds to those on Road 1 of the treatment sites given similar design features. Speeds along Road 2 of the control site (east-west direction) were assumed to be at the speed limit, in this case at 50 km/h.

To evaluate the impact of the mini central island on mitigating impact angle, the incidence of drivers traversing the roundabout (thereby reducing the benefit of the presence of the island) was recorded and the worst case impact angle calculated of two vehicles colliding while circulating the central island. To do this, a DVD recorder was mounted on a pole at one of the treatment sites and footage recorded. Driver behaviour patterns and compliance to road design regulations at the intersection was noted. The island was marked in 200 mm increments and encroachment of the island was categorised in terms of full, semi and non-compliance. Encroachment was defined as follows: “compliant” defined as the encroachment of the island of less than 200 mm; “semi-compliant” 200 mm-1800 mm encroachment; “non-compliant” greater than 1800 mm encroachment. The worst-case impact angles were calculated for a typical collision at the intersections in question using CORELDRAW software and a scaled diagram of the intersection. Any changes to impact angles were included in to calculations of respective kinetic energy (KE) levels at the intersections and compared to potential KE at a ninety-degree collision to establish relative safety levels.

These results were analysed and compared to those at the selected control site. Approach speeds, departure speeds, speeds at the intersections (impact speed) were analysed using the IBM SPSS statistical package (Version 20.0). Independent t-tests were used to compare the speeds at the intervention sites to the speeds at the control site.

Results

Mean Speed

The analysis consisted of 533 vehicles. In the interest of maintaining required paper length, only the mean impact speeds are reported, although approach and departure speeds were also collected. The mean impact speed at sites 1 and 2 were 23.78 km/h and 22.17 km/h respectively. Given there were no differentiating features on the intersecting road of each treated intersection (east-west direction), the same mean speeds were assumed for Road 2 of each treated site. The mean impact speed measured at the control site was 12.61 km/h. Given drivers had right of way on the intersecting road of the control site (Road 2), it was assumed that mean travel speed would be at the speed limit of 50 km/h.

Overall speed environmental at intersections

While results indicate higher mean speeds on Road 1 of the treatment sites compared to the control site, when mean speeds on Road 1 and Road 2 were averaged, average speeds were found to be lower at the treatment site than at the control site. At treatment sites 1 and 2, taking mean impact speeds to be equal along either road, average speeds were 23.78 km/h and 22.17 km/h respectively. At the control site, taking speeds along the road with right of way to be at the speed limit (50 km/h), average speed was found to be 31.3 km/h. Taking a mass of 1 tonne, overall KE at the treatment sites were calculated to be lower than those at the control site.

Impact Angle and Compliance

Scaled drawings of the mini-roundabout on site indicate a reduced impact angle of approximately 15 degrees as a result of the mini central island. This can lead to a reduction in overall KE of around 13% (Table 1). However, video footage of the subject sites suggests compliance to the central island during peak periods was low. Nearly all vehicles encroached the central island to some extent. In the AM period, encroachment was typically greater than 1800 mm, drivers being non-compliant to the presence of the island. In the PM period where perhaps time pressure was not a prominent factor, encroachment was typically a third, or drivers can be considered semi-compliant to the island.

Table 1: Summary of key results

	Mean Impact Speed (km/h)	Std Dev	Average Impact Speed across both roads (km/h)	Av KE across both road (kJ)	AV KE across both road incorporating Impact Angles (kJ)	% reduction in av KE
Site 1 (n=272)	23.78	8.18	23.78	21.82	18.99	13%
Site 2 (n=230)	22.17	7.59	22.17	18.95	16.49	13%
Control (n=31)	12.61	6.41	31.31	37.81	37.81	0%

Discussion

Safety Implications for Drivers

Results of this preliminary study suggest some safety benefits in the use of mini-roundabouts on local roads. While this is not evident when comparing only the mean speeds along one road of each site, when considering the overall kinetic energy at the treated sites, the average levels of kinetic energy in vehicle involved crashes were far more favourable at the treated sites than those at the control site. Using the respective average velocities for each direction, and using a standard mass of vehicle (1 tonne), the average KE for the intersection was calculated. This indicated that average KE at the treated sites was approximately 20 kJ compared to 38 kJ at the control site. Based on studies on velocities relating to biomechanical tolerance for side impact crashes, (Tingvall and Haworth, 1999) limits of KE levels are around 97 kJ, (Candappa, Logan et al 2014) indicating that at the control site, the potential KE is well over third the tolerable levels while at the treatment sites, this is around a fifth (Figure 1). This indicates that considering the site as a whole, the KE generated by a typical crash at the control site is higher than that generated at either treated site. This suggests that in the event of a crash, sites with a mini-roundabout are likely to produce less severe injury outcomes than sites with a Give Way sign. The slightly reduced angles are also likely to contribute to reduced KE levels. While compliance to the central island appears to be an issue at the sites studied, this appears to be more a problem when only one vehicle is present at the intersection. Potential conflict could arise when a heavy vehicle unable to circulate the island and traverses over the island, conflicts with a passenger vehicle circulating the island. This is considered an infrequent occurrence however given these mini-roundabouts are intended for local roads where the incidence of heavy vehicles is restricted more to garbage trucks, ambulances and perhaps the occasional truck.

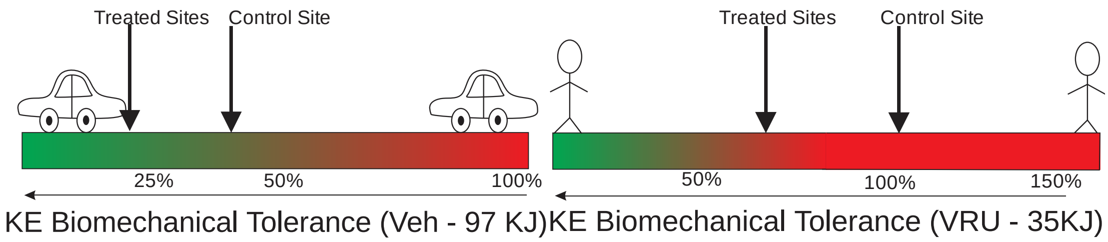

Figure 1 – relative KE levels for vehicle and vulnerable road user crashes

Safety benefits associated with the mini-roundabouts are generally in line with early UK studies that suggest reductions in crashes at mini-roundabouts, and an FHWA study that found mini-roundabouts to provide similar benefits to traditional roundabouts (AustRoads, 2013). Brillon (2011) also found a decrease in crashes in Germany (30%) when converting from cross intersections to mini-roundabouts. Another US study however, found there to be no change in crash numbers after mini-roundabout installation (Waddell and Albertson, 2005 cited in Austroads, 2013).

Safety Implications for Pedestrians and Cyclists

Safety benefits are also associated with mini-roundabouts when considering collisions involving pedestrians and cyclists. At the treated sites, KE levels were around 20 KJ, around 60 % of what is regarded as the maximum tolerable KE levels for vulnerable road users. (Tingvall and Haworth, 1999) At the control site, KE can be around 40 kJ, over the survivable levels. Impact angles are not expected to greatly affect these KE levels, though the specific point of contact with the vehicle can sometimes exacerbate outcomes. This increase in safety levels for vulnerable road users is in line with some overseas study findings that suggest mini-roundabouts can improve safety for vulnerable road users, while other studies report higher injury crash reductions for pedestrians and cyclists.

Future research

A study using a larger database is recommended to further validate these findings. Some safety benefits were apparent through the use of mini-roundabouts, particularly in the form of speed reduction. However, the mean speeds were found to be higher at the mini-roundabout than at the Give Way control site. This could suggest a greater speed reduction is effected by Give Way signs than a mini central island. In order to achieve the goal of safer local intersections, it is worth investigating further whether the US practice of All-Way Stop signs on local streets produce similar lowered speeds through intersections, producing similar or greater safety benefits at lower costs.

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