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Safety effectiveness of converting signalized intersections to roundabouts

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ABSTRACT

Roundabouts may be new builds but often are conversions from existing intersections. When contemplating the later, there is a need to estimate the safety effects of conversions. Several studies have estimated large reductions in crashes and severity; however, these results pertain mainly to conversions from unsignalized intersections. Results for conversions from signalized intersections have been less conclusive or consistent and tend to be somewhat dated. The objective of this study was to fill this void by estimating the safety effectiveness of converting *signalized* intersections to roundabouts.

Several states helped to identify signalized intersections that were converted to roundabouts in the recent past. In total, 28 conversions were identified in the United States. The empirical Bayes (EB) method was employed in an observational before–after study to estimate the safety effects. Data from select states were also used in a cross-sectional analysis to investigate the compatibility of results from cross-sectional and before–after studies.

The EB results indicated a safety benefit for converting signalized intersections to roundabouts. There were reductions in both total and injury crashes, with a larger benefit for injury crashes. Further analysis indicated that the safety benefit of roundabouts for total crashes decreased as traffic volumes increase, a result that suggests the need for the development of a crash modification function, a task for which more data would be required. The safety benefit for injury crashes was sustained across all traffic volumes. Both trends were supported by the cross-sectional analysis. Based on the analysis, it appears that roundabouts have the potential to significantly reduce crashes and severity at signalized intersections.

A key aspect of the study was the estimation of the standard deviation of the distribution of the CMF in addition to the conventionally estimated standard error of the mean CMF value. For some CMFs, especially the CMFs for total crashes, the standard deviation of the distribution was larger than the standard error of the mean value of the CMF, indicating substantial variation in the treatment effect across sites.

1. Introduction, background and motivation

Intersections present a significant safety concern, accounting for approximately 2.21 million crashes and 6770 fatal crashes in 2009 (NHTSA, 2009). The National Cooperative Highway Research Program (NCHRP) 500 Series Report, vol. 12, identifies safety issues related to signalized intersections and potential countermeasures to address the safety issues (Antonucci et al., 2004). Specifically, objective 17.2 B identifies several strategies to reduce the frequency and severity of intersection conflicts through geometric improvements. A specific strategy listed in this section is "construct special solutions", which includes conversion of signalized intersections to roundabouts. It is important to note, however, that converting a signal to roundabout is relatively high cost and the timeframe for implementation is intermediate or long-term. This type of improvement may not be applicable for agencies focusing on low-cost, short-term solutions. As identified in NCHRP 500 Series Report, vol. 12, key issues to consider for this strategy include total entering traffic volumes, turning movements, and operational characteristics (Antonucci et al., 2004).

This study investigates the safety effects of converting signalized intersections to roundabouts. Roundabouts have the potential to reduce both the frequency and severity of crashes compared to a similar signalized intersection. Regarding crash frequency,

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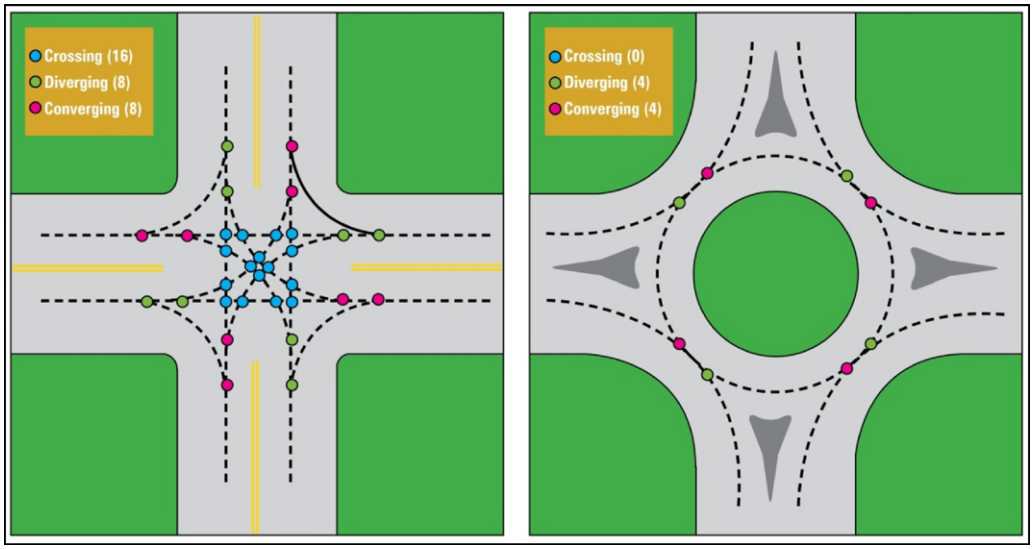

Fig. 1. Illustration of conflict points for a signalized intersection and roundabout.

roundabouts have fewer potential conflict points than a signalized intersection. A conventional signalized intersection of two roads with one lane per approach has 32 potential vehicle-vehicle conflict points. A similar single-lane roundabout has just 8 potential conflict points as shown in Fig. 1. The types of crashes are also fundamentally different for roundabouts, which has the potential to reduce crash severity by eliminating typically serious severity crashes. Specifically, crashes related to crossing path and left-turn movements do not exist in a roundabout. The geometric design of a roundabout also encourages reduced speeds, which reduces the likelihood of injury if a crash occurs.

A comparison of predicted crash rates for conventional intersections in the United States and roundabouts in the United Kingdom revealed safety benefits for roundabouts at lower traffic volumes (less than 50,000 entering vehicles per day). For total entering volumes of 20,000 vehicles per day, the crash rate was 33 percent lower for roundabouts than for signalized intersections in urban/suburban areas and 56 percent lower in rural areas. For total entering volumes of 40,000 vehicles per day, the crash rate was 15 percent lower for roundabouts than for signalized intersections. The safety performance of roundabouts and signalized intersections was relatively comparable at higher volumes (ITE, 1999).

A study of roundabouts in Maryland contained before–after comparisons of roundabout conversions that occurred between 1993 and 2000 (Cunningham, 2007). The study was comprised of two parts, (1) a before–after comparison of locations where a roundabout replaced a stop sign or intersection control beacon (15 single-lane roundabouts and three two-lane roundabouts), and (2) a more detailed analysis of the 15 single-lane roundabout conversions. For the single-lane roundabout locations, there was a significant reduction in the total crash rate (1.36 crashes per million entering vehicles (MEV) before to 0.27 crashes per MEV after) and the injury crash rate (0.79 crashes per MEV to 0.09 crashes per MEV). For the two-lane roundabout conversions, there was a general reduction in both total and injury crashes, although one location had a 147 percent increase in total crash frequency. For the more detailed analysis of the 15 single-lane roundabout conversions, the total crash rate decreased by 60 percent, the fatal crash rate decreased by 100 percent, the injury crash rate decreased by 82 percent, and the property-damage-only (PDO) crash rate decreased by 27 percent. Right-angle, rear-end, opposite-direction, sideswipe, left-turn, nighttime, and wet surface crashes decreased by 91 percent, 11 percent, 100 percent, 75 percent, 95 percent, 5 percent, and 30 percent, respectively. In contrast, the fixed-object crash rate increased by 724 percent. The reductions in total, fatal, injury, PDO, angle, opposite-direction, left-turn, and wet surface crash rates were statistically significant at a five percent level.

A before–after study of roundabout conversions in the United States employed the empirical Bayes (EB) methodology to control for regression-to-the-mean and other trends in crash occurrence (Persaud et al., 2001). The analyses used data from seven states where a total of 23 intersections were converted to modern roundabouts between 1992 and 1997. Of the 23 intersections, 19 were previously stop-controlled, and four were signal-controlled. For the signalized intersections, the EB procedure estimated highly significant reductions of 35 percent for all crashes and 74 percent for injury crashes. Three of these roundabouts had multilane circulation designs. A later study (Rodegerdts et al., 2007), applying the same methodology and using these same four sites with an additional five converted intersections, found highly significant reductions of 48 percent for all crashes and 78 percent for injury crashes. When broken down by area type, the four suburban sites had a 67 percent reduction in all crashes, but no results could be obtained for injury crashes due to a small sample size. The five urban sites had a statistically insignificant one percent reduction for all crashes and a 60 percent reduction in injury crashes.

A Danish study found that at signalized dual carriageway intersections there was a 9.2 percent reduction in crashes for two-phase signals and a 7.8 percent reduction for three-phase signals (separate right-turn phase – left-hand driving) when the signals were replaced with roundabouts (Jørgensen and Jørgensen, 1994). According to Ourston (1996), another study from the Netherlands investigated the effect of conversion of nine traffic signals to roundabouts. They found a 27 percent reduction in total crashes and a 33 percent reduction in casualties.

To sum up on this cursory literature review, it is evident that there is little consistent knowledge on the safety effects of conversion of signalized intersections to roundabouts, and little or no knowledge on the circumstances under which such conversion will be more or less safety effective. This void, taken together with the identified issues in the NCHRP 500 Series Report, provided the motivation for this study, for which the primary objective was to use a substantially larger database than earlier U.S. studies to shore-up estimates of the safety effectiveness of converting signalized intersections to roundabouts and to better identify circumstances (e.g., geometric and traffic conditions) under which conversion of signals