# A Model For Average Speed Estimation And Crash Prediction Using Vehicle Path Data

Craig Lyon and Bhagwant Persaud - Persaud and Lyon Inc. - Steven Chan – Transoft Solutions Inc.

## Introduction

Research has shown roundabouts to significantly lower expected crash rates compared to traditional intersection designs. This improvement in safety is believed to be related to lower vehicle speeds and the more favorable angles between conflicting vehicle paths which lead to less severe crashes. Since modern roundabouts are designed to slow down traffic, speed control is essential to optimizing safety performance. It also stands to reason that the expected safety performance of a roundabout can be related to expected vehicle speeds.

The Highway Safety Manual uses Safety Performance Functions (SPFs) and Crash Modification Factors (CMFs) to predict expected crash frequencies. Safety Performance Functions are statistically derived equations that predict the expected crash frequency of a site. Crash Modification Factors may be either single values or equations which are multiplied by the SPF and are typically derived through before-after evaluations or cross-section studies of safety countermeasures. At the present time, the HSM does not include a chapter for roundabouts although this is planned for future editions.

SPFs have been developed both in the U.S. and internationally for roundabouts. However, the SPFs developed tended to include few variables useful for evaluating the safety impacts of alternate designs. This is perhaps not surprising given that such functions are in fact difficult to estimate, given that roundabouts tend to have very few crashes and design features with little variation. More recent research has modeled crashes at roundabouts as a function of vehicle speeds at various points in the roundabout. The premise being that if the safety performance of a roundabout can be related to vehicle speeds, and speed can be better estimated than crash experience can, then speed can be used indirectly as a surrogate in evaluating the safety implications of decisions in designing or re-designing a roundabout.

## Objective

The objective of this research is to develop a vehicle speed prediction model based on vehicle path data and to in turn use these predicted speeds to predict crashes at roundabouts. Such models could be used to evaluate the safety impacts of alternative designs, compare the relative safety of existing roundabouts and compare roundabouts with alternative intersection options.

## Description of Data

The database of roundabouts used for the present research was originally constructed for NCHRP Project 3-65 "Applying Roundabouts in the United States". The database includes geometric, traffic and crash data for 138 roundabout approaches, 34 of which have speed data. The speed data includes the average vehicle speed for approaching, entry, upstream circulating and upstream exiting vehicles.

The database was supplemented with the entry, circulating and exiting vehicle path radii for the design vehicle and the entry angle determined by the TORUS software. In TORUS, the fastest paths are constructed from arcs that are tangent where they meet, and the speeds are functions of the arcs' radii. Figure 1 shows the various vehicle movements, R1 to R5. At a given location there are multiple fastest paths coming from the different approaches and overlapping therefore some assumption is necessary to combine these into an average predicted vehicle speed for entering, circulating and exiting vehicles. For entry and exiting speeds TORUS provides two speed estimates which are both considered. The 'alternate speed' estimate computes then entry and exiting speeds by evaluating the circulating speed, acceleration/deceleration rates and distance along the vehicle path. Both speed estimation methods are described in NCHRP Report 672 Roundabouts: An Informational Guide, Second Edition. Table 1 documents which fastest path measurements were considered for each speed estimate. The V1 to V5 speeds correspond to the R1 to R5 paths in Figure 1. If only one of the desired speed predictions was available then it was used. If more than one was available then an average was taken.

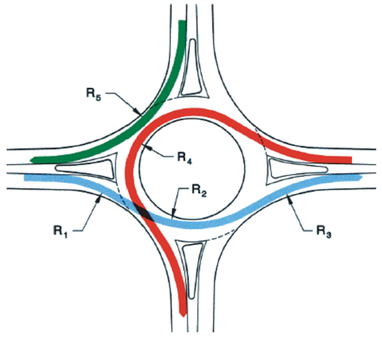


**Table 1 – Predicted Speeds to Consider by Movement**

| Approach | Entry | Circulating | Exiting |
|---|---|---|---|
| North | North V1 | East V2<br>South V4 | South V3<br>East V5 |
| South | South V1 | West V2<br>North V4 | North V3<br>West V5 |
| East | East V1 | South V2<br>West V4 | West V3<br>South V5 |

## Prediction of Vehicle Speed

The modeling approach for speed prediction was to develop simple multi-variable linear regression models with the assumption that the error terms are normally distributed, consistent with previous research. For the speed variable the average of the entering, exiting and circulating speeds at an approach, denoted IAS, was modeled.

The independent variables which most consistently exhibit a high positive degree of correlation with vehicle speed are the inscribed circle diameter, central island diameter, circulating radius and circulating width. As would be expected, the degree of correlation between these same variables is also very high. This would indicate that these variables should be considered for inclusion in the speed prediction models but it is unlikely that they can all be included together.

Surprisingly, the correlation coefficients for entry and approach width had a negative correlation with vehicle speed indicating that as the lane width increases speeds go down. This counterintuitive result can be explained by the negative correlation between lane widths and the inscribed circle diameter and the vehicle path radii. As the inscribed circle diameter or path radii increase the lane width tends to be smaller. Therefore the larger lane widths tend to be for roundabout arms with a tighter path radii/smaller inscribed circle where speeds are lower.

Several models were attempted and compared for their goodness-of-fit statistics. The final model selected is:

IAS in mph = intercept + b1*circrad + b2*entryrad

Where,
circrad is the circulating vehicle path radius
entryrad is the entering vehicle path radius
circwidth is the roadway width for the circulating vehicle
The intercept term and b1 and b2 are the parameter estimates

**Table 2 – Final Speed Prediction Models**

| Speed Measure | intercept | $b_1$ | $b_2$ | R-Squared |
|---|---|---|---|---|
| IAS | 9.11674<br>(1.03868) | 0.12502<br>(0.01698) | 0.00817<br>(0.00656) | 0.69 |

## Crash Prediction

Consistent with state-of-the-art methods, generalized linear modeling, with the specification of a negative binomial (NB) error structure, was used to develop the crash prediction models.

The speed-based crash model uses the average vehicle speeds predicted by the speed prediction model. The model form is:

$$Y = \exp^{(intercept)} (AADT)^{b1} \exp^{(b2*IAS)}$$

Where,
Y = total crash frequency for specific approach per year
AADT = entering AADT on approach
IAS = average of the entry, upstream circulating and upstream exiting mean speeds in mph

**Table 3 – Comparison of Estimated and Observed Speed Based Crash Prediction Models**

| | intercept | $b_1$ | $b_2$ | Overdispersion |
|---|---|---|---|---|
| Model based on estimated speeds | -12.9094<br>(3.5055) | 0.8467<br>(0.3794) | 0.3336<br>(0.0749) | 0.9869 |
| Model based on observed speeds | -12.8046<br>(2.838) | 0.8075<br>(0.3045) | 0.3388<br>(0.0587) | 0.5568 |

Table 3 compares the parameter estimates between the new model and a model for crashes based on observed speeds using the same locations. This model is discussed in Chen, Y., Persaud, B., Lyon, C., 2011. Effect of speed on roundabout safety performance - Implications for use of speed as a surrogate measure. Presented at the 90th Annual Meeting of the Transportation Research Board, Washington, D.C., 2011.

It can be seen that the parameter estimates are very close. What can be taken away from this is that a crash prediction model could be developed based on speed predictions estimated using fastest path data instead of observed speeds. This will allow for a larger dataset of roundabouts to be used when observed speed data are not readily available, which is currently the case.

## Conclusions

The modeling of average vehicle speed using TORUS related vehicle path radii was successful.

The suggested approach of predicting speeds based in part on vehicle path radii and then predicting crashes based on vehicle volumes and predicted speeds has advantages.

1. The roundabout level crash models from NCHRP Report 672 only use circulating lanes and number of approaches, so the approach using vehicle path radii to estimate speed is an improvement because the impact of roundabout geometry is better taken into consideration.
2. The approach level crash models from NCHRP Report 672 contain few geometric variables within each limiting their usefulness. The application of several models also complicates the analysis task.
3. Complex roundabouts such as those with spiral transitions, oval shapes etc. may be analyzed. Such non-standard geometries are not represented in geometry based crash models.
4. Using predicted speeds instead of observed speeds in future research will expand the dataset available for crash modeling and result in better crash prediction models.

April, 2014