Modeling Roundabouts: Lessons Learned in Idaho

Ryan W. Peterson, P.E., PTOE

ryanp@pecidaho.com

Stephen J. Lewis, P.E., PTOE

steve@pecidaho.com

Kent J. Fugal, P.E., PTOE

kent@pecidaho.com

Ryan D. Lancaster, E.I.T.

ryanl@pecid.com

Project Engineering Consultants, Ltd.,

1307 N.39th Street, Suite 101

Nampa, Idaho

Phone: 208-466-7190

Fax: 208-466-7168

March 1, 2008

Word Count = 3328 (text) + 750 (tables) = 4078

Modeling Roundabouts: Lessons Learned in Idaho

ABSTRACT
Modern roundabouts are a relatively new intersection treatment in the United States and particularly in Idaho. Due to a lack of data and the complex geometry of modern roundabouts, calibrating and validating models to evaluate capacity at roundabouts has proven difficult. Several choices exist to perform such analysis ranging from empirical models like RODEL and the Highway Capacity Manual, to analytical models such as aaSIDRA, to micro-simulation models including VISSIM and Paramics. Each method and software has its advantages and disadvantages, as well as its proponents and critics.

This paper presents a summary of lessons learned over the course of the Ada County Roundabout Study, which consisted of the development of the Ada County Highway District Roundabout Application Guidelines, and the Amity Road Corridor Study. These projects involved the analysis of roundabouts using a gap acceptance-based micro-simulation model (VISSIM) and an empirical-based model (RODEL), as well as comparing roundabouts to signalized intersections. These lessons are fairly generic and can be applied to modeling roundabouts as a whole. They include calibration: the importance of knowing how empirical models are calibrated and issues with calibrating and validating gap-acceptance based models; and roundabouts vs. signalized intersection comparisons: why and why not to make these comparisons and how it can be done.

INTRODUCTION
In recent years, the authors have been involved with several roundabout design, planning, and design policy development projects. Inevitably the question arises concerning the capacity of roundabouts and how that capacity compares to other intersection types. This has required the use of a computer model to estimate the capacity of this intersection type and has led to an evolutionary learning process paralleling the national debate regarding the subject of modeling roundabouts. This paper is not intended to serve as an exhaustive analysis of roundabout analysis software; neither is it a recommendation to use one modeling software package over the other. Rather, the purpose of this paper is to present some observations made by the authors that may be useful to other practitioners when modeling roundabouts. In the interest of providing some background information, an overview of each project follows with a description of the objectives of the project and the tools used to meet those objectives. The next section will summarize the lessons learned from these projects and will examine specific aspects of each in more depth.

ACHD Roundabout Application Guidelines
This project, the first phase of the Ada County Roundabout Study, involved the development of roundabout siting and design guidelines for Ada County, Idaho. These guidelines are meant to assist the Ada County Highway District (ACHD) as well as other agencies, developers, and consultants in implementing roundabouts at intersections across the county. Highlights of the study include research of existing best practices nationwide, application and siting guidelines, design parameter guidelines, sample roundabout configurations, guidelines for designing roundabouts for expandability from single-lane to dual-lane operation, VISSIM and RODEL modeling to test the design parameters, a cost comparison between roundabouts and signals, research into future Americans with Disabilities Act (ADA) issues affecting roundabouts, and a

peer review by a national expert.

Amity Road Corridor Study

This was the second phase of the Ada County Roundabout Study and consisted of a concept study of six arterial intersections on Amity Road (McDermott Rd., Black Cat Rd., Ten Mile Rd., Linder Rd., Locust Grove Rd., and Eagle Rd.) in Ada County, Idaho. The intent of the project was to use the newly developed siting and design guidelines to evaluate the appropriateness of constructing roundabouts at the study intersections. The analysis included a comparison of roundabout alternatives and signal alternatives at study intersections and required a capacity analysis. VISSIM was used to perform the roundabout analysis and Synchro was used to perform the signal analysis.

LESSONS LEARNED

Difficulty in Calibration/Validation

The importance of understanding how a model was or is calibrated becomes very important when modeling roundabouts. Furthermore, the ability to calibrate that model to local conditions can prove very difficult, given the relatively few roundabouts in the United States (U.S.) and, consequently, the lack of sufficient data to which the model can be calibrated.

The analyst has the responsibility to code and calibrate a model for a specific location. The different software packages often provide defaults for the numerous model parameters; however, the user must then modify some of the default parameters to more closely match local conditions. This assumes that the behavioral models and theory behind the software have already been validated and verified by the model developers, and that those respective behavior models and theory adequately describe the general conditions of the motorists to be modeled.

Modeling was a tool used in the development of the ACHD Roundabout Application Guidelines. RODEL and VISSIM were used in the testing. In addition to the model output, guidance from the FHWA Roundabout Guide and recommendations for “rules of thumb” used by experienced roundabout designers and national experts were used to provide a range of capacity estimates that could be used to define upper and lower bounds for planning level capacity analysis. In addition, previous work documenting similar efforts was reviewed. (1)(2)(3). Throughout this process, the authors faced the challenge of using an empirical model and calibrating a micro-simulation model.

RODEL (version 1) is a computer application developed by Barry Crown of the Staffordshire County Council in England. RODEL estimates capacity by using empirically-based equations developed through research performed by R.M. Kimber in the late-1970’s at 86 roundabouts on the British roadway system as well as 36 geometric variants at the UK Transport Research Laboratory (TRL). In 1996, the TRL repeated the capacity measurements at 35 roundabouts in order to update the equations. The results served to confirm the accuracy of the existing equations and no revisions or updates were needed. The data collected is extensive and RODEL has been shown to produce accurate capacity estimates in the framework of its calibration.

The concerns the authors have with RODEL lie in its calibration. The data used to develop the RODEL regression equations were collected in the United Kingdom. Vehicles used for these observations were likely smaller on average than vehicles found on U.S. roadways. Also, U.S. drivers are less familiar with roundabouts and likely less aggressive than British drivers. These factors could result in smaller headways, resulting in the possibility of RODEL reporting higher capacity estimates than would be realistic in the U.S. Recent study in NCHRP Report 572 “Roundabouts in the United States” (4) shows promise in recalibrating the UK-based capacity equation with a relatively-simple change to the Y-intercept.

It was not possible for RODEL to be calibrated to local conditions for the ACHD Roundabout Application Guidelines analysis. However, by varying the confidence levels (CL) in the RODEL analysis between 50% and 85%, it was possible to check how sensitive the results were to minor changes in traffic flow and capacity. The 50% CL represents the most-likely capacity and provides an equal comparison to other intersection analyses, while the 85% CL represents an improbable or pessimistic estimate. From what the authors surmised from conversations with other practitioners, this approach in the use of RODEL was consistent with typical practice.

VISSIM is a micro-simulation model, where individual vehicles are modeled using distributions for parameters such as driver aggressiveness, vehicle speeds, vehicle type, and other parameters. These parameters can, and should, be adjusted to reflect local driver behavior. Only a modest amount of data has been available from roundabouts in the U.S. The lack of data presents a challenge in calibrating a micro-simulation model. The extended amounts of time needed to calibrate the model and budgetary constraints further restrict the model calibration. The VISSIM model developed in the ACHD Roundabout Application Guidelines analysis was calibrated using multiple sources of information. Sources included the data collected for the NCHRP 572 report - this report summarizes the largest data collection effort undertaken in the U.S. and provides at least some idea of driver behavior at roundabouts. In conversations with other practitioners, the authors have heard criticisms of this report such as that sample size was small, that many of the roundabouts studied were not operating at capacity, that the studied roundabouts had poor approach geometry, and other arguments. However, it is the authors’ opinion that this data needs to be considered, at least in conjunction with the international models, and represents a large step in the direction of developing a U.S. based roundabout model. Of particular use were the critical and minimum headway estimates. With this data, the authors estimated minimum gap times for passenger cars and heavy vehicles which were then used to calibrate the priority rules at the approaches to the modeled roundabouts. In addition, speeds on entry, circulation, and exit were estimated using the FHWA Roundabout Guide (5), the results of NCHRP 572, and AASHTO’s A Policy on Geometric Design of Highways and Streets (6). Output from the VISSIM model was then compared to the capacity estimates in NCHRP 572.

RODEL and the calibrated VISSIM model were used to perform an analysis using four different traffic scenarios and two geometric conditions. The results of this analysis are useful to the discussion at hand.

The four traffic scenarios used in this analysis consisted of typical commuter traffic with a heavy through movement on each approach, heavy left-turning traffic, high truck percentages, and an 80/20 percent imbalance between the major and minor volumes.

The two different geometric configurations consisted of a single-lane roundabout with a 110-foot inscribed circle diameter (ICD), 100-foot entry radius, and 400-foot exit radius; and a dual-lane roundabout with a 150-foot ICD, 100-foot entry radius, and 400-foot exit radius. In addition, a single-lane roundabout with an ICD of 130 feet and a dual-lane roundabout with a 180-foot ICD were analyzed under the typical commuter scenario to evaluate the effects of a larger ICD.

Table 1 compares the results of the simulation between the different software packages, guidance found in the FHWA Roundabout Guide, and "rules of thumb" used by experienced roundabout designers and national experts.

TABLE 1 Comparison of Capacity

	Circulating + Entering (C+E) Merge Capacity (Veh/Hour)				**ADT Capacity (Total Entering Veh/Day, All Approaches)[1]**			
	Single-Lane		**Dual-Lane**		**Single-Lane**		**Dual-Lane**	
	At Least	**Not More Than**	**At Least**	**Not More Than**	**At Least**	**Not More Than**	**At Least**	**Not More Than**
VISSIM	1000	1300	1500	2000	18,000	23,000	26,000	40,000
RODEL	1300	1500	2200	2550	25,000	30,000	44,000	51,000
"Rules-of-Thumb"	1100	1400	1900	2300	NA	NA	NA	NA
FHWA Roundabout Guide	NA	NA	NA	NA	20,000	27,000	40,000	51,000
Recommended for ACHD	1100	1400	1800	2300	22,000	27,000	39,000	49,000

[1]ADT simulation numbers were calculated assuming 10% of daily traffic occurring in highest peak hour (k=.10). ADT's are also based on a typical 4-leg intersection configuration.

As shown in Table 1, the capacity estimates from VISSIM were consistently lower than the estimates from RODEL. The results are consistent with the findings of NCHRP 572 which was expected, since NCHRP 572 data was used to calibrate the VISSIM models.

Values from the FHWA Roundabout Guide and "rules of thumb" were typically in between those of the software packages. The authors used the results of the RODEL and VISSIM analyses as high and low limits and made recommendations that were within these ranges.

This analysis led the authors to two conclusions. First, with the uncertainty surrounding the different roundabout modeling software, and the limited amount of local data available for calibration, perhaps the best approach would be to use more than one software package and use engineering judgment to compare the results and make recommendations. This makes it extremely important for roundabout modelers to be familiar with the software they are using. By knowing the background, theory, sensitivity to calibration parameters, and requirements of calibration of the software used, an analyst is better able to report valid results.

The second conclusion was that the NCHRP 572 report, which included the largest data collection effort undertaken at U.S. roundabouts, can, and should be used to calibrate a micro-simulation model to reflect U.S. driver behavior.

Roundabout vs. Signalized Intersection Comparison

There are multiple issues to consider in comparing roundabouts to signalized intersections. These include safety, environmental factors, and cost. In evaluating the feasibility of a roundabout at a given location, a comparison between the operations of the proposed roundabout over a signal is often requested. This issue is often given the most weight in the comparison between the two intersection types. This was the case in the Amity Road Corridor Study that was completed as the second phase of the Ada County Roundabout Study.

An initial traffic analysis was performed for each of the study intersections. The purpose of this analysis was to determine the range of appropriate alternatives for each intersection. VISSIM was used to perform the roundabout analysis and Synchro was used to perform the signal analysis. VISSIM was chosen to analyze the roundabouts because with the parameters used for this study, it tended to yield higher delays (lower capacities) than RODEL. VISSIM results were considered to give more conservative results for the study.

Two sets of traffic projections were obtained for use in this study. According to the original scope of the study, peak-hour volumes from the Community Planning Association of Southwest Idaho (COMPASS) travel demand model were obtained and used to calculate 5-, 10-, 15-, and 20-year traffic projections. The model volumes supplied by COMPASS incorporated the "Community Choices" demographics adopted as part of the Communities-in-Motion (CIM) long range transportation plan. In addition to the CIM projections, ACHD supplied 2030 peak-hour turning movement projections estimated as part of the South Meridian Transportation Plan performed by Washington Group International (WGI). These projected volumes are based on the COMPASS model and Community Choices demographics, but also incorporate changes based on the latest draft future land uses that are being considered by the City of Meridian in the South Meridian Planning Process. These projections are generally greater than those calculated from the base CIM model.

In order to address the difference in traffic projections, model output for 2030 was also obtained from COMPASS and turning movements were projected. VISSIM and Synchro were then used to analyze all study intersections with both CIM and WGI volumes for comparison purposes. The calibrated VISSIM model from the first part of the study was used to perform the roundabout analysis. At most of the intersections, the analysis designated a clear operational advantage of one alternative over another. However, this was not the case with the Ten Mile Rd. intersection and a discussion of the results at this intersection will be useful.

Based on the combined entering and conflicting volumes expected at this intersection under 2030 conditions, traffic analysis was performed assuming a single-lane roundabout for the CIM scenario and a dual-lane roundabout for the WGI scenario. The results of the VISSIM simulations are shown in Table 2.

TABLE 2 Results of Roundabout Analysis

Scenario	**Approach Delay (# Lanes)**			
	EB	**WB**	**NB**	**SB**
CIM (single-lane)	17.2 (1)	33.6 (1)	11.2 (1)	73.4 (1)
WGI (dual-lane)	34.7 (2)	29.1 (2)	9.7 (2)	23.7 (2)

The volumes expected at this intersection were fairly evenly distributed under the CIM scenario. The largest expected approach volumes at this intersection are on the southbound and westbound approaches. While dual lanes may be needed on these approaches, single-lanes are adequate on the northbound and eastbound approaches under the CIM scenario. Under the WGI scenario, this intersection performs well as a dual-lane roundabout.

A signal analysis was also performed for this intersection using the CIM and WGI scenarios. Due to the need to separate left-turn traffic from through and right-turn traffic under signalization, this analysis was performed for the CIM scenario assuming one shared thru-right lane and one left-turn lane on each approach. The higher volumes under the WGI scenario required three assumed lanes on each approach: a left-turn lane, a thru-lane and a shared thru-right-turn lane. The results of that analysis are shown in Table 3.

TABLE 3 Results of Signalized Intersection Analysis

Scenario	Approach Delay (# Lanes)			
	EB	WB	NB	SB
CIM (signal)	18.8 (2)	35.4 (2)	12.7 (2)	27.2 (2)
WGI (signal)	18.5 (3)	26.7 (3)	23.6 (3)	19.7 (3)

Based on the information provided in the Tables 2 and 3, it would be natural to conclude that a signal at this intersection would provide the best operational characteristics. However, the authors still made the recommendation to build a roundabout at this location. This decision was made by considering operations, safety benefits, cost, and other factors. The operational analysis was not a significant consideration at this intersection for two reasons. First, it was recognized that calibrating a roundabout model is difficult for reasons stated previously and VISSIM and Synchro are based on different capacity methodologies and would, therefore, yield different results.

The second reason the operational analysis was not the primary contributing consideration in the recommendation is that there was some question as to what roundabout configuration and signal configuration are equivalent. For example, does adding a right-turn bypass lane on a roundabout equate to adding a right-turn lane on a signal; is a two-lane roundabout approach equivalent to two, three, or even four approach lanes on a signal.

An operational analysis is very important in evaluating the appropriateness of a signal or a roundabout; however, these questions reduce confidence in relying strictly on modeled operations analysis as the primary contributor in deciding between a roundabout and a signal. Because of these uncertainties it is necessary to include all factors of comparison, including cost, safety, and other factors.

CONCLUSIONS

Calibration/Validation

Calibrating a model to estimate roundabout capacity is difficult regardless of what software package is selected. At some point, a model needs to be developed that is calibrated to U.S. driver behavior. As more roundabouts are built in the United States, more opportunities for data collection will become available to help determine driver behavior through this intersection alternative.

The data used to develop RODEL was collected in the United Kingdom. Vehicles used for these observations were likely smaller on average than vehicles found on U.S. roadways. Also, U.S. drivers are less familiar with roundabouts and likely less aggressive than British drivers. These factors could result in smaller headways, resulting in the possibility of RODEL reporting higher capacity estimates than would be realistic in the U.S.

The concern with micro-simulation models is the potential for error due to their flexibility. The "garbage in – garbage out" concept is intensified with increased opportunities to calibrate parameters. Obtaining correct calibration parameters is paramount in producing a reliable model. A limitation of micro-simulation models is that they are not sensitive to variations in geometry. The modeler is responsible for calibrating parameters that define how motorists react to variations in geometry. This is difficult again, because of the lack of local data available for calibration.

Perhaps the best approach would be to use more than one software package and use engineering judgment to compare the results and make recommendations. This makes it extremely important for roundabout modelers to be familiar with the software they are using. By knowing the background, theory, sensitivity to calibration parameters, and requirements of calibration of the software used, an analyst is better able to report valid results.

NCHRP Report 572 contains valuable information that can be used in calibration. The report is the most extensive United States study to date on driver behavior in roundabouts. Despite concerns voiced with this data (the small sample size, the lack of roundabouts operating at capacity, the studied roundabouts had poor geometry at roundabout approaches), used with engineering judgment, this information can be used to more closely calibrate a roundabout capacity model to reflect U.S. driver behavior.

Roundabout vs. Signalized Intersection Comparison

Two issues were encountered when comparing roundabout alternatives to signal alternatives. The first was the difference in capacity methodologies between software packages typically used for roundabout analysis and those used for signal analysis and how those differences could affect the results of the analysis. The second issue was deciding what roundabout and signalized intersection geometries to compare.

The conclusion was that to make an operational comparison between roundabouts and signalized intersections, the following should be considered:

- Agreement needs to be reached on equivalent roundabout and signalized intersection geometry
- Analysis with the same modeling software package. This would require micro-simulation modeling software like VISSIM which will require more time and budget commitment.

In deciding whether a roundabout or signal is more appropriate at a given location, the question should not only be what type of intersection will perform better operationally. The operational analysis should be used to determine if either design will perform with the projected design year volumes, and how much reserve capacity is available with each alternative. If an operational analysis shows that both alternatives will work, other considerations such as safety and cost can be evaluated.

References

1. Stanek, David; Milam, Ronald T., *High-Capacity Roundabout Intersection Analysis: Going Around in Circles.* National Roundabout Conference, 2005

2. Trueblood, Michael; Dale, Jim, *Simulating Roundabouts with VISSIM*. 2nd Urban Street Symposium, July 28-30, 2003
3. Kinzel, Christopher S; Trueblood, Michael T., *The Effects of Operational Parameters in the Simulation of Roundabouts*, TRB Annual Meeting, 2004
4. Rodegerdts, Lee, et. al. *Roundabouts in the United States*. Publication NCHRP Report 572. Transportation Research Board, 2007.
5. Robinson, Bruce W., et. al. *Roundabouts: An Informational Guide*. Publication FHWA-RD-00-067. FHWA, U.S. Department of Transportation, 2000.
6. *A Policy on Geometric Design of Highways and Streets*, American Association of State Highway and Transportation Officials, 2004.