Evaluation of Analytical Tools used for the Operational Analysis of Roundabouts

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ABSTRACT

Roundabouts have long been a staple as an intersection configuration in the United Kingdom and elsewhere in Europe. Although they have been present in limited numbers in North America, they have only recently been a subject of interest in Ontario. Roundabouts can provide increased safety and reduced delay to road users under suitable circumstances. The Ontario Ministry of Transportation has initiated a variety of activities aimed at the investigation of roundabouts as an alternative to signalized intersections in appropriate locations. One such activity is the selection of a suitable method or methods for evaluating the operational performance of roundabouts. A variety of methods are available, ranging from analytical/empirical to simulation. This paper reports on initial investigations to compare the efficacy of six methods, based on their performance with respect to level-of-service evaluation at several case-study roundabouts. It was apparent that all methods reasonably estimated delay at lower volume levels. Unfortunately, the available data did not cover situations close to or at capacity levels sufficiently well to arrive at a definitive conclusion under those conditions. However, it was apparent that the results from the various methods demonstrated increasing variability with increasing traffic levels. Based on the evaluation reported here, a provisional strategy has been proposed for the operational evaluation of roundabouts in Ontario. However, further evaluation is required in conjunction with additional data collection under congested conditions to confirm the proposed strategy.

Introduction

Roundabouts have long been a staple as an intersection configuration in the United Kingdom and elsewhere in Europe. Although they have been present in limited numbers in North America, they have only recently been a subject of interest in Ontario, the Region of Waterloo being a leader in this regard. Roundabouts can provide increased safety and reduced delay to road users under suitable conditions. The Ontario Ministry of Transportation has initiated a variety of activities aimed at the investigation of roundabouts as a possible alternative to signalized intersections in appropriate locations. One such activity is the selection of a suitable method or methods for evaluating the operational performance of roundabouts. A variety of tools are available, ranging from analytical/empirical to simulation-based methods. This paper reports on a comparison of six modelling and evaluation tools with the objective being the development of a common strategy for the evaluation of roundabout operations.

Literature review

There has been an ongoing debate as to the applicability of available roundabout operational analysis tools: however, there are few studies comparing the tools in detail and only a handful that have included comparisons of predictions to observed North America data. Of the studies that have included comparisons to field data, most have focused on the macro-analytical models, particularly RODEL (from the United Kingdom) and aaSIDRA (from Australia). Examples include Akçelik et al. (1,2) which compare the Australian gap-acceptance model with the RODEL/ARCADY linear regression models using single case-study roundabouts.

NCHRP Report 572: Roundabouts in the United States (3) was a large research effort undertaken to establish standards for roundabouts in the United States, including standards for operational analysis. The study reviewed capacity prediction models from France, Germany, Switzerland, the United Kingdom and Australia, including RODEL and aaSIDRA in the context of American field data. The data collected included a large number of roundabouts across the United States. This review identified an almost universal over-prediction capacity relative to the American case-study data. After attempting to calibrate the various tools to the available data, the authors concluded that estimating a new model based on gap-acceptance theory (referred to in the current paper as the NCHRP equations) was a more promising approach. The resulting equations were proposed for inclusion in the 2010 version of the Highway Capacity Manual.

Stanek and Milam (4) attempted to identify a suitable analysis tool for use in a study of proposed roundabouts in northern California. The FHWA equation (5), RODEL, aaSIDRA, PARAMICS, and VISSIM were tried. No field data was available for comparison, but the authors recommended the use of macroscopic models only for unsaturated conditions but microsimulation models to account for over-saturated conditions, non-standard geometries and system influences. In an attempt to better understand the application of microsimulation to roundabouts, Kinzle and Trueblood (6) evaluated four analysis packages; HCS, aaSIDRA, SimTraffic and VISSIM, for a case study roundabout under various demand scenarios. They also evaluated the effectiveness of the available adjustment parameters. Careful and thorough calibration was recommended for the use of such tools, but, again, field data was unavailable for calibration. Similarly motivated, Ambadipudi (7) compared VISSIM to RODEL and aaSIDRA, with a focus on establishing guidelines for the application of VISSIM to multi-lane roundabouts and evaluating the need for micro-simulation when analyzing roundabouts in a system context.

Gagon et al. (8) recently completed a study with a similar problem in mind as the authors of this paper, and compared aaSIDRA, RODEL, PARAMICS, SYNCHRO/SimTraffic and VISSIM when applied to two case study roundabouts in New Hampshire. Both locations were recently built, single-lane roundabouts with typical geometry. The study compared field delays to the estimates of the five models using default parameters, and (where available) calibrated parameter values. It was found that when calibrated, aaSIDRA and VISSIM were best able to replicate the observed delays, but that the uncalibrated results varied substantially. The authors also suggested that calibration may be site-specific, with no one-size-fits-all set of parameters available.

Description of the tools evaluated

The six roundabout analysis tools reviewed in this study included three micro-simulation tools (PARAMICS (9), VISSIM (10), AIMSUN (11)), two macro/analytical tools based on gap acceptance theory (SIDRA (12), NCHRP (3)), and one tool based on empirical regression (RODEL (13)). ARCADY has the same foundation as RODEL and the two can be considered functionally equivalent.

The three micro-simulation tools reviewed are similar in that they are all discrete-time simulations that process individual vehicles through a road network using various sub-models, such as car-following and gap-acceptance. The tools differ in the details of their sub-models, how they are applied and the way in which the user interacts with the software. With all three tools, the user can specify the detailed geometry of the roundabout and a range of local and global driver and vehicle behaviour parameters. Both AIMSUN and PARAMICS calculate critical gaps based on input geometry and driver behaviour, with some behavioural parameters specified as a distribution, which mimics the real-world distribution of accepted/rejected gaps. In VISSIM, the gap size must be entered directly into the model, requiring the user to either know before-hand the effect of geometry on gap acceptance behaviour, or to iteratively calibrate the behaviour at each approach.

SIDRA (previous versions were referred to as aaSIDRA) uses a theoretical gap-acceptance model and gap-acceptance parameters derived from observations at a large number of Australian roundabouts. The primary inputs are the lane configuration, lane widths, entry radii, roundabout diameter, and the origin-destination flow pattern. SIDRA is notable for accounting for unbalanced lane utilization in its estimation of delay and can be calibrated to some extent.

The NCHRP equations are derived from observations of roundabouts in the United States as presented in NCHRP Report 572. The equations are based upon gap acceptance theory, with the only inputs being the origin-destination flow pattern and the number of lanes in each approach. While it does recognize individual critical lanes, the user must estimate lane-utilization. The equations can also be calibrated directly to local observations of critical gap and follow-up headway.

RODEL and ARCADY use an empirical model based on the application of statistical regression of a large data set of observed roundabout operations in the United Kingdom. The tool is intended to aid designers in selecting the best geometry for a given location and traffic demand. The research on which these models are based showed that entrance capacity was sensitive to entry lane geometry (width, flare, curb radius, angle) and roundabout diameter, as well as to conflicting flow. RODEL does not, however, provide a direct method for local calibration, although some parameters can be adjusted. ARCADY is very similar to RODEL but provides additional flexibility including greater calibration ability.

Evaluation

The evaluation of the tools was conducted at several levels. First, the tools were evaluated qualitatively with respect to a number of dimensions such as their applicability, incorporation of roundabout geometrics and driver behaviour, ease of use and input requirements, outputs and other issues. The second stage involved actual application of the tools to case-study roundabouts to quantitatively assess how well they were able to replicate real-life conditions. Based on these evaluations, several of the tools were provisionally selected for use in Ontario and were further evaluated as to their compatibility and ability to be combined into an evaluation "strategy".

Qualitative evaluation

Applicability

Several key issues were considered with respect to applicability. The first of these is geographic transferability. This is primarily of interest for those tools incorporating empirical studies, namely ARCADY/RODEL and the NCHRP method. In the case of ARCADY/RODEL, the equations defining roundabout performance are based on extensive observations made at roundabouts in the United Kingdom, as well as on research conducted on test tracks. Since roundabouts are more commonplace there and have been in use for a significant period of time, one would expect that the driver behaviour would reflect greater experience with roundabouts and that the predicted performance of a given configuration would be higher than if based on observations of comparable roundabouts in North America. Previous estimates place this difference at between 15% and 20% (3). The NCHRP performance prediction equations are based on observations of roundabouts in the United States and yield more conservative results. Roundabouts are a more recent phenomenon in the United States and are relatively few in number: drivers therefore have less experience using them and tend to exhibit more conservative behaviour. In fact, follow-up observations reported by Mensah et al. (14) about a decade after the original NCHRP surveys indicate that the passage of time, and presumably increased driver experience at the surveyed locations, has lead to higher observed performance and correspondingly increased capacity. The SIDRA model combines general theory with empirical inputs based on Australian experience. In contrast, micro-simulation models are largely generic, although built-in default driver behaviour parameters may reflect conditions in their country of origin. The ability of micro-simulation models to be calibrated or "tuned" to the situation in which they will be used largely sidesteps the transferability question but does mean that the extra calibration step is required.

Also of interest is the applicability of a given tool to roundabouts of different configurations. With respect to an isolated roundabout, configuration includes a number of descriptors, the principal ones being the number of lanes on the circulating and approach roads and the number of approaches, although other geometric parameters are involved. Theoretically, tools incorporating empirical data are only as general as the datasets on which they were based are comprehensive. The use of the NCHRP method is restricted to one and two-lane roundabouts for this reason. However, this is not believed to be a significant practical issue in that the datasets are large and do cover many of the configurations typically encountered.

Another issue is applicability in a network context. It is often desirable to be able to predict interactions between proximate roundabouts and intersections, including the incidence and impacts of queue spillback and the metering of vehicle arrivals. Although the ARCADY/RODEL, NCHRP, and SIDRA models are limited to the analysis of isolated roundabouts, micro-simulation models can be extended to include the network surrounding a given roundabout.

A final applicability issue involves the level of traffic being evaluated. As with configuration, empirical methods are only as general as the observations on which they were based. In the case of the NCHRP method, there is a distinct lack of suitable data at higher volume levels and the generality of this method is therefore limited in this respect. Analytical and micro-simulation methods do not suffer from this limitation to the same degree although the basic driving behaviour parameters on which they are based, such as reaction time and gap acceptance, can vary with different levels of congestion and may require calibration.

Transparency

The micro-simulation models are largely transparent, the visual animations and detailed outputs giving a comprehensive picture of modelled vehicle dynamics and driver behaviour. In contrast, the analytical/empirical tools are essentially “black boxes” in this regard. The value of transparency lies in the ability of the analyst to confirm realistic operation of the model through the review of actual operation or intermediate results.

Ease of use and input requirements

Generally speaking, the micro-simulation tools require more effort and have more extensive input requirements than the analytical/empirical tools. Creating a detailed physical representation of the roundabout and simulating operation is a resource-intensive exercise with respect to both data requirements and effort. In contrast, the analytical/empirical models are quite parsimonious. The higher level of effort required to micro-simulate is of particular concern when a variety of alternative roundabout configurations and traffic scenarios are being analyzed. Among the micro-simulation models, PARAMICS was the easiest to set up with almost automatic development of a generic roundabout that could then be fine-tuned as required. VISSIM required the greatest effort with AIMSUN falling between the two.

Sensitivity to roundabout geometry

All of the tools evaluated incorporate the major roundabout design parameters, including the number of approaches, and the number of circulating lanes. ARCADY/RODEL uses only the width of the approach as a continuous variable whereas the others are sensitive to the actual number of lanes on the approaches. ARCADY/RODEL also directly incorporates inscribed diameter, flaring and entry angle and radius as input parameters while SIDRA recognizes inscribed diameter and flaring. The NCHRP model is not sensitive to detailed geometry. The micro-simulation models are sensitive to geometry to varying degrees although PARAMICS is the only example where vehicle dynamics react automatically to geometry. In the case of AIMSUN, the ease of entry, as dictated by flare, approach angle, and approach radius, is incorporated indirectly but automatically through the definition of vehicle conflict areas. This approach can also be approximated manually in VISSIM. In both AIMSUN and VISSIM, the impact of inscribed diameter is incorporated indirectly through the definition of desired speed within the roundabout.

Sensitivity to driver behaviour

Two of the key driver behaviour parameters are gap acceptance and lane utilization (for multi-lane approaches). SIDRA is largely based around a gap acceptance model and recognizes lane utilization. The NCHRP method equations reflects gap acceptance and evaluation is oriented to the critical lane in an approach. ARCADY/RODEL does not incorporate either variable directly although gap acceptance and lane utilization are implicit in the data on which it was based. The micro-simulation models incorporate gap acceptance indirectly through definition of reaction times, conflict areas, and priority rules. Lane utilization is directly modelled and can be adjusted to match site-specific circumstances.

Outputs and performance measures

ARCADY/RODEL are set up to provide only a limited set of key performance measures, this being tied to the nature of the observational data on which they were based. SIDRA provides a wider range of performance measures. Micro-simulation models can provide an enormous array of detailed output data which can be sliced in a variety of ways to yield a very comprehensive operational picture. Nonetheless, all of the models provide estimates of capacity, vehicular delay, and queuing, sufficient to characterize the basic performance or level-of-service of a roundabout.

Quantitative evaluation

Methodology

The six roundabout evaluation tools were evaluated quantitatively by applying them to five case-study locations and comparing their predictions of level-of-service (delay) with values observed in the field. All roundabout geometric parameters were supplied as required for each tool. Calibration was undertaken where possible for a given tool: this was particularly beneficial in the case of the micro-simulation tools.

Case-study roundabouts

While there were several factors of interest in selecting case study roundabouts, the dominant consideration was the availability of traffic volume and delay data during periods where operation was at or above capacity. Both single and double-lane roundabouts were considered, with either three or four approaches. Roundabouts were sought which had geometric parameters within "typical" ranges, which were isolated from system effects such as nearby intersections, and which were not affected significantly by pedestrian or heavy vehicle activity.

Initially, roundabouts in the Region of Waterloo were expected to provide suitable case studies: however the existing traffic flows at most of these locations were typically at levels significantly less than capacity. One exception was the recently constructed roundabout located at Arthur Street South and Sawmill Road, where one of the approaches experiences delay during the peak hour. It was necessary to look to the extensive video database compiled for NCHRP Report 572 from roundabouts in the United States to find additional locations. Four locations, described in Table 1, were selected from this database for use in the study. For each location, simultaneous traffic flows in origin/destination or turning movement format and delay measurements, preferably collected simultaneously, were required. For the Arthur/Sawmill roundabout, this information was collected through a purpose-designed survey. For the roundabouts in the NCHRP database, the information was extracted from video footage.

Unfortunately, it was only possible to obtain the required data during periods where performance was at level-of-service A, B, or C with average delays less than 25 seconds. In the case of the Arthur/Sawmill roundabout, traffic volumes were relatively low during the survey, even during peak periods, and only minor delays were observed. In the case of the roundabouts in the NCHRP database, the field-of-view of the "fish-eye" cameras used to collect the video footage did not include the ends-of-queue on any approaches operating at level-of-service D or lower and delays could therefore not be measured under congested conditions.

Observations

For 11 individual approaches, average delays were estimated using each tool and were compared with the observed delays. Table 2 summarizes these results for each of the six evaluation tools. To measure the fidelity of the delay estimates, three different measures of the error of estimate were used. First, the difference between the estimated delay and the observed delay was averaged over the 11 approaches as shown on Figure 1(a). Figure 1(b) summarizes the mean difference between the observed and estimated delays for each tool, expressed as a percentage of the observed delay. Finally, the root mean squared (RMS) error was calculated for each tool as shown on Figure 1(c). Figure 2 summarizes the percentage of the approaches for which each evaluation tool estimated the correct level-of-service. For this graph, the level-of-service was based on the delay criteria for unsignalized intersections as documented in the Highway Capacity Manual (2000).

On the basis of the delay estimation error and recognizing the limited sample, the micro-simulation models appear to provide more realistic results as shown in Figure 1. This likely derives, at least in part, from the increased calibration capabilities of these tools. Nonetheless, at these low levels of congestion and delay, the variation between methods is not large. This is particularly evident in practical terms: Figure 2 shows that, with the exception of the NCHRP method, which tends to over-estimate delay at low traffic volume levels, there is no significant difference between the methods in their ability to predict the level-of-service.

To compensate in part for the unavailability of data at higher levels of congestion, traffic volumes in all approaches for four roundabouts were scaled up by 20% and 40% and the six tools applied to the resulting scenarios. It is neither possible to compare the results with observed data, nor to comment on the fidelity of individual methods. However, it is obvious from the final column of Table 3 and from the individual values in the table that the variability among the delay estimates for the six tools increases dramatically as the traffic volumes increase. Furthermore, it appears that the simulation tools tend, as a group, to produce fewer unreasonable estimates.

One question not addressed in this study is the definition of the capacity of a roundabout. In keeping with the current standard in intersection capacity analysis, this study has utilized delay as the criterion for roundabout level-of-service and capacity, capacity being equivalent to level-of-service F or worse. For roundabouts, we have used the delay criteria associated with unsignalized intersections as shown on Figure 2, rather than those normally used for signalized intersections. The literature also includes roundabout capacity definitions based on the presence of queues for a specified period of time, normally a few minutes. Definitions for roundabout capacity and level-of-service require further consideration.

Developing an operational evaluation strategy for roundabouts

Although it is not possible on the basis of the available data to arrive at a definitive conclusion on the relative merits of each of the operational evaluation tools tested, it is necessary to come up with at least a provisional strategy for the operational evaluation of roundabouts. This provisional strategy can serve as a reasonable interim measure until more comprehensive data is available. The factors considered in selecting a provisional strategy were as follows:

1. There is no significant practical difference between the delay estimates provided by the various tools at low-to-moderate traffic volumes.
2. RODEL, and by extension ARCADY, have known value as roundabout design tools and are commonly used today. Their ease of use enables many design options to be analyzed efficiently. ARCADY is probably a better choice to go forward with due to its Windows-based graphic user interface, calibration capability (although limited), and more reliable technical support. As noted previously, RODEL/ARCADY estimates of roundabout capacity may be 15-20% higher than that achieved in practice in North America.
3. Micro-simulation models are resource-intensive in terms of both data and effort.
4. Micro-simulation models have the capability to address non-standard roundabout designs and evaluate roundabouts in a network context.
5. It appears that the micro-simulation models produce more reasonable results at higher traffic volumes. Previous experience also suggests that micro-simulation models may also be more capable in situations where there is a gross imbalance between traffic volumes on the different approaches to a roundabout. It is also noted that

RODEL/ARCADY does not account for imbalances in lane utilization that may result from traffic patterns or other aspects of driver behaviour.

6. Among the micro-simulation models, AIMSUN and VISSIM seem to provide the best results although VISSIM is the more difficult of the two to apply to roundabouts.

One element required to complete this provisional strategy is a traffic volume threshold to differentiate low-to-moderate from high traffic volumes. To address this need, a supplementary comparison of ARCADY and AIMSUN was undertaken with the objective of establishing traffic volume ranges over which these two methods are compatible and ranges over which they diverge. The procedure used involving establishing a “curve” depicting the approach capacity predicted by ARCADY as a function of the opposing flow. This curve was then adjusted downward by 15% with respect to the approach capacity. The roundabout used in this case was the 2-lane Arthur/Sawmill roundabout in the Region of Waterloo. An AIMSUN model of this roundabout was then calibrated to give the same approach capacity at a conflicting flow of approximately 800 vehicles/hour. Only minor adjustments of the reaction time in the AIMSUN model were required to accomplish this: the adjustments made were, in fact, consistent with typical driver behaviour in small-to-medium size urban areas. This AIMSUN model was then run at different levels of conflicting flow to provide a complete approach capacity curve. Figure 3 summarizes the comparison of the curves for two of the approaches for this roundabout. A proposed threshold is shown at a conflicting flow of 1,200 vehicles/hour (600 vehicles/hour/lane), the approximate point at which the divergence between the ARCADY and AIMSUN capacity estimates begins to increase markedly. At conflicting volumes above this threshold, not only are the ARCADY results less conservative than the AIMSUN results, but the divergence is increasing.

Conclusions - A proposed provisional strategy for the operational evaluation of roundabouts.

Based on the analysis and discussion above, the following provisional strategy is proposed for the operational evaluation of roundabouts in Ontario:

ARCADY (or RODEL), with an appropriate capacity adjustment factor (approximately 15% reduction) should be used to assist in the design and operational analysis of roundabouts. However, if one of the following conditions is present, alternative or supplementary analysis using a micro-simulation tool should be considered and may be necessary:

1. The scenario being analyzed involves a conflicting traffic flow of greater than 600 vehicles/hour/lane;
2. The scenario being analyzed exhibits a significant imbalance in approach traffic volumes or lane utilization;
3. The roundabout is of unusual configuration or has unusual design features not amenable to analysis using ARCADY;
4. The roundabout is in close proximity to other intersections or traffic features, resulting in potential network interactions such as queue spillback;
5. Movement through the roundabout includes significant volumes of pedestrians or heavy vehicles.

VISSIM and AIMSUN both appear to yield realistic results for roundabouts based on this evaluation, although development of a roundabout model is somewhat easier within AIMSUN.

It is recognized that current thinking will likely lead to a new Highway Capacity Manual procedure for roundabouts based on the findings of NCHRP Report 572. However, it is believed that the strategy proposed above is a more useful and general approach that can be of assistance in both the design and operational analysis of roundabouts.

It is also recognized that the provisional strategy proposed above was necessarily based on limited available data. It is recommended that the strategy be amended as necessary to reflect the results of future research and data collection, particularly with respect to roundabout operation under congested conditions.

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Tables

Table 1: Descriptions for five case-study roundabouts

LOCATION	NUMBER OF APPROACHES	NUMBER OF CIRCULATING LANES	PEAK HOUR APPROACH VOLUMES (VEH/HOUR)	AGE (YEARS)
MD 139 / Bellona Ave, Baltimore, Maryland	4	Part single/ part double	50 – 1,070	15
MD 2 / MD 408 / MD 422 Lothian, Maryland	4	Single	60 – 1,060	12
RT 9 / RT 5 Brattleboro, Vermont	4	Double	620 –1,100	11
Mile High Dr / Bethel Ave Port Orchard, Wash.	3	Single	670 – 850	8+
Arthur St. S / Sawmill Rd Waterloo, Ontario	4	Double	250 – 1,180	3

Table 2: Average delay predicted by six methods relative to observed delay for 11 roundabout approaches

APPROACH	AIMSUN	PARAMICS	VISSIM	NCHRP	RODEL	SIDRA	OBSERVED
A	7.2	9.0	7.9	9.1	4.1	5.6	7.6
B	6.6	6.6	8.4	9.5	18.7	13.3	5.7
C	7.4	11.0	10.3	13.7	2.5	7.5	7.1
D	12.5	12.0	9.1	14.2	4.6	7.6	8.3
E	7.9	7.7	7.3	11.5	4.7	6.7	7.3
F	6.8	6.1	5.9	10.8	5.1	6.9	7.4
G	8.4	6.3	7.6	11.2	4.6	6.2	6.4
H	12.3	16.0	11.7	8.4	11.3	8.2	13.8
I	8.4	12.0	9.3	8.2	3.5	6.6	5.3
J	17.6	12.4	18.2	12.8	7.3	13.9	18.3
K	18.8	16.0	18.4	13.0	3.8	8.7	16.1

Table 3: Average delay for 4 roundabouts predicted by six methods for scaled-up traffic levels

LOCATION	TRAFFIC LEVEL	AIMSUN	PARAMICS	VISSIM	NCHRP	RODEL	SIDRA	OBSERVED	VARIABILITY AROUND MEAN
A	base	7	9	8	9	4	6	7.6	1.5
	+20%	4	8	14	10	6	8	-	2.4
	+40%	30	11	41	12	9	10	-	11.1
B	base	9	8	11	10	16	13	8.6	2.3
	+20%	13	10	20	91	58	14	-	21.8
	+40%	41	27	61	282	214	15	-	80.7
C	base	12	13	12	14	4	8	9.6	3.0
	+20%	22	14	50	14	4	9	-	10.3
	+40%	49	18	82	38	7	11	-	22.2
D	base	6	7	6	9	4	6	7.0	1.2
	+20%	15	9	15	31	6	7	-	6.5
	+40%	39	12	165	445	9	8	-	103.3

Notes
1. The average for each roundabout excludes approaches for which observed data was unavailable
2. The variability was calculated as the mean of the absolute values of the differences between the value for each method and the mean (excluding obvious outliers) for all methods.

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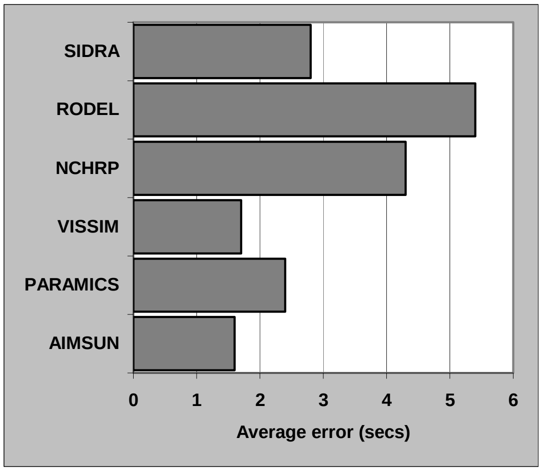
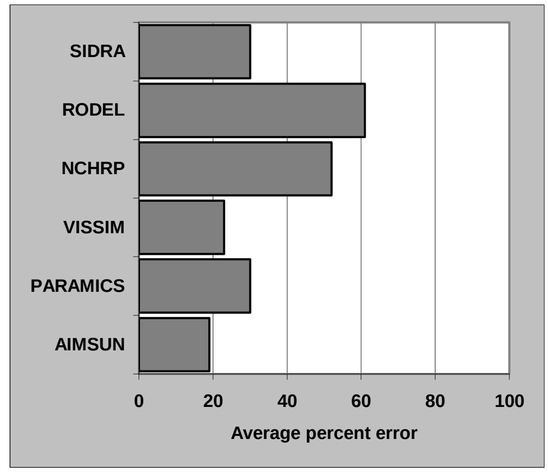
Figure 1: Average prediction error for six methods applied to 11 roundabout approaches

(a) Average prediction error in seconds of delay



(b) Average per cent prediction error



(c) Average root mean square prediction error

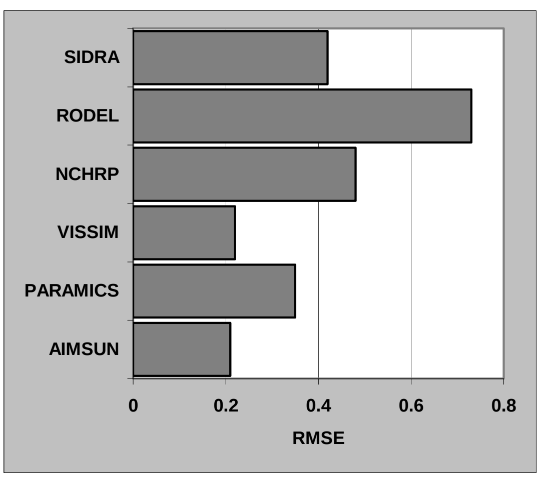


Figure 2: Percentage of approaches where the correct level-of-service was estimated

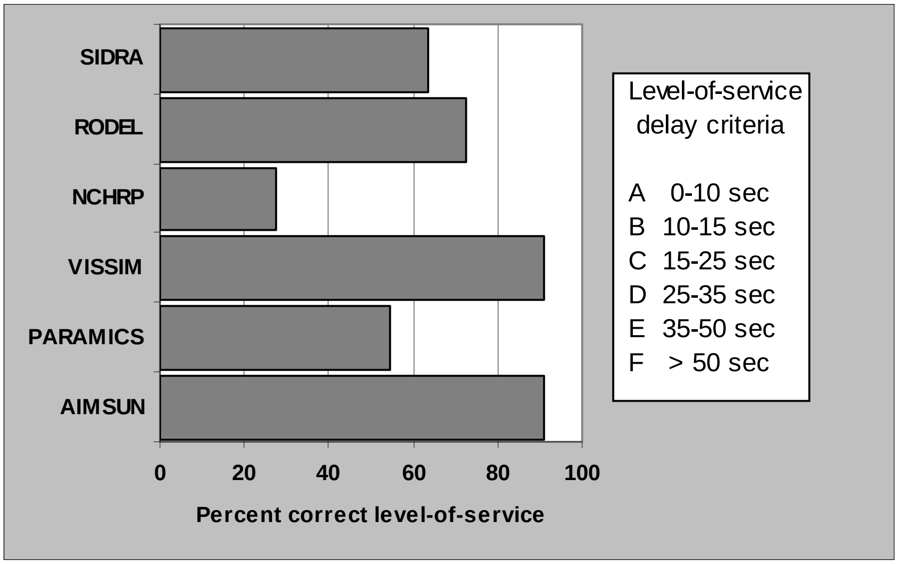


Figure 3: AIMSUN vs. ARCADY estimates of approach capacity relative to opposing traffic volume for some sample roundabout approaches.