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ROUNDABOUT EVALUATION AND DESIGN: A SITE SELECTION PROCEDURE

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A report of the findings of

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16. Abstract

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EXECUTIVE SUMMARY

This study surveyed IDOT staff about roundabouts, evaluated two popular roundabout software programs (aaSIDRA and RODEL), developed a multi-criteria site selection procedure, and used it to identify 10 potential intersections in Illinois that may reduce fatalities and severe injuries by using a roundabout. One third of districts were familiar with the RODEL and aaSIDRA, but they did not have working knowledge of this software. Some districts were concerned about proper roundabout usage by unfamiliar, younger, or elderly drivers. For the same traffic conditions, aaSIDRA yielded higher delay than RODEL for most of the reasonable volume combinations. Capacity values from RODEL are very similar to FHWA's 2000 Guide and both are higher than the new NCHRP 572 model, but aaSIDRA's capacity curves are similar to that of NCHRP 572. This study used aaSIDRA for developing the proposed site selection procedure. A multi-criteria site selection procedure was developed and its application is presented. The factors considered in the site selection process included crash history, intersection delay (LOS), roundabout capacity, distribution of traffic volume among approaches, location of intersection, and input from "local" engineers. It is recommended that, for the time being, IDOT should follow the FHWA Roundabout Guide (2000) in conjunction with the findings of recently published NHCRP Report 572 as a guideline for design of roundabouts. The upcoming FHWA Roundabout Guide and a new roundabout chapter in the 2010 Highway Capacity Manual will have significantly new information that IDOT could use to develop its own roundabout design guide.

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CHAPTER 1 INTRODUCTION

Roundabouts are considered as an alternative intersection design and have been used in several states in the United States including California, Colorado, Florida, Kansas, Maryland, New York, and Wisconsin. Over 1,000 roundabouts currently exist in the U.S., and the number is increasing. The Illinois Department of Transportation (IDOT) is interested in promoting the use of roundabouts at appropriate locations to improve traffic safety. A NCHRP Report 572 published in 2007 concluded that "In general, roundabouts have improved both overall crash rates and, particularly, injury crash rates in a wide range of settings (urban, suburban, and rural) for all previous forms of traffic control except for all-way stop control, for which no statistically significant difference could be found." The study found that for all 55 intersections combined that were converted to roundabouts, the average reductions were 35% in all crashes and 76% in major injury crashes (fatal and severe injury). The study showed average reductions for 36 two-way stop controlled intersections (out of the 55) that were converted to roundabout were 44% in all crashes and 81% in major injury crashes (fatal and severe injury). For the 10 all-way stop controlled intersections that were converted to roundabouts, the reductions were -3% in all crashes and -28% in major injury crashes. For nine signalized intersections converted to roundabouts, the reductions were 48% in all crashes and 78% in major injury crashes when suburban and urban data were combined. Four of the nine intersections were in the suburbs, and they had 67% reduction in all crashes and no reduction in major injury. Five of the nine intersections were in urban areas and there was practically no reduction in all crashes, but major injury crashes reduced by 60%. These new findings are more reliable than the previous findings about the safety effects of roundabouts. The NCHRP Report 572 also concluded that "Overall, single-lane roundabouts have better safety performance than multilane roundabouts. The safety performance of multilane roundabouts appears to be especially sensitive to design details."

Roundabouts work on a yield at entry principle which causes slow traffic instead of stopping traffic thus reducing the delay caused at the intersection. The approaches at the roundabout can be designed to reduce the speed of entering traffic thus providing a much safer environment for pedestrians and bicycle users. As per the IDOT Bureau of Safety Engineering Policy, SAFETY 1-06, Highway Safety Improvement Program Appendix E, http://www.dot.il.gov/illinoisSHSP/hsip.html the "Conversion of stop control intersection (single lane approach) to roundabout, CRF is 60% for all crashes in rural areas and 70% for all crashes in urban areas." All of these facts show that installing roundabouts might be effective in crash reduction, and hence, roundabouts can be used as an alternative intersection type in high crash locations.

This limited scope study had the following objectives:

1. Identify 10 potential intersections in Illinois that have a potential to reduce fatalities and Class A injuries by using a roundabout design.
2. Evaluate existing roundabout design software.
3. Obtain feedback from IDOT District and Central offices about roundabouts.
4. Develop a design/selection guideline for roundabouts.

Crash frequency and roadway information data were used to identify potential locations. Also, feedback from IDOT District offices was obtained before finalizing the 10 intersections in Illinois that have the potential to be converted to roundabouts. A short questionnaire was sent to all the IDOT District offices to learn about their exposure to roundabout design, roundabout construction, site selection process, concerns they may have about roundabouts, and their experience with the various roundabout software programs. Using the information gathered from the districts, the technical review panel for this study decided to look into two roundabout software programs, RODEL and aaSIDRA. An urban compact roundabout with typical dimensions was used to analyze the effects of various traffic volume combinations on delay. The delay and capacity of the two software programs were also compared.

A step-by-step, multi-criteria approach was developed for selecting potential sites for roundabouts. The factors considered in the site selection process included crash history, intersection delay (LOS), roundabout capacity, distribution of traffic volume, location of intersection, and input from “local” engineers. The site selection procedure is applied in identifying the top 10 potential roundabout locations in Illinois. The report recommends processes for site selection and design that may be used to develop an IDOT policy for roundabouts.

The first Roundabout Informational Guide was published by FHWA in 2000. It is still used by many organizations as the main reference for roundabout design. Since the publication of the FHWA Guide in 2000, the results of a multi-year NCHRP study on United States roundabouts was published in 2007. The NCHRP Report 572 has many new findings on how the roundabouts work in the U.S. conditions. Based on the findings of the NHCRP study, a roundabout chapter is being developed for the anticipated 2010 Highway Capacity Manual. In addition, the FHWA is updating the 2000 Guide to reflect the new findings about roundabouts. These two documents, when they become available, will be a great source of information about roundabouts in the U.S. and can be used to develop a roundabout design guide for IDOT.

CHAPTER 2 SURVEY OF ROUNDABOUT USE IN ILLINOIS

2.1 INTRODUCTION

A short survey was developed and sent to IDOT District offices to learn about the state of practice on roundabouts in Illinois. The survey queried about the various issues related to roundabouts. A copy of the survey is given in Appendix A, and the summary of the survey responses is given in Table 2.1.

2.2 RESULTS OF THE SURVEY

All nine IDOT Districts responded to the survey. The survey showed that the roads under IDOT jurisdiction include three roundabouts that are either existing or under construction. All three of these roundabouts are in IDOT District 8. Additionally, two districts have four roundabouts in the planning stages that would also be under IDOT jurisdiction. Four districts reported they are aware of seven roundabouts in their districts that are not under IDOT jurisdiction. The surveys showed increasing interest in roundabout use in Illinois.

Table 2.1. Summary of Responses from IDOT District Offices to the Roundabout Survey

District	**Question 1**	**Question 2**	**Question 3**	**Question 4**			**Question 5**			**Question 6**
	Response (# of RAB)	**Response (# of RAB)**	**Response (# of RAB)**	**HCS**	**RODEL**	**aaSIDRA**	**HCS**	**RODEL**	**aaSIDRA**	**Response**
1	No	No	Yes(3)	Yes	No	Yes	-	-	-	C
2	No	Yes (2)	Yes(1)	Yes	Yes	No	Seems very limited in applications	Was exposed to in training. Seems powerful and good tool	-	A
3	No	No	-	No	No	No	-	-	-	C
4	No	No	No	Yes	No	No	Simplistic with a lot of wiggle room as to the acceptable gap the analyzer may use	-	-	B
5	No	No	No	No	No	No	-	-	-	C
6	No	No	Yes(1)	Yes	Yes	Yes	Unsure of results of analysis compared to actual operation	Familiar with but have not used	Have not used	C
7	No	No	No	No	No	No	-	-	-	A
8	Yes(3)	Yes (2)	Yes(2)	No	Yes	Yes	-	DOESN'T WORK WITH OUR COMPUTERS	CONSULTANTS HAVE USED. APPEARS TO BE PREFERABLE	A
9	No	Yes	No	Yes	No	No	Haven't really used much- Require some type of study	-	-	A

"-" indicates No Response

Table 2.1 Continued. Summary of Responses from IDOT District Offices to the Roundabout Survey

District	Question 7		Question 8	Question 9	Question 10		Question 11	Question 12	Question 13	Question 14	Question 15
	Response	comment	Response	Response	Response	Comment	Response	Response	Response	Response	Response
1	No	-	C	C	Yes	Aggressive drivers	A	C	No	Yes	Yes
2	Yes	-	C	C	Yes	Elderly drivers, New drivers	B&C	C	Yes	Yes	Yes
3	Don't know	Would encourage public education prior to construction	C	C	Yes	Older Drivers, Uneducated in signing and/or proper use	C	C	Yes	Yes	No
4	Don't know	-	A	C	Yes	Older Drivers and teenagers	B	C	Yes	Yes	Yes
5	Yes	Depends on location and how it is presented to the public	B	C	Yes	Older Drivers, Teens	-	C	Yes	No	No
6	Don't know	-	C	C	Yes	Older Drivers, Unfamiliar Drivers	D	B	No	Yes	Yes
7	Don't know	-	C	C	Yes	Older Drivers	B	C	No	No	No
8	Yes	-	C	C	Yes	-	B&E	C	No	No	Yes
9	Yes	-	C	C	Yes	Older Drivers, Young Drivers	B	C	Yes	Yes	Yes

"-" indicates No Response

Table 2.2. Comments from Districts about Questions 11, 13, and 14

District	**Question 11**	**Question 13**	**Question 14**
	Comment	**Comment**	**comment**
1	-	-	Northwestern Univ.
2	Depends on location. But generally a little electricity. Higher for construction, lower for operation, land acquisition could be a problem in urban locations	1. There are safety concerns, patterns of angle crashes, K's& A's 2.There are opportunities to minimize overall impact with R.A 3. Operational (e.g.: no signal warrant) or geometric constraints place limits on more traditional intersections. There is no specific procedure. Potential locations are identified and discussed in P.D	Northwestern Univ. & FHWA
3	-	Pending a BDE guideline: "Roundabouts: An Informational Guide", US DOT – FHWA – Publication #FHWA-RD-00-067. Also, "Participant Workbook from FHWA Resource Center for "Roundabouts Workshop – Planning & Designing Intersections for Safety	May 8 & 9, 2007 – 50 D2 & D3 employees & local agency reps attended.
4	-	Not so much a guideline but an observation. There are intersections we have changed from a 2-way to a 4-way stop due to the high number of angle and turning crashes that don't meet signal warrants or are inappropriate for signals. We gain a safety benefit but lose out on intersection capacity. There is also a location that a left-turn lane cannot be added at signalized intersection (parking) that could accommodate a roundabout and not lose the parking. The roundabout would reduce the turning crashes	-
5	-	FHWA-RD-00-0067	-
6	-	Minimum & Maximum volume guidelines for the site selection of both rural and urban roundabouts	-
7	-	-	-
8	Initial construction can be somewhat higher. Future maintenance is a lot lower	-	-
9	Cost of R/W Issue	Low speed- Documented high accident site in location signals are not a good solution and R/W is plentiful	-

"-" indicates No Response

Table 2.3. Comments from Districts about Questions 16

District	**Question 16**
	Comment
1	-
2	The district is very open to opportunities to implement roundabouts. We are interested in being involved in the development of the statewide guidance. Contact us any time.
3	If Illinois is going to actively introduce roundabouts into our highway system, I believe public education will be the key for their success. Proper usage and signing should be introduced into the "Rules of the Road" and driver's education programs as soon as possible. IDOT-BDE should develop and provide policy guidelines
4	In Illinois it appears the Locals will be the lead on most roundabout projects, but the locals that use State/Federal funding often rely on the guidelines set in BDE Manual. Currently Illinois offers no guidance. There is a gap that needs to be addressed.
5	-
6	-
7	-
8	More classes for Phase I project- Project managers and operations and traffic engineers. Opening classes to personnel other than the geometric unit will promote further understanding of roundabouts and their benefits
9	Our district has a phase I study w/ a roundabout at the intersection of IL13 and IL154, pindeneyville-perry county and we have several wye intersections we would consider for roundabouts

"-" indicates No Response

The districts' responses showed that three districts were familiar with aaSIDRA and three with RODEL, but did not have the working knowledge of them. Five districts indicated that they were familiar with the Highway Capacity Software (HCS), and most of them pointed out the limitations of HCS.

The participants were asked if their district encouraged roundabout design/ implementation. Four districts said yes, one district said no, and four districts said they were neither encouraged nor discouraged. They were asked if they thought the community, in general, would respond positively if a roundabout was built in their district. Four districts responded positive, one negative, and four said they do not know. This suggests that most of the communities in Illinois would probably be in favor of building roundabouts. In all districts, except two, pedestrian and bike safety considerations neither encouraged nor discouraged building roundabouts. One district said that pedestrian safety considerations encourage it to build roundabout, but another district said this discourages it from building roundabouts.

The districts were asked how traffic management during construction of a roundabout would affect their decision. All districts, except one, said it neither encourages nor discourages them from building roundabouts. One district said it discourages them.

The districts were asked if they were concerned about proper roundabout usage by certain driver groups. All districts responded positively. Seven districts were concerned about the proper use of roundabouts by elderly drivers. Four districts mentioned that they are concerned about the proper use of roundabouts by new drivers or young drivers. These issues should be considered when roundabouts are being constructed in the districts. The participants were asked if they had a guideline/procedure for selecting the sites that might be appropriate for roundabout construction. Five of them said they do not have a guideline/procedure, but four said they do. One district said they use the FHWA Roundabouts: An Informational Guide. Another district said they use the FHWA Guide and the Participants Workbook from a Roundabout Workshop conducted by FHWA. One district said that the appropriate site might be a low speed, high crash intersection where signal installation is not a good solution and right of way is plentiful. Another district said they do not have a specific procedure. Potential locations are identified and discussed with the Program Development office. They consider locations where there are safety concerns (patterns of angle crashes and fatalities and severe injuries), "opportunities to minimize overall impact" by using roundabouts, and locations where operational or geometric constraints limit the effectiveness of more traditional intersections.

The districts were asked if they had any training about roundabouts in their districts. Six districts said yes, but three districts answered no to this question.

The districts were asked if a roundabout was considered in their district as a safety countermeasure for intersections with severe crashes (angle, turning, head-on type crashes). Six districts responded that roundabouts have been considered as a safety countermeasure for intersections with severe crashes, but three districts said no.

In summary, the survey showed that IDOT jurisdiction includes three roundabouts built or under construction and four roundabouts in planning stages. Three districts were familiar with the RODEL and aaSIDRA, but they did not have the working knowledge of them. Seven districts were concerned about proper roundabout usage by elderly drivers, and four of them were concerned about new drivers or young drivers. Most districts responded that roundabouts have been considered as a safety countermeasure for intersections with severe crashes. The survey indicated that the districts do not have a procedure for selecting the sites that might be appropriate for roundabout construction.

CHAPTER 3 SITE SELECTION PROCEDURES OF OTHER STATES

Some state DOTs have site selection procedures in their roundabout guides (manuals). Most of them have identified locations where roundabout construction may be difficult and should be done with caution. The site selection procedures of the following state DOTs are reviewed as a part of this study.

1. Kansas
2. Florida
3. Oregon
4. Maryland
5. Wisconsin
6. California
7. Arizona

The following two tables briefly summarize the conditions mentioned by various states as appropriate and inappropriate for roundabout construction. These tables are not comprehensive and are meant to be a quick reference.

Table 3.1. Conditions Mentioned as Appropriate for Roundabout Construction

	Criteria	Kansas	Oregon	Maryland	California	Arizona
1	Intersections with historical safety problems.	Yes	Yes	Yes	Yes	Yes
2	Intersections with relatively balanced traffic volumes	Yes	-	-	Yes	Yes
3	Intersections with a high percentage of turning movements.	Yes	Yes	Yes	Yes	Yes
4	Intersections where a community enhancement may be desirable.	Yes	Yes	-	Yes	Yes
5	Intersections or corridors where traffic calming is a desired outcome of the project.	Yes	Yes	-	Yes	Yes
6	Intersections where widening one or more approach may be difficult or cost-prohibitive, such as at bridge terminals.	Yes	-	-	Yes	Yes
7	Intersections where traffic growth is expected to be high and future traffic patterns are uncertain.	Yes	Yes	Yes	Yes	Yes
8	Locations where the speed environment of the road changes (for instance, at the fringe of an urban environment).	Yes	-	-	Yes	Yes
9	Locations with a need to provide a transition between land use environments (such as between residential and commercial uses).	Yes	-	-	Yes	Yes
10	Roads with a historical problem of excessive speeds.	Yes	-	-	Yes	Yes
11	At intersections where traffic volumes on the intersecting roads are such that STOP or YIELD signs or the T intersection rule result in unacceptable delays for the minor road traffic.	-	Yes	Yes	-	-
12	At intersections where traffic signals would result in greater delays than a roundabout.	-	Yes	Yes	-	-
13	At intersections with more than four legs.	-	Yes	Yes		
14	At intersections of arterial roads in outer urban areas where traffic speeds are high and left turning traffic flows are high.	-	Yes	Yes	-	-
15	At intersections of local roads where it is desirable not to give priority to either road.	-	Yes	-	-	-
16	At intersections where U-turns are desirable.	-	-	Yes	-	-
17	At Freeway Interchange Ramps.	-	-	Yes	-	-

Table 3.2. Conditions Mentioned as Inappropriate for Roundabout Construction

	Criteria	Kansas	Oregon	Maryland	California	Arizona
1	Intersections in close proximity to a signalized intersection where queues may spill back into the roundabout.	Yes	Yes	Yes	Yes	Yes
2	Intersections located within a coordinated arterial signal system.	Yes	Yes	Yes	Yes	Yes
3	Intersections with a heavy flow of through traffic on the major street opposed by relatively light traffic on the minor street.	Yes	Yes	-	Yes	Yes
4	Intersections with physical or geometric complications.	Yes	Yes	Yes	Yes	Yes
5	Locations with steep grades and unfavorable topography that may limit visibility and complicate construction.	Yes	-	-	Yes	Yes
6	Intersections with heavy bicycle volumes.	Yes	-	-	Yes	Yes
7	Intersections with heavy pedestrian volumes.	Yes	Yes	-	Yes	Yes
8	Where peak period reversible lanes may be required.		Yes	Yes		
9	Where large combination vehicles or over-dimensional vehicles frequently use the intersection and insufficient space is available to provide for the required geometric layout.	-	Yes	-	-	-
10	Where it is desirable to be able to modify traffic via signal timings.	-	-	Yes	-	-

Note: “-” in Tables 3.1 & 3.2 does not mean that the state said no to the criteria, it just means that the state did not state the criteria explicitly.

A brief summary of site selection procedures for the sate DOTs is given here. The actual site selection procedures are given in Appendix B

The Kansas DOT *Roundabout Guide* (2000) provides information about the locations favoring roundabout construction and locations where roundabouts have to be constructed with more caution. The *Kansas Roundabout Guide* is a supplement to *FHWA's Roundabouts: An Informational Guide.*

Florida DOT has a procedure to justify if a roundabout is suitable for an intersection scheduled for improvement. Florida uses an eight-step procedure for conducting a roundabout justification study. There are seven justification categories (community enhancement, traffic calming, safety improvement, all-way stop alternative, low volume signal alternative, medium volume signal alternative, and special conditions) indicating the primary reason for roundabout design. However, when more than one location are being considered for improvement, the procedure does not describe how to pick the top locations (Florida, 1996).

The Oregon DOT manual describes the situations where a roundabout is appropriate and the situations where a roundabout is inappropriate. Traffic volume, delay, and geometry are considered in selecting among all-way stop, signal, or roundabout design alternatives (Oregon, 1998).

The Maryland manual states that roundabouts should be considered for a wide range of intersections types including the freeway terminal interchanges, state route intersections, and state route and local road intersections. A general set of site selection guidelines is provided. The applicability of a roundabout at a particular intersection is left to the designer who considers many other factors (capacity, cost/benefit, percentage of each user group, right-of-way, traffic growth and safety). It gives example of sites where a roundabout is suitable and those where it is not (State of Maryland, 1995)

The Wisconsin manual indicates that, in general, any intersection, urban or rural, that meets the criteria for a four-way stop condition or traffic signal should be evaluated as potential site for a modern roundabout. A roundabout should be considered where an existing 4-way stop or signal has operational problems. Typical intersection analysis will include criteria such as crash data, crash diagrams, user delay, or level of service for all traffic movements, appropriate design vehicle, right-of-way impacts and other safety improvements for pedestrians and bicyclists.

The California manual instructs the user to follow the site selection procedure as mentioned in the FHWA guide (Caltrans, 2003). The FHWA site selection procedure does not have a step-by-step process for selecting a suitable site but lists the appropriate and inappropriate locations for roundabout construction.

Arizona uses the same criteria mentioned in the FHWA Guide and Kansas DOT Guide to name locations where a roundabout is beneficial and locations were roundabouts have to be used with caution.

The manuals from these states did not provide a step-by-step process for selecting suitable sites, but provided a general description of locations that are appropriate or sites at which caution should be exercised (some called it inappropriate) for roundabout construction. Only Florida DOT had a procedure to justify if a roundabout was suitable for an intersection that was already pre-selected for improvement, but it did not describe how to select the top locations among potential intersections.

To improve the procedure for selecting sites for roundabouts, this study developed a step-by-step site selection procedure for roundabout construction that considers crash history, delay, capacity, traffic volume, and input from “local” engineers.

CHAPTER 4 ROUNDABOUT SOFTWARE COMPARISON

Based on the feedback from IDOT District offices and in consultation with the project Technical Review Panel, two software programs, RODEL and aaSIDRA, were selected for further evaluation. The evaluation is based on review of features of the software, delay, and capacity values for an assumed typical roundabout. The scope of study did not permit field data collection for evaluation. A brief description of each model is given in Appendices C and D.

4.1 ASSUMED TYPICAL ROUNDABOUT

The assumed typical roundabout has four approaches. Four sets of entering and corresponding circulating flows can create main conflicting paths within a roundabout (EB, WB, NB and SB entry flows with their corresponding circulating flows). One of them would be more critical than the others. It was assumed that critical point was created by the eastbound entry and its corresponding circulating volume to the left of the entry flow. Hence, we assumed a situation where traffic was mainly eastbound and southbound and the remaining directions had very low traffic (10 vph on each). More description of the roundabout is given in appendix D.

4.2 COMPARING DELAYS

Delay to entering traffic in a roundabout is mainly a function of the corresponding circulating traffic volume. So, it is possible to plot a curve to show equal delay for different combinations of circulating and entering flows. Using such a curve, for a given delay one can determine the number of entering vehicles and the corresponding number of circulating vehicles. A selected number of such curves for both RODEL and aaSIDRA are shown in Figure 4.1.

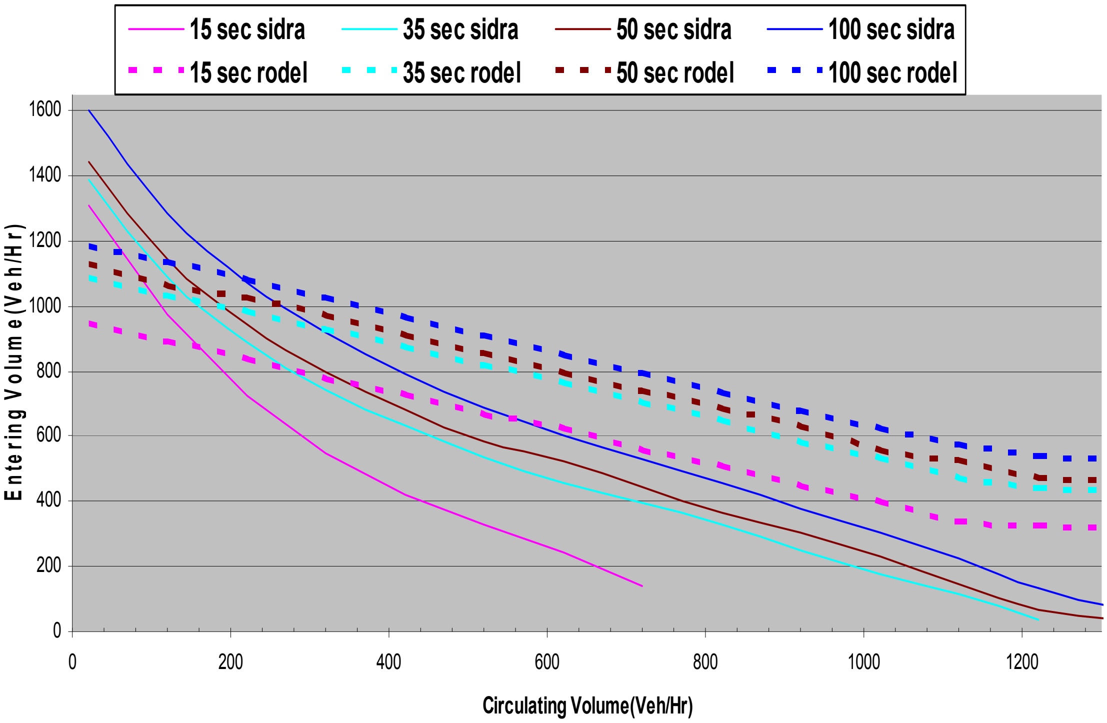

Figure 4.1. Equal delay curves for aaSIDRA and RODEL.

These graphs are distinctly different for RODEL and aaSIDRA. When overlapped, they result in the pattern shown in Figure 4.1. The figure shows only a few of the delay lines, but the trend remains the same for the rest of the delay lines. Delays obtained from the software are different, and that is mainly due to the different capacity equations they use. For the same traffic conditions, aaSIDRA yielded higher delay than RODEL for most of the reasonable volume combinations. RODEL yielded higher delay than aaSIDRA only when the circulating volume was very low (around 20 vph or less).

4.3 COMPARING CAPACITIES

This study compared the capacity values from the following five models:

i. HCM
ii. RODEL
iii. aaSIDRA
iv. NCHRP
v. FHWA

Although such comparisons have been made by other researchers, this study uses the comparison as a part of site selection procedure.

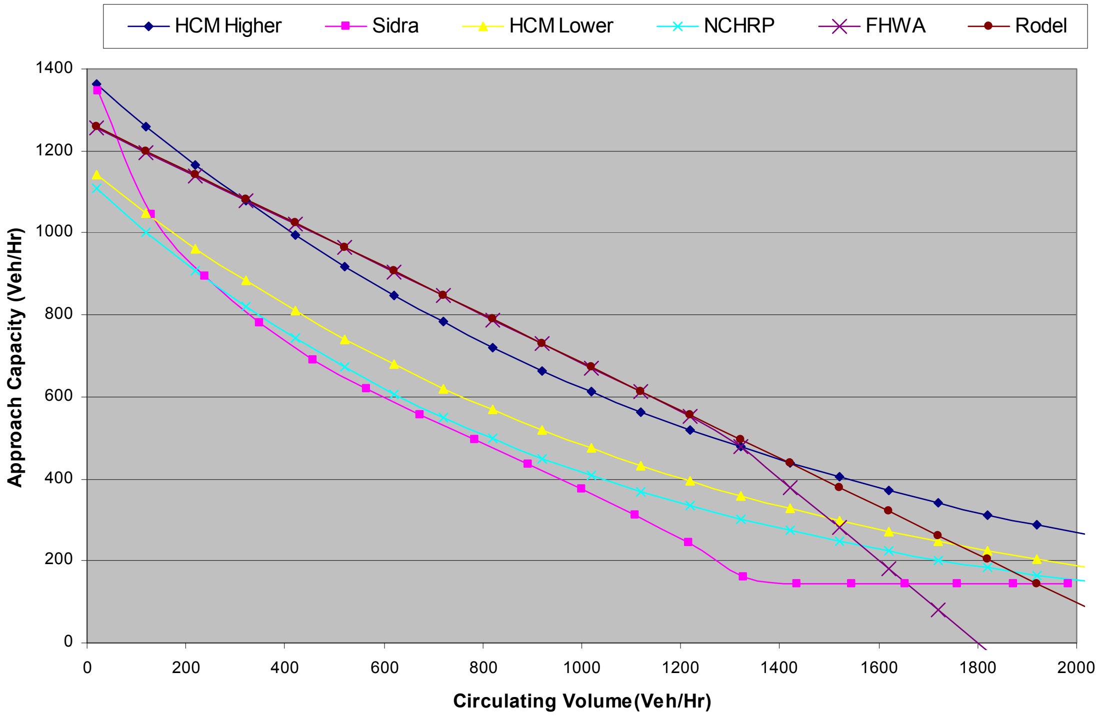

Figure 4.2. Various capacity curves.

From the graph, it can be seen that aaSIDRA yields lower capacity than RODEL for practically all circulating volumes (V_c). In addition, aaSIDRA and NCHRP capacities are very close for circulating volumes (V_c) of 200-800, and then they diverge. aaSIDRA yields lower capacity than HCM lower bound for practically all V_c values. As for RODEL, it yields higher capacity than HCM upper bound for V_c >300. Capacity values of RODEL are very similar to FHWA's 2000 Guide (they are basically the same model for the most part), and both are higher than the NCHRP 572 model. aaSIDRA's capacity curves are similar to that of NCHRP 572, which is the latest result from roundabouts in the United States. Thus, delay curves from aaSIDRA were used in developing the proposed site selection procedure presented in the next section.

4.4 SUGGESTED SOFTWARE

Capacity values from RODEL were very similar to FHWA's 2000 Guide (they are basically the same model for the most part), and both are higher than the NCHRP 572 model. For the assumed typical roundabout aaSIDRA's capacity curves were similar to that of NCHRP 572, which is the latest result from roundabouts in the U.S. Also, for the same traffic conditions, aaSIDRA yielded higher delay than RODEL for most of the reasonable volume combinations. Furthermore, the current version of aaSIDRA is more user-friendly than RODEL, but the upcoming Version 2 of RODEL will be windows based and expected to be more user-friendly. Based on these factors, this study suggests using aaSIDRA for capacity analysis of roundabouts.

CHAPTER 5 PROCEDURE TO SELECT POTENTIAL INTERSECTIONS

5.1 SITE SELECTION PROCEDURE

The following sections detail the major steps in site selection:

Step 1: Get the relevant crash data and traffic data for the intersection types you are considering for a roundabout (RA).

Step 2: Decide the predominant factor in decision making. Is the predominant factor reducing crashes (only safety) at the intersection, or is it improving the overall performance of the intersection which includes safety as well? If crash reduction is the primary concern, then follow Step 2S. If the overall performance improvement is the primary concern, then follow Step 2T.

Step 2S: Rank the intersections based on the cumulative weight index (CWI) of crashes and select the top “n” locations (n can be 10-20 locations).

Step 2T: Rank the intersections based on Rate of Fatal plus Severe (RFS) and select the top n locations. The severe crashes are the Type A and Type B injuries.

Step 3: Depending on the type of roundabout to be constructed (urban, rural or urban compact), use the respective chart provided and check if the roundabout is feasible for the traffic volume expected at the intersection. If feasible, proceed to Step 4 (How to decide on feasibility will be discussed later). Otherwise, try to see if optimizing your roundabout by changing design elements can provide an acceptable level of performance (often delay). If results are acceptable, follow Step 4. However, if the performance is still unacceptable with the optimized design, then the designed roundabout is not a feasible solution for this site.

Step 4: For each of the top locations, check if there is any reason to believe roundabout construction is not feasible. Eliminate such locations, and select the top locations.

5.2 SITE SELECTION PROCEDURE FLOWCHART

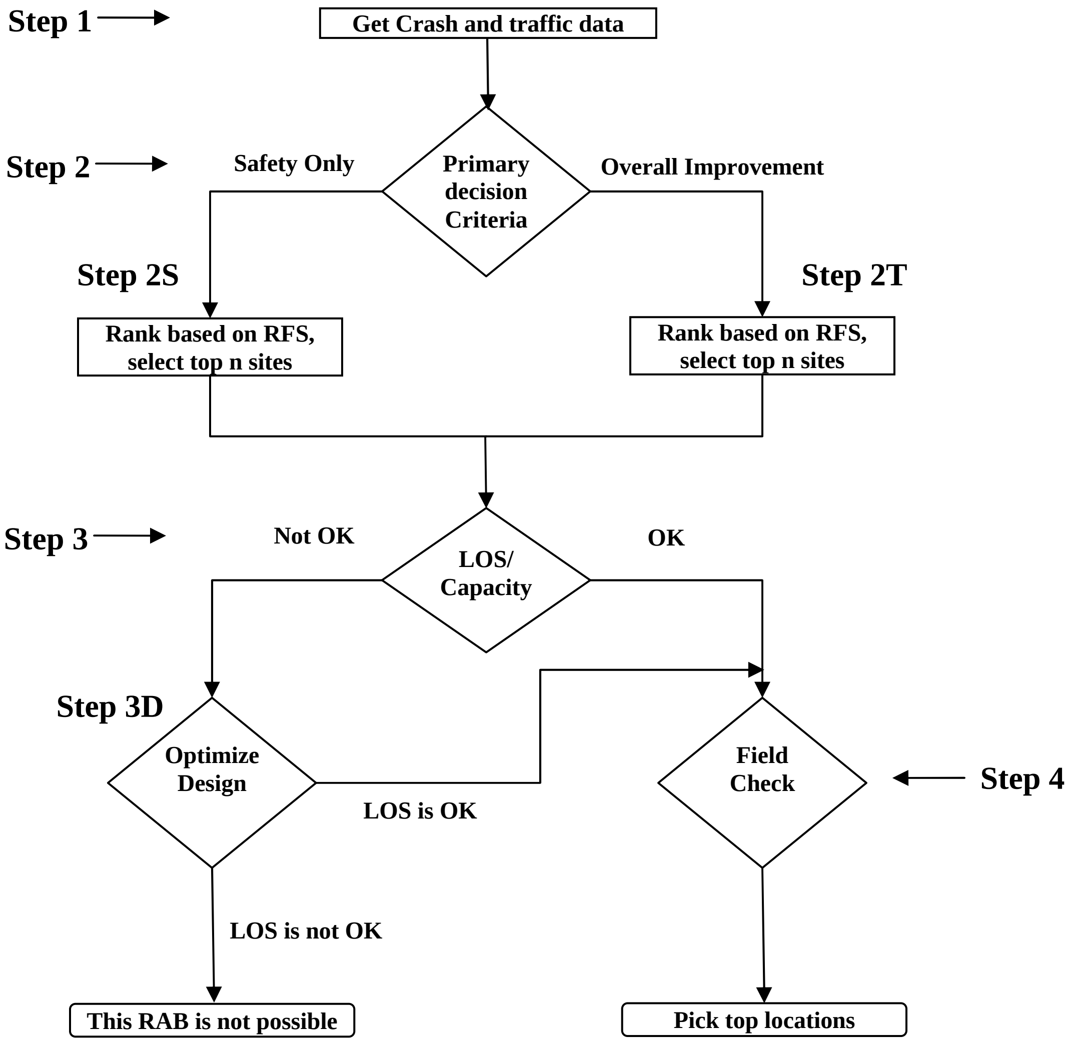

Figure 5.1. Flowchart for selection of potential top location.

5.3 DETAILED EXPLANATION OF STEPS

Step 1: Intersection Data

From the pool of all intersections, select a subset of intersections that are considered for building roundabouts. For example, all the two-way stop intersections located on two-lane rural highways. For these intersections, get multiyear crash data (5 year crash data is desirable) and traffic volume information (ideally for the same time).

Step 2: Ranking

If crash reduction is the primary concern and the main goal is to reduce the severity of crashes at the intersections, then follow Step 2S. However, if the primary concern is the overall improvement of the intersection (in terms of operation and of course safety), then use follow Step 2T.

Safety consideration can be based on several factors that indicate safety performance of the intersection. Four of such factors were considered:

1. Cumulative weight index (CWI) of crashes
2. Rate of the cumulative weight index (RCW)
3. Frequency of fatal plus severe injury (FSI) crashes
4. Rate of the fatal plus severe injury (RFS)

Cumulative Weight Index (CWI)

Depending on the severity of a crash, a weight is assigned to each crash type. A fatal crash is given a weight of 3760. An A-type injury crash is given a weight of 188, and a B-type injury crash is given a weight of 48.2. These are the weights IDOT uses in assessing the safety of an intersection. The sum of the weights of the crashes at the intersection gives the cumulative weight index.

Cumulative weight index =

no. of fatalities *3760 + no. of A-type injuries*188 + no. of B-type injuries*48.2

When intersections are ranked based on the CWI, the intersections with severe crashes rise to the top of the list. Thus, this method should be used when crash reduction is the primary concern. Following this approach is called Step 2S in this study.

Rate of Cumulative Weight (RCW)

The cumulative weight index does not consider the fact that the number of crashes at an intersection may depend on the volume of traffic using it. For example, suppose one intersection has a CWI of 1500 and ADT of 10,000 and another location has a CWI of 1000 and ADT of 2000. If the CWI method is used for ranking, intersection 1 will be picked, but intersection 2 looks like the one with more problems when traffic volume is considered. To avoid such selection, the intersections are ranked based on RCW.

$$RCW=CWI/Ln\ (ADT)$$

It is not realistic to assume that the CWI is a linear function of traffic volume, so we assumed that it is a logarithmic function of ADT.

This ranking method may be used to check if there are intersections with a high number of crashes but with lower traffic volume. In these situations one should consider both CWI and RWC.

Fatal Plus Severe Injury (FSI) Crashes

Consider two intersections, one with two fatalities and another one with one fatality, 15 A-type injuries, and 13 B-type injuries. The CWI method would pick the location with the two fatalities; however, the fatalities may come from one crash that occurred in an unusual circumstance that is not really roadway or traffic related (e.g. a drunk driver). On the other hand, the single fatality plus the 28 injury crashes at the other intersection are very unlikely to be all random events with no relation to some degree to the driving, traffic, or roadway conditions there. Thus, the FSI method ranks the intersections by the frequency of fatal crashes first. Then within each subgroup (0 fatality, one fatality, two fatalities, etc), it ranks them based on the frequency of severe injury crashes. Thus, with the FSI method, the intersections with higher fatalities initially get higher ranks. Then, the top locations within each subgroup are compared to the top locations in the next subgroup. Thus, the intersection with two fatalities is compared to the intersection with one fatality and 28 severe injuries. At this point, a side-by-side comparison of all the important information about geometry, traffic, driving conditions, and other factors about those two locations is recommended. A knowledgeable individual, preferably a team of people who are familiar with the sites and have intersection design expertise, should conduct this comparison. Therefore, the single crash that caused two fatalities would be compared to the intersection with one fatality and 28 injury crashes. In this case, it is clear that the intersection with one fatal and 28 injury cashes should be picked over the one with two fatalities. During this process, many other qualitative and quantitative factors should be considered that heavily rely on knowledge of technical staff about the local conditions. This type of ranking can be used at the district level or county level. In the FSI method, the type of injury crashes to be considered and their importance relative to a fatal crash can be modified by the user.

Rate of Fatal plus Severe (RFS)

The FSI method does not consider traffic volume, which can be a significant factor in the crash frequency. It was proposed to find the rate of fatal plus severe injury (RFS) crashes. The RFS is determined as the ratio of FSI to log of ADT.

$$RFS = FSI / Ln(ADT)$$

This ranking method is used when the main criteria is improving the overall performance of the intersection that includes safety. In this study, this method is called Step 2T.

Comparing the Ranking Methods

The four methods to assess the severity of a safety problem were compared using five-year crash data (2001-2005). The four methods were used to rank the intersections in each highway district. From each highway district (there are 9 IDOT districts), five top-ranked intersections with selected. The locations selected based on CWI were used as a base to compare the other methods. Out of these 45 locations selected by CWI, 29 of them showed up when the ranking was based on RCW. Similarly, 40 locations showed up with FSI ranking and 39 locations with RFS ranking (see the following Figure 5.2 and Table 5.2). This comparison indicates a very close agreement among the methods, though some more than others. The RFS that considers volume of traffic picked 39 of the same locations that CWI picked even though the former considers traffic volume and the latter does not. From this comparison, it seems that the ranks as per the FSI method and RFS method are not much different, but CWI and RCW have the largest discrepancy.

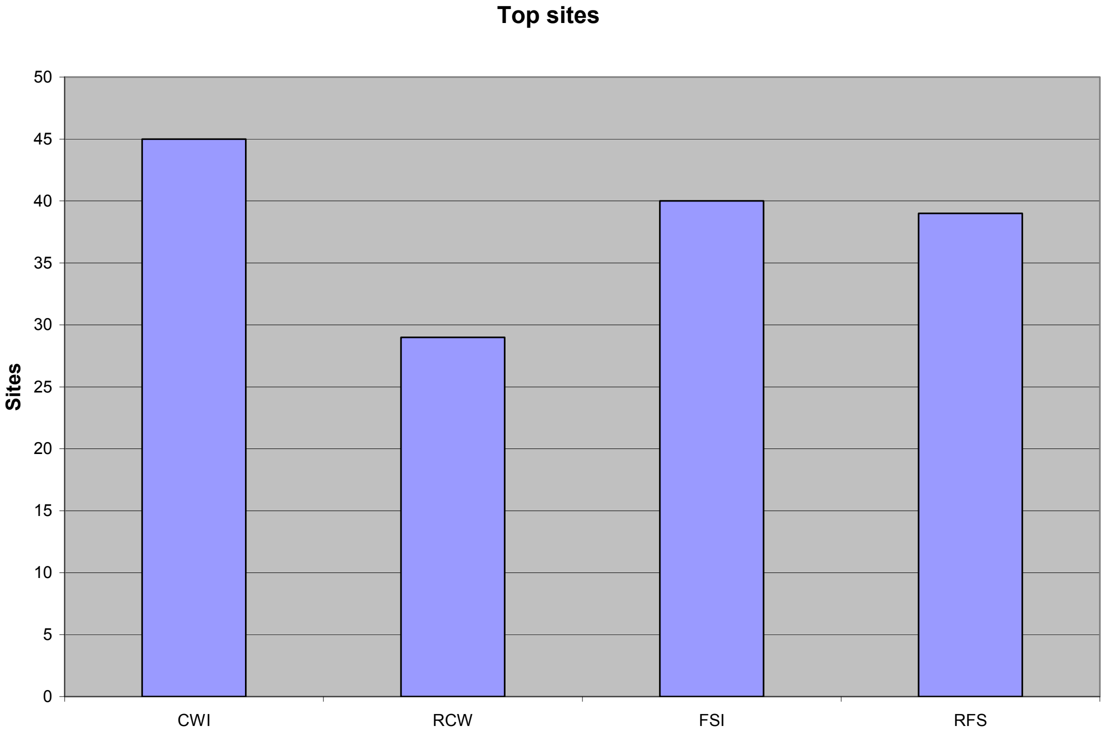

Figure 5.2. Comparison of four methods for selecting top-ranked intersections.

Table 5.1. Comparison of Four Ranking Methods

District	Ranks			
	Cumulative weight Index	**Rate of cumulative index**	**Fatal + Severe Injury**	**Rate of Fatal+ Severe Injury**
1	1	2	2	2
	2	1	1	1
	3	3	3	3
	4	4	5	5
	5	5	4	4
2	1	2	1	1
	2	5	2	2
	3	3	4	4
	4	1	3	3
	5	4	5	5
3	1	1	1	1
	2	2	3	3
	3	3	2	2
	4	5	4	4
	5	6	5	5
4	1	1	1	1
	2	2	2	2
	3	8	3	3
	4	16	4	5
	5	38	7	7
5	1	1	1	1
	2	2	2	2
	3	15	5	6
	4	28	6	5
	5	30	3	4
6	1	18	1	1
	2	39	2	2
	3	40	5	6
	4	38	3	3
	5	1	9	7
7	1	7	1	1
	2	5	2	3
	3	8	3	4
	4	11	7	8
	5	27	10	13
8	1	1	1	1
	2	4	3	3
	3	6	2	2
	4	3	5	5
	5	2	4	4
9	1	1	1	1
	2	3	2	2
	3	2	3	3
	4	4	4	4
	5	5	5	5
Top Locations	**45**	**29**	**40**	**39**

Step 3: Los/ Capacity Check

The decision to build a roundabout may hinge on a desired level of delay (LOS) or a certain desired capacity that the facility should provide. Before doing the LOS/Capacity Check, a “quick-check” should be done for each of the top “n” intersections to see if a typical roundabout is sufficient for that traffic volume combination. To do the quick-check, the investigators established the lower ADT threshold for each roundabout type. The suggested ADT threshold for LOS of “C” for an urban-compact roundabout is 16,000, for an urban roundabout is 21,000, and that for a rural roundabout is 27,000. These thresholds are established using the delay curves and considering the worst volume combination that yields the design LOS. If the sum of ADT of the intersecting roads is below the threshold, then the roundabout is feasible. Otherwise, the LOS/Capacity Check should be done. The quick-check is sufficient when the volumes are much below the ADT threshold. Otherwise, DDHV (directional design hour volume) should be used.

For LOS/Capacity Check, the volume of mixed traffic (cars, trucks, buses) needs to be converted to passenger car equivalent (PCE) unit. For converting trucks to passenger car units, use a PCE factor of 2 (as used in HCM). Then, find the hourly traffic the roundabout would be designed for, using the following relationship.

$$DDHV=AADT*K*V$$

Where:

DDHV = Directional Design Hour Volume (in passenger car units),
AADT = Average Annual Daily Traffic (in passenger car units),
K = Percent of ADDT that occurs during design hour.
V =Directional distribution factor

To compute the directional design hour volumes, use these default values if field data is not available: K=0.10 and V=0.65. Then, use the DDHV that is in passenger car unit to do a capacity check or LOS check as described below.

Capacity Check

The capacity requirement is used to determine if a roundabout can serve the demand. If the demand at the intersection is less than the capacity served by the roundabout, then the roundabout may be feasible. It is suggested to use capacity values obtained from the NCHRP model or aaSIDRA software; although one other (HCM 2000, RODEL, and FHWA 2000 Guide) may also be used if justified.

Each model uses different input variables for calculating the capacity of the roundabout, but the major input is the conflicting (circulating) volume. Chapter 4 of this report presents a comparison of the capacity values obtained from these models/software programs. For a known conflicting (circulating) volume, one can draw a vertical line in Figure 4.2 to intersect the corresponding capacity curve to get the capacity for the entry leg.

LOS Check

This approach is recommended when the delay (LOS) at the intersection is the major concern in the decision making process. In this method, for a known circulating and entering volume, one determines the delay (LOS) of the roundabout either from the delay curves or from the software. The curves based on aaSIDRA for a typical urban-compact roundabout, urban roundabout, and rural roundabout are shown in Figures 5.4-5.6, respectively. These figures are created based on values given in Table D.1 in Appendix D.

Using these figures, the delay (LOS) for a given entering and circulating volume can quickly be estimated. The lines labeled with LOS correspond to the thresholds used in HCM for unsignalized intersections. In addition, a delay line (an LOS line) can be used to determine what combination of entering and circulating volume can be handled at that level.

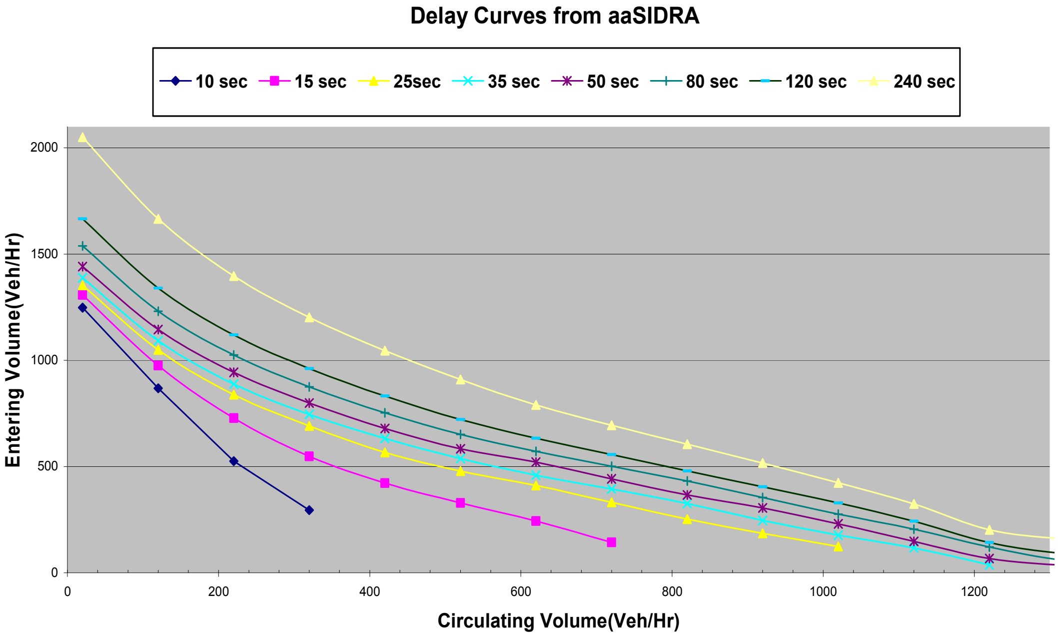

Figure 5.4. Urban Compact Roundabout Delay curves from aaSIDRA software.

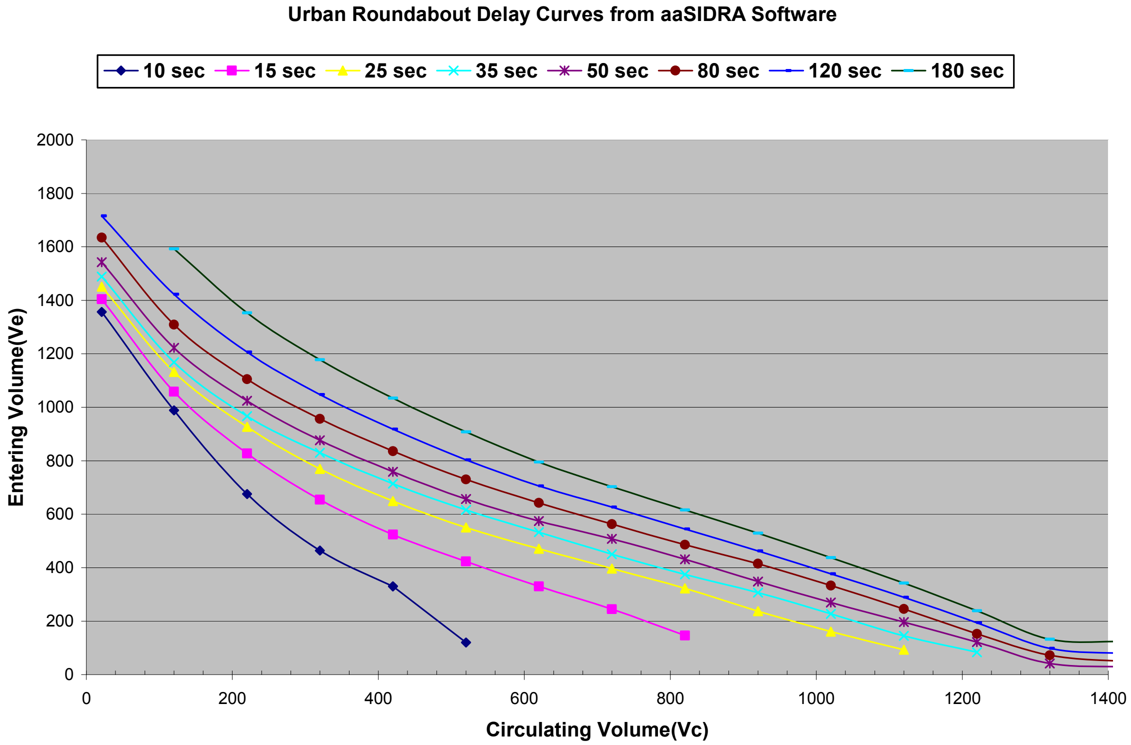

Figure 5.5. Urban Roundabout Delay Curves from aaSIDRA software.

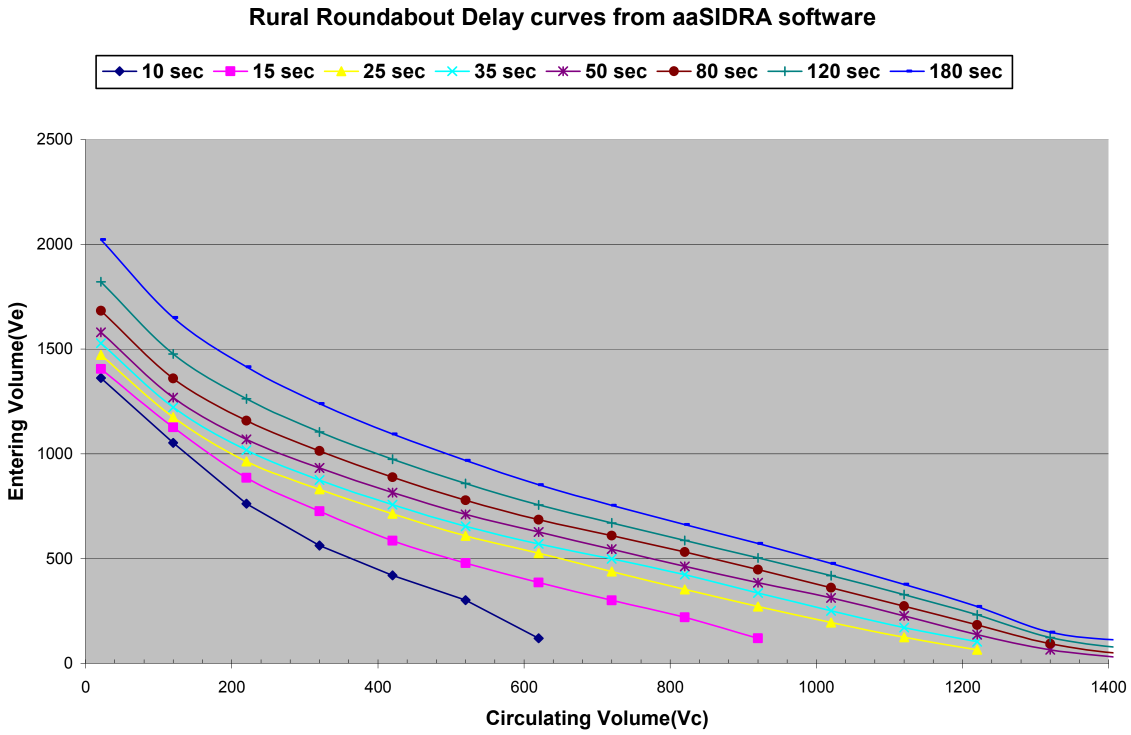

Figure 5.6. Rural Roundabout Delay Curves from aaSIDRA software.

To use the delay curves, the entering and circulating volumes are needed. These are the two DDHV values computed previously. The intersection of these volumes on the delay curve represents a delay value. If this delay value is below the desired delay value, then a roundabout is feasible. However, if it exceeds the desired delay level by a small amount (under 20% or so), then use the software to optimize the design elements to see if the delay can be brought down to an acceptable level. If the desired level is exceeded by a large amount, consider an alternative design (such as a different roundabout type or other types of intersection designs).

These graphs are meant to be a quick guide, not an ultimate decision making tool. Several variables can be changed to optimize the roundabout design. To optimize the design, use software and change the variables to see if a roundabout can be designed for a specific location. This activity is referred to as Step 3D in this report.

Step 4: Apply Field Check

At this stage, a reduced set of intersections exists at which roundabout design seems reasonable. Some of these locations might not be suitable for roundabouts due to geometric restrictions, traffic composition, or steep grades etc. Under such circumstances, one needs to eliminate those locations from the list or has to carefully consider the limitations of the site during roundabout construction. There are general guides on where not to use roundabouts. A few such situations as described in the *Kansas Roundabout Guide* (2000):

a) Intersections in close proximity to a signalized intersection where queues may spill back into the roundabout.
b) Intersections located within a coordinated arterial signal system.
c) Intersections with a heavy flow of through traffic on the major street opposed by relatively light traffic on the minor street.
d) Intersections with physical or geometric complications.
e) Locations with steep grades and unfavorable topography that may limit visibility and complicate construction.
f) Intersections with heavy bicycle volumes.
g) Intersections with heavy pedestrian volumes.

This list is not exhaustive, but gives ideas for consideration. Local technical staff should expand the list to cover the conditions that reflect their experience.

Final Decision

After going through these steps, the locations that remain on top of the list are potential locations for building roundabouts. Local knowledge should be used to determine which intersection should be improved first and what the potential payoff would be. It is suggested that local engineers or technical staff who are familiar with these locations should consider all other constraints (such as cost, ROW, sight distance) as well as the local community preferences before finalizing their decision.

CHAPTER 6 APPLICATION OF SITE SELECTION PROCEDURE

This chapter discusses how to select the top locations in Illinois and illustrates how the selection procedure presented in Chapter 5 works.

STEP 1: INTERSECTION DATA

For intersections in Illinois, the investigators collected information pertaining to the location, inventory number, crash type, number of crashes, daily traffic distribution (AADT), etc. This report pertains to single-lane roundabouts, and hence from the data set of Illinois intersections, the intersections with multi-lanes were eliminated. From the remaining set, the intersections with traffic signals were also eliminated. The remaining intersections were sorted by district, and each district was analyzed separately.

STEP 2: RANKING

For each of the districts, the intersections were ranked based on a priority factor. In this project, our main priority factor was crash reduction, so the intersections were ranked based on the Cumulative Weight Index (CWI). This is Step 2S in the procedure. As explained in Chapter 5, each crash type is given a weight and the cumulative weight index (CWI) is calculated for each intersection. A higher CWI implies that the intersection had more severe crashes. The intersections were sorted from highest to lowest CWI and the top 20 locations (the user can change this number) were selected.

STEP 3: LOS/ CAPACITY CHECK

For each of the top 20 intersections per district, the investigators did a “quick-check” to see if a typical roundabout is sufficient for the traffic volume there. All top 20 locations in all districts, except four locations in District 1, satisfied the quick-check requirements. For those four locations, the LOS check was conducted. The directional design hour volumes were computed using K=0.10 and D=0.65. This resulted in one DDHV for east west and another DDHV for north-south direction. The LOS for roundabout design was assumed to be “C” or better (user can specify the LOS). Then, the urban roundabout delay curves were used to check if the DDHV combinations can be handled by the roundabout. For all four of them, the typical urban roundabout was not sufficient. Then the delay curves for the typical rural roundabout were used. Two of the sites had lower volumes and two had higher volumes. The two that had high volumes were deleted; but the other two were kept because the volume did not exceed the urban roundabout thresholds by a large amount. The sum of ADT for one intersection was 26,000 and for the other was 25,000.

STEP 4: APPLY FIELD CHECK

For the remaining locations on the list, in the order they appear, the field conditions should be checked to see if there are any reasons to believe that a roundabout may not be suitable there. This step needs to be conducted by engineers who are familiar with the sites.

To assess the suitability of the site for roundabout construction, the top five locations in each district and top ten locations in District 1 were selected. District staff are intimately familiar with these locations. Therefore, the Geometric Engineer of each district was asked for his or her opinion about the sites in his/her district. He or she was asked to select the top three locations (top five for District 1) from the list or suggest alternate locations if the top sites were not on the list.

It turned out that there were a few selected from the investigator’s top set but most of them were the choice of the district. Some data was received from District 9 that described why they did not select some of the locations the investigators suggested, as shown in Table 6.1.

Table 6.1. Reasons for Not Selecting Five Sites Suggested to District 9

CWI Rank	**Reason for not selecting**
1	Improvement done (cutting hill and flashing beacons)
2	N.R
3	Improvement done (adding lanes and shoulders)
4	Proximity of rail road
5	Proximity of rail road

This further supported the notion that local information should be obtained during site selection. The investigators presume that similar reasons could be found in other districts. Table 6.2 shows the locations selected by the districts as the top ranking potential sites. Alongside the locations are the relative ranks given to the locations as per each of the ranking methods discussed in Step 2 of the site selection procedure.

Table 6.2. Top Sites Suggested by IDOT Districts

District	Location		Ranking	Our Ranking			
	Major street	Minor street		Cumulative wt.	Cum. Rate	Crash Freq.	Injury rate
1	-	-	-	-	-	-	-
2	IL251	IL72	1	91	91	94	92
	US 52	Freeport Rd.	2	3	3	4	4
	US 30	IL136	3	21	15	25	25
3	Raccuglia Dr.	Airport Rd.	1	*			
4	IL-9	Springfield	1	64	64	74	71
	Farmington Rd	Kickapoo Creek Rd.	2	*			
	US 150	Maher Rd.	3	5	38	6	7
	US 150	Washington	4	70	67	82	75
5	IL133	Atwood/Author Dr. (Vine St)	1	732	732	502	453
	US150	IL49	2	0	0	0	0
	IL10	700 E Rising Rd.	3	1	1	1	1
6	FAP 662/IL4	FAP753/IL104	1	138	136	228	340
	FAS 728/IL138	FAS 1766/Old US 66	2	84	77	83	76
	FAS 1613/Old US36	FAS 621/Ch10	3	*			
	FAP 310/US 67	FAP 612/IL100/103	4	0	0	0	0
	FAP 714/IL48	FAP 42/IL127	5	513	513	197	155
7	US 40	IL 185/Sunset	1	0	0	0	0
	IL 250	Christy	2	5	13	7	7
	US 40	IL128	3	2	5	2	4
8	Market St	Columbia Ave	1	*			
	IL 013	IL 015	2	0	0	0	0
	IL 140	IL 157	3	0	0	0	0
9	IL 13	IL 154	1	0	0	0	0
	IL 37	OLD US 51	2	750	750	750	618
	IL 149	IL 184	3	0	0	0	0
	IL 154	US 51	4	159	157	190	214
	IL 37	IL 146	5	643	643	643	440
		Total Sites	**27**	**5**	**3**	**3**	**3**

*****	Couldn’t find information in database
0	No Crashes found at location in 2001-05 dataset
-	No Response from the district

As Table 6.2 shows, a few locations selected by the district had no information in the project database or no crashes during 2001-05. The investigators contacted the districts and obtained information about those locations. The information was used in selecting the recommended sites.

TOP LOCATIONS FOR ROUNDABOUT IMPROVEMENT

Following the four-step procedure, the investigators recommend the following 10 sites in Districts 2 through 9 as potential roundabout locations. Since District 1 did not respond to our survey, no sites from District 1 are given because Step 4 which seeks "local" input was not completed. In addition, five alternative locations are suggested as backup.

Table 6.3. Top 10 Locations Chosen for Roundabout Improvement in Illinois

District	Location				Rank	
	Major street	Minor street	Selected	Alternate	Dist.	UI
2	US 52	Freeport Rd.	S		2	3
	IL 251	IL 72		A	1	91
3	Raccuglia Dr.	Airport Rd.	S		1	352
4	US 150	Maher Rd.	S		3	5
	IL 9	Springfield	S		1	64
5	IL10	700 E Rising Rd.	S		3	1
	IL133	Atwood/Author Dr (Vine St)		A	1	732
6	IL 4	IL104	S		1	157
	IL138	Old US 66		A	2	59
7	US 40	IL128	S		3	2
	IL 250	Christy	S		2	5
8	Market St.	Columbia St.	S		1	*
	IL 013	IL 015		A	2	671
9	IL 13	IL 154	S		1	25
	IL 37	Old US 51		A	2	211
	Total		10	5		

* Couldn't find information in database

CHAPTER 7 CONCLUSIONS AND RECOMMENDATION

The project's initial survey showed IDOT jurisdiction included three roundabouts built or under construction and four roundabouts in planning stages. Three districts were familiar with the RODEL and aaSIDRA, but they did not have the working knowledge of this software. Seven districts were concerned about proper roundabout usage by elderly drivers, and four districts were concerned about proper usage by new drivers or young drivers. Most districts responded that roundabouts have been considered as safety countermeasure for intersections with severe crashes. The survey indicated that the districts do not have a procedure for selecting the sites that might be appropriate for roundabout construction. Therefore, this study developed such a procedure.

Two most popular software programs for roundabouts, aaSIDRA and RODEL, were evaluated. aaSIDRA is more user-friendly than RODEL, but the upcoming Version 2 of RODEL will be windows-based, and it is expected to be more user-friendly than the current version. Delays obtained from the software are different; this is mainly due to the different capacity equations they use. For the same traffic conditions, aaSIDRA yielded a higher delay than RODEL for most of the reasonable volume combinations. Capacity values from RODEL are very similar to FHWA's 2000 Guide (they are basically the same model for the most part), and both are higher than the NCHRP 572 model. aaSIDRA's capacity curves are similar to that of NCHRP 572 (note NCHRP 572 represents the latest findings based on the data from roundabouts in the United States). Thus, this study used aaSIDRA for developing the proposed site selection procedure and suggests using it in the capacity analysis of roundabouts.

A four-step multi-criteria site selection procedure was developed, and its application is presented. The factors considered in the site selection process included crash history, intersection delay (LOS), roundabout capacity, distribution of traffic volume among approaches, location of intersection, and input from "local" engineers.

The investigators recommend roundabouts be considered as an alternative intersection during all intersection improvements. The site selection process described above was used to identify the top 10 locations in Illinois where roundabout design should be considered. It is recommended to use the site selection procedure developed in this study as discussed in Chapter 5 and applied in Chapter 6. Further modification to this procedure is needed to cover other types of roads (multi lane) and traffic conditions that are not covered in this study.

It is recommended that, for the time being, IDOT follows the FHWA Roundabout Guide (2000) in conjunction with the findings of recently published NHCRP Report 572 as a guideline for design of roundabouts. The upcoming FHWA roundabout guide and a new roundabout chapter in the Highway Capacity Manual, which are anticipated to be published in 2010, will have significantly new information that could be used to develop a roundabout design guide for IDOT. For signing and marking of roundabouts, IDOT should use the latest information in MUTCD until the new version of the manual is published in the near future.

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APPENDIX A: SURVEY OF IDOT PERSONNEL ON ROUNDABOUTS

Final Draft (7/17/07)

The University of Illinois at Urbana-Champaign is conducting a study about Roundabout Evaluation and Design for IDOT. The study requires survey of IDOT personnel about Roundabouts. Your response to this survey is an important part of the study. If you have any questions or comments, please contact Professor Ray Benekohal at (217) 244-6288 (rbenekoh@uiuc.edu) or Mr. Sean Coyle, IDOT District 4, at (309) 671-3456 (Sean.Coyle@illinois.gov). Thank you very much for your cooperation.

1. Are there any roundabouts built or under construction in your District that are under IDOT jurisdiction?
    a. Yes. How many roundabouts? _____
    b. No
    c. I don't know

2. Are there any roundabouts planned in your District that would be under IDOT jurisdiction?
    a. Yes. How many roundabouts? _____
    b. No
    c. I don't know

3. Are there any roundabouts in your District that are NOT under IDOT jurisdiction?
    a. Yes. How many roundabouts? _____
    b. No
    c. I don't know

4. Are you familiar with any software program for roundabout design or evaluation?
    a. Yes. Please list them, A. ____________, B. ___________, C. ____________
    b. No

5. What is your impression of the roundabout software you have used?
    A.____
    B.____
    C.____

6. Do you think your District encourages roundabout design/implementation?
    a. Yes
    b. No
    c. Neither encourages nor discourages

7. Do you think the community, in general, would respond positively if a roundabout is built in your District?
    a. Yes
    b. No
    c. I don't know

8. Do pedestrian safety considerations encourage/discourage you from building a roundabout?
    a. They encourage me to build roundabouts
    b. They discourage me from building roundabouts
    c. Neither encouraged nor discouraged

9. Do bicycle safety considerations encourage/discourage you from building a roundabout?
    a. They encourage me to build roundabouts
    b. They discourage me from building roundabouts
    c. Neither encouraged nor discouraged

10. Are you concerned about proper roundabout usage by some driver groups?
    a. Yes. Please list the groups
    b. No
    c. No opinion

11. Is the cost of constructing a roundabout compared to a signalized intersection with a similar number of lanes….
    a. A lot higher?
    b. Somewhat higher?
    c. About the same?
    d. Somewhat lower?
    e. A lot lower?

12. How does traffic management during construction of a roundabout affect your decision?
    a. It encourages me to build roundabouts
    b. It discourages me from building roundabouts
    c. Neither encourages nor discourages

13. Do you have a guideline/procedure for selecting the sites that might be appropriate for roundabout construction?
    a. Yes. Please describe it OR provide a copy of it
    b. No. What should such a guideline/procedure include?

____
____
____
____
____
____
____
____

14. Has there been any training about roundabouts available in your District?
    a. Yes
    b. No
    c. I don’t know

15. Has a roundabout been considered in your District as a safety countermeasure for intersections with severe crashes (angle, turning, head on type crashes)?
    a. Yes
    b. No
    c. I don't know

16. Do you have any suggestions/comments?

____
____
____
____
____
____
____
____

17. Please Provide:

Name: ____
Position: ____
Number of years in current position: _______________________________________
District: ______________________________, City ___________________________
Phone Number: ____
Email Address: ____

Please return the survey to:

Professor Ray Benekohal
Dept of Civil and Environmental Engineering
205 N. Mathews Ave
Urbana, IL 61801

THANK YOU VERY MUCH FOR YOUR PARTICIPATION IN THIS SURVEY.

APPENDIX B: SITE SELECTION GIUDES OF OTHER DOTS

The site selection sections of the roundabout design guides for the following states are discussed below:

1. Kansas
2. Florida
3. Oregon
4. Maryland
5. Wisconsin
6. California
7. Arizona

KANSAS STATE MANUAL

The Kansas DOT manual gives information about the locations favoring roundabout construction and locations where roundabouts have to be constructed with more caution. The site selection guidance contained in the KDOT manual is below.

The following text has been directly taken from Kansas Roundabout Guide, *A supplement to FHWA's Roundabouts: An Informational Guide.*

Sites Where Roundabouts are Often Advantageous

Roundabouts are often advantageous over other traffic control at the following locations and conditions:

- Intersections with historical safety problems.
- Intersections with relatively balanced traffic volumes
- Intersections with a high percentage of turning movements.
- Commercial development or urban area.
- Intersections where a community enhancement may be desirable.
- Intersections or corridors where traffic calming is a desired outcome of the project.
- Intersections where widening one or more approach may be difficult or cost-prohibitive, such as at bridge terminals.
- Intersections where traffic growth is expected to be high and future traffic patterns are uncertain.
- Locations where the speed environment of the road changes (for instance, at the fringe of an urban environment).
- Locations with a need to provide a transition between land use environments (such as between residential and commercial uses).
- Roads with a historical problem of excessive speeds.

Sites at Which Caution Should Be Exercised With Roundabouts

There are a number of locations and site conditions that often present complications or difficulties for installing roundabouts. Some of these locations can also be difficult or problematic for other intersection alternatives as well. Therefore, these site conditions should not necessarily preclude a roundabout from consideration. However, extra caution should be exercised when considering roundabouts at these locations:

- Intersections in close proximity to a signalized intersection where queues may spill back into the roundabout.
- Intersections located within a coordinated arterial signal system.
- Intersections with a heavy flow of through traffic on the major street opposed by relatively light traffic on the minor street.
- Intersections with physical or geometric complications.
- Locations with steep grades and unfavorable topography that may limit visibility and complicate construction.
- Intersections with heavy bicycle volumes.
- Intersections with heavy pedestrian volumes.

FLORIDA STATE MANUAL

Florida DOT had developed a procedure to justify the roundabout in a location. This is a very good method to follow if the intersection to be improved is known. If such a case prevails where the district officials know which intersection to improve and are looking for various alternatives, this procedure is recommended. But in a realistic situation, more than one location is being considered for improvement. The guide does not describe a way to pick a top location from a set of locations.

The following text has been directly taken from Florida Roundabout Guide.

Roundabout Justification Procedure

An eight step procedure for conducting a roundabout justification study based on the discussion presented in this chapter has been developed. These steps are described as follows:

Step 1 - Obtain Common Data

The common data includes all of the information that is independent of the justification category. All data required for a signal warrant study are normally required for the justification of a roundabout. These data should be summarized on the standard MUTS forms, where applicable. The following items are normally required:

- Peak hour turning movement volumes should be summarized by 15 minute intervals;
- Twenty-four hour approach volumes for each leg of the intersection are normally obtained to identify the heaviest eight hours for signal warrant analysis;
- Bicycle and pedestrian counts for the intersection should be gathered where their numbers are significant. Special consideration should be paid to future pedestrian and bicycle traffic generators, such as plans to build a school near the intersection;
- Detailed crash records should be compiled to analyze the frequency and types of collisions occurring at the existing intersection;
- Community considerations should be addressed, including the need for parking, the landscaping character of the area and existence of other traffic management strategies; Percentage of large trucks that would be using the intersection is important because of the geometric constraints imposed by a roundabout;
- Transit routes (and frequencies) through the intersection along with any stops which are located within 0.5 km should be documented; Posted and design speeds for all approaches should be obtained; and

- Miscellaneous data, such as existing geometrics, area population, land uses and distances to other intersections and adjacent intersection control treatments, will also be useful in most cases.

In most cases, traffic volume should be projected to some point in the future. The basis for these projections should be identified.

Step 2 - Identify Justification Category

The justification category indicates the primary reason for which the roundabout should be installed. There are seven justification categories described in Table 2-1. The choice of the justification category will determine what, if any, additional data are required and what analyses should be carried out.

TABLE 2-1. ROUNDABOUT SELECTION CATEGORIES AND JUSTIFICATION CONDITIONS

CATEGORY AND DESCRIPTION		AWSC WARRANT MET?	AWSC LOS	SIGNAL WARRANT MET	SIGNAL LOS	NUMBER OF LANES	CONDITIONS FOR JUSTIFICATION
1	COMMUNITY ENHANCEMENT	N/A	N/A	N/A	N/A	1	Typically applied in commercial and civic districts. Aesthetics are important
2	TRAFFIC CALMING	NO	A	NO	A	1	Primarily a residential application. Demonstrated need for traffic calming.
3	SAFETY IMPROVEMENT	N/A	N/A	N/A	N/A	N/A	Existence of safety problem which would be alleviated by use of a roundabout intersection treatment.
4	ALL-WAY STOP ALTERNATIVE	YES	B - D	NO	A - B	1	Delay should compare favorably with AWSC
5	LOW VOLUME SIGNAL ALTERNATIVE	YES	D - F	YES	A - C	1	Delay should compare favorably with signal.
6	MEDIUM VOLUME SIGNAL ALTERNATIVE	YES	F	YES	B - D	2	Delay should compare favorably with signal. Other justifying factors required.
7	SPECIAL CONDITIONS (such as unusual geometrics, high volumes, right of way limitations, etc.)	Y/N	N/A	Y/N	N/A	1 - 3+	Site specific justification required.

Step 3 - Obtain Data Requirements Specific to a Particular Category

Any category-specific data not required for Step 1 or 2 should be obtained now. For example, documentation of area complaints about speeding vehicles may be required as justification for traffic calming.

Step 4 - Perform Preliminary Geometric Design to Establish Feasibility

Using guidelines provided in Chapter 4, prepare a preliminary geometric design of a roundabout for this location to establish the physical feasibility. Based on the preliminary design, assess the feasibility of a roundabout at this location. Note any special features or design criteria required to prepare the preliminary design.

Step 5 - Analyze the Performance of a Roundabout

Using procedures established in Chapter 3, an analysis of the performance of a roundabout at that location should be prepared. The aaSIDRA program will normally be used for this purpose. To assign a level of service to the roundabout or any of its approaches, the unit delays (seconds per vehicle) should be estimated using aaSIDRA, and the HCM level of service thresholds for unsignalized intersections should be applied. All assumptions regarding operating parameters should be clearly identified.

Step 6 - Analyze the Performance of Alternative Control Modes

If the roundabout is being justified as an alternative to other control modes, a complete analysis of the performance of these modes should be carried out. Comparisons with traffic signal performance should describe the signal operation plan (lane use, left turn protection, phasing plan, timing plan, etc).

Step 7 - Assess Contraindications and Propose Mitigation Treatments

Any contraindications identified in Steps 1 through 6 should be documented. A description of mitigation efforts or measures to alleviate or reduce the effects of the contraindication should be provided for each contraindication. Contraindications are identified in Section 2.2.

Step 8 - Final Recommendations

Prepare final recommendations summarizing the study and indicating the basis for justification of a roundabout as the most appropriate control mode for the intersection. In some cases, a cost/benefit analysis may strengthen the recommendation.

Roundabout Justification Study Summary and Report

To facilitate the justification process, a standard report summarizing the results of a roundabout justification study is included in Appendix B. This report includes the following five sections:

1. A cover page indicating the location, agency and date;
2. A summary of general and approach-specific characteristics, justification categories and attachments to the report;
3. A summary of miscellaneous observations that are relevant to the justification of a roundabout at the location in question;
4. A summary of the contraindications that have been identified and their proposed mitigation treatment; and
5. A comparison of the performance of a roundabout with alternative control modes and the final recommendation narrative. The material in Appendix B has also been incorporated into the Florida MUTS Manual [1]

OREGON STATE MANUAL

The following text has been directly taken from Modern Roundabouts for Oregon by Oregon DOT.

Roundabouts may be appropriate in the following situations:

- At intersections where traffic volumes on the intersecting roads are such that STOP or YIELD signs or the T intersection rule result in unacceptable delays for the minor road traffic. In these situations, roundabouts would decrease delays to minor road traffic, but increase delays to the major road traffic.
- At intersections where traffic signals would result in greater delays than a roundabout. It should be noted that in many situations roundabouts provide a similar capacity to signals, but many operate with lower delays and better safety, particularly in off-peak periods.
- At intersections where there are high proportions of left-turning traffic. Unlike most other intersection treatments, roundabouts can operate efficiently with high volumes of left-turning vehicles.
- At intersections with more than four legs. If one or more legs cannot be closed or relocated, or some turns prohibited, roundabouts can provide a convenient and effective treatment. With STOP or YIELD signs, it is often not practical to define priorities adequately, and signals may be less efficient due to the large number of phases required (resulting in a high proportion of lost time).
- At cross intersections of local and/or collector roads where a disproportionately high number of accidents occur which involve either crossing traffic or turning movements. In these situations, STOP or YIELD signs may make little or no improvement to safety, and traffic signals may not be appropriate because of the low traffic volumes. Roundabouts, however, have been shown to reduce the casualty accident rates at local and/or collector road intersections.
- In this example the left-turner from A to D would stop the through movement from C to A, thus allowing traffic from D to enter roundabout. Traffic from D would then stop the through movement from A thus allowing traffic from B to enter the roundabout. Left turners from A in this example would initiate traffic flow on adjacent entries B and D which would otherwise experience longer delay.
- On local roads, and to a lesser extent on arterial roads, roundabouts can improve safety and neighborhood traffic management.
- At rural cross intersections (including those in high-speed areas) where there is an accident problem involving crossing or left turn (vs. opposing) traffic. However, if the traffic flow on the lower volume road is less than about 200 vehicles per day, consideration could be given to using a staggered T treatment.
- At intersections of arterial roads in outer urban areas where traffic speeds are high and left turning traffic flows are high. A well-designed roundabout could have an advantage over traffic signals in reducing left turn opposed type accidents and overall delays.
- At T or cross intersections where the major traffic route turns through a right angle. This often occurs on highways in country towns. In these situations the major movements within the intersection are turning movements which are accommodated effectively and safely at roundabouts.
- Where major roads intersect at Y or T junctions, as these usually involve a high proportion of left turning traffic.

- At locations where traffic growth is expected to be high and where future traffic patterns are uncertain or changeable.
- At intersections of local roads where it is desirable not to give priority to either road.

Inappropriate Sites for Roundabouts

Roundabouts may not be appropriate in the following situations:

- Where a satisfactory geometric design cannot be provided due to insufficient space or unfavorable topography or unacceptably high cost of construction, including property acquisition, service relocations etc.
- Where traffic flows are unbalanced with high volumes on one or more approaches, and some vehicles would experience long delays.
- Where a major road intersects a minor road and a roundabout would result in unacceptable delay to the major road traffic. A roundabout causes delay and deflection to all traffic, whereas control by STOP or YIELD signs or the T intersection rule would result in delays to only the minor road traffic.
- Where there is considerable pedestrian activity and due to high traffic volumes it would be difficult for pedestrians to cross either road. (This may be overcome by the provision of pedestrian crossing facilities on each leg of the roundabout).
- At an isolated intersection in a network of linked traffic signals. In this situation a signalized intersection linked to the others would generally provide a better level of service.
- Where peak period reversible lanes may be required.
- Where large combination vehicles or over-dimensional vehicles frequently use the intersection and insufficient space is available to provide for the required geometric layout.
- Where traffic flows leaving the roundabout would be interrupted by a downstream traffic control which could result in queuing back into roundabout. An example of this is a nearby signalized pedestrian crossing. The use of roundabouts at these sites need not be completely discounted, but they are generally found to be less effective than adopting signalized intersection treatment.

MARYLAND STATE MANUAL

The following text has been directly taken from Maryland DOT's Roundabout Design Guidelines.

General

Roundabouts should be considered at a wide range of intersection types including but not limited to; freeway terminal interchanges, state route intersections, and state route/local route intersections. Roundabouts perform better at intersections with roughly similar traffic volumes and at intersections with heavy left turning movements. Roundabouts can improve safety by simplifying conflicts, reducing vehicle speeds and providing a clearer indication of the driver's right-of-way compared to other forms of intersection control.

Site Selection Criteria

The following site selection guidelines are intended as general guidelines only. The designer should determine the applicability of a roundabout at a particular intersection by considering the following items:

- Capacity Analysis of all methods under consideration
- Cost/Benefit Analysis
- Percentage of Truck Traffic
- Bicycle and Pedestrian Traffic
- Right-of-Way Consideration
- Parking Requirements
- Compatibility with Adjacent Intersection
- Safety Aspects
- Effect of Possible Traffic Growth
- Speed of Traffic
- Installation and Maintenance Costs

Roundabout Shortlisting Guidelines

Introduction

The following guidelines are based on existing design manuals from England, Australia, and other countries, and video tapes of existing roundabouts. The guidelines are not meant to be rigid but should be used in conjunction with engineering judgment, and traffic analysis. For example, it could be stated that a roundabout should not be placed where there is an existing signal in close proximity (i.e. Chevy Chase Circle) because the queues from the signal may extend temporarily into the roundabout. Intuitively, this would not seem to be an appropriate place for a roundabout; however traffic analysis may indicate that a roundabout may work better than any other solution. The proposed intersection treatment, therefore, should be chosen based on the advantages/disadvantages, benefits/costs that it provides.

Location

- High Accident Location (with left turn or right angle accidents)
- Capacity/Delay Problem Intersection
- Intersection in which traffic signal was requested but not warranted.
- 4-Way Stops
- Traffic Volume and Composition
- Heavy Delay on Side Street
- Flow Distribution with Heavy Left Turn Movement (makes signals less efficient – no impact on roundabout)
- DHV of 7000 or Less (initially)

Right-of-Way

- Generally take no more right-of-way than comparable solution using signals:

Appropriate Sites for Roundabouts

- Heavy delay on minor road.
- Traffic signals result in greater delay.
- Intersection with heavy left turning traffic.
- Intersection with more than four legs or unusual geometry.
- At rural intersections (including those in high speed areas) at which there is an accident involving crossing traffic.
- Where major roads intersect at “Y” or “T” junctions.
- At locations where traffic growth is expected to be high and where future traffic patterns are uncertain or changeable.
- At intersections where U-turns are desirable.
- At Freeway Interchange Ramps.
- High accident intersection where right angle accidents are prominent.

Inappropriate Site for Roundabouts

- Where a satisfactory geometric design cannot be provided.
- Where a signal interconnect system would provide a better level of service.
- Where it is desirable to be able to modify traffic via signal timings.
- Where peak period reversible lanes may be employed.
- Where the roundabout is close to existing signals and queueing from the signal could be a problem.

WISCONSIN STATE MANUAL

The following text has been directly taken from Wisconsin DOT’s Facilities Development Manual.

There are no warrants for when to construct roundabouts. In general terms, any intersection, urban or rural, that meets the criteria for a four-way stop condition or traffic signal, also qualifies for evaluation as a modern roundabout. Therefore, if an intersection warrants a signal or a 4-way stop within the design life of the proposed project, then include the roundabout alternative in the overall analysis. Where there is an existing 4-way stop or signal and there are operational problems with the current control, then the roundabout shall be considered as a viable alternative. In either case, roundabouts are a potential intersection control strategy until such time that the analysis indicate that the roundabout alternative is not appropriate. Typical intersection analysis will include criteria such as crash data, crash diagrams, user delay or level of service for all traffic movements, appropriate design vehicle (WB-65 on the STH system), right-of-way impacts and other safety improvements for pedestrians and bicyclists.

FHWA and AASHTO have made intersection safety a high priority. The objective is to improve the design and operation of highway intersections. When compared to signalized intersections, studies show that roundabouts typically reduce overall delay and congestion, they increase capacity and they improve safety. For example, right-angle collisions are a prominent cause of death at signalized intersections. Studies have shown [2] that signalized intersections converted to roundabouts experienced significantly fewer injury and fatality crashes and fewer overall crashes.

CALIFORNIA STATE MANUAL

The following text has been directly taken from California DOT's DIB number 80-01 for roundabouts.

Chapter 3 of the Guide also communicates factors which may significantly influence the design of a roundabout, and may, in some cases, lead to a decision that a roundabout is not a viable alternative for a given location. Planners or engineers may wish to consider measures suggested in Chapter 3 of the Guide that will allow the inclusion of a roundabout among the range of alternatives despite less than optimal circumstances.

ARIZONA STATE MANUAL

The following text has been directly taken from Roundabouts: an Arizona case study and design guidelines.

Arizona uses the same criteria mentioned in the FHWA guide and Kansas DOT guide as the locations where roundabout is beneficial and locations were roundabouts have to be dealt with caution.

APPENDIX C: REPORT ON aaSIDRA SOFTWARE

The major factors that influence the output of aaSIDRA are presented in this section.

C.1 INFLUENCING FACTORS

The influential factors are grouped in three categories:

i. Geometry
ii. Movement
iii. Analysis

C.1.1 Geometry

The geometrical factors that can influence the capacity and delay of the roundabout are divided in the following sub-groups:

i. Intersection
ii. Approaches& lanes
iii. Roundabout

C.1.1.1 Intersection

In aaSIDRA, user can choose the orientation of the legs in the roundabout.

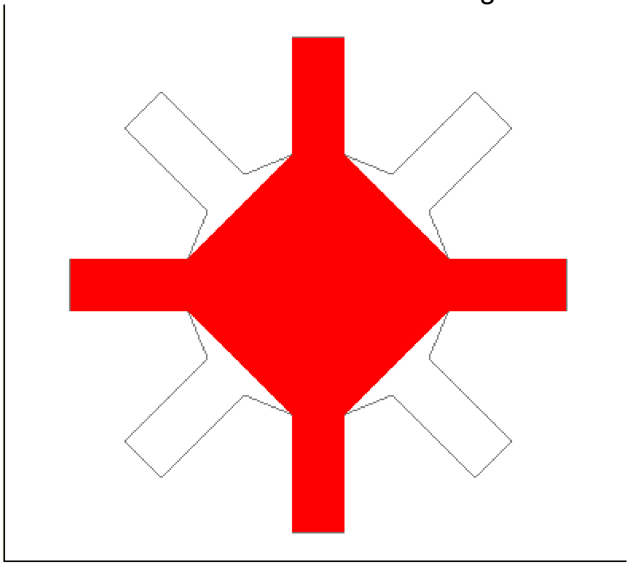

Figure C.1. Screenshot of Orientation of legs in a roundabout in aaSIDRA. (Source: aaSIDRA INTERSECTION software)

By interactive selection method, the user can select the orientation of the different legs of the roundabout under consideration

C.1.1.2 Approaches & Lanes

In this section, the user can choose items such as the number of lanes, type of movement, lane width, length and slope of the lane.

C.1.1.3 Roundabout

This section has all the basic geometrical inputs of the roundabout and the nature of traffic at the roundabout. The inputs in this section constitute:

1. Island diameter
2. Circulating width } Geometrical inputs
3. Circulating lanes
4. Extra bunching
5. Environmental Factor } Nature of Traffic
6. Entry or circulating flow adjustment

C.1.2 Movement

After describing the geometry of the roundabout under consideration, the various movements at the approaches are described. This includes the following data:

C.1.2.1 Definitions & Path Data

In this input field, the user can enter the various movements that are possible at the roundabout and eliminate the unwanted movements. The user can also include the speed of each approach separately.

C.1.2.2 Volumes

The user has to enter the volume of traffic anticipated at the intersection. The input includes the following parameters:

i. Percentage of heavy vehicles in the flow
ii. Time period of data collection
iii. Peak flow period
iv. Amount of traffic in each movement
v. Peak flow factor

C.1.2.3 Movement

The user can define the queue length at the intersection for each movement separately. In this module, one can also specify the degree of saturation of the intersection and can alter the movement type for each flow.

C.1.2.4 Gap Acceptance-Data

As the gap-acceptance values are different for different countries, the software enables the user to input the value of this choice. The other input characters in this section include follow-up headway and heavy vehicle equivalent.

C.1.3 Analysis

aaSIDRA software gives the option to its user to perform the following analysis:

1. Sensitivity and design life analysis
2. Cost analysis

C.1.3.1 Sensitivity and Design Life Analysis

In this mode, the roundabout can be analyzed based on the following sensitivity parameters:

i. Lane width at entry
ii. Lane utilization
iii. Roundabout Island Diameter
iv. Critical gap & follow-up headway
v. Basic Saturation Flow
vi. Cruise speed

Design life of the roundabout can be calculated or analyzed based on the growth rate of traffic and the probable lifetime of the roundabout.

C.1.3.2 Cost Analysis

The cost incurred due to the construction of a roundabout can be determined by a cost analysis. This helps in determining the usefulness of a roundabout at the location. The cost benefit function can be used to determine the scope of the project.

C.2 SCENARIO

The roundabout considered has four entries, and at each entry, the entering traffic conflicts with the circulating traffic. The magnitude of the conflict depends on the volume of circulating traffic and the entering traffic. Four locations within a roundabout can have such conflicts, and one of them would be more critical than the others. The roundabout was tested assuming the critical point is created by the eastbound entry. It would be same for any other entry for the same circulating and entry traffic. Hence it is assumed that the traffic is high in just two of the directions and the remaining directions have traffic at a minimum value of 10 vph. As shown below, the southbound through and the eastbound through are the major movements.

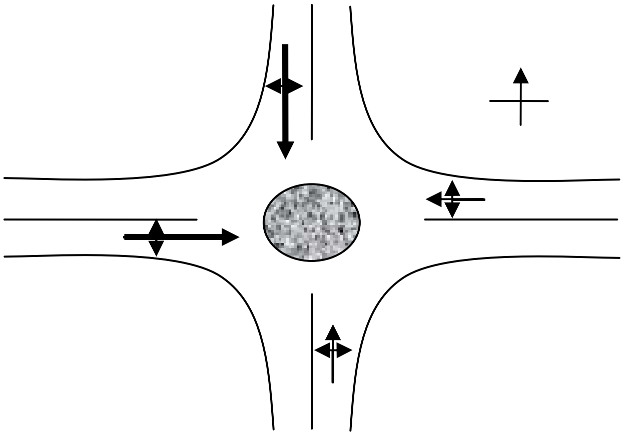

Figure C.2. Main flows are eastbound and southbound.

C.3 VALUES USED

“Typical” values were selected that would represent the following roundabouts:

i. Urban-compact roundabout
ii. Urban roundabout
iii. Rural roundabout

For all the three types of roundabouts, the following was assumed:

i. Four approaches/ Legs
ii. Single lane entry with single circulating lane
iii. No heavy vehicle traffic and no banned movements

The other variables are different for each of the roundabout type.

Table C.1. Various Inputs in aaSIDRA Software

	Variable	Urban-Compact	Urban	Rural
Geometry	Island Diameter	60 ft	95 ft	120 ft
	Circulating Width	20 ft	20 ft	20 ft
	Circulating Lanes	1	1	1
	Extra bunching	0	0	0
	Environmental factor	1.2	1.2	1.2
Movement	Approach cruise Speed	40	40	40
	Exit Cruise Speed	40	40	40
	Approach travel Distance	1600	1600	
	Peak Flow Factor	92%	92%	92%
	Vehicle Occupancy	1.2	1.2	1.2
	Period of data collection	60 min	60 min	60 min
	Peak Flow Period	15 min	15 min	15 min
	Critical gap	4 sec	4 sec	4 sec
	Follow-up headway	2 sec	2 sec	2 sec
	Heavy Vehicle Equivalent	2	2	2
Analysis	Sensitivity Analysis	N.A	N.A	N.A
	Cost parameters	N.A	N.A	N.A

C.4 EFFECT OF CHANGING VARIABLE

The main goal of the experiment was to determine the effect of circulating traffic at a roundabout on the delay of the entering traffic. It was assumed that all the movements at the roundabout have 10 vph except for the through traffic in the eastbound and southbound approaches. This assumption allows for examination of the effect of circulating flow. This can be done using any corner of a roundabout. In this case, the circulating flow is the southbound through traffic, and the entering flow is the eastbound though traffic. The right turning traffic does not often create a critical point.

The following volume combination cases were examined:
Case i: Both the heavy traffic-carrying movements are equal.

Case ii: Constant circulating flow (in our case, increasing entering traffic).
Case iii: Variable Circulating flow (i.e. increasing circulating flow).

C.4.1 Case i: Balanced Flow

Case i occurs when both entering and circulating traffic volumes are the same. The volume on both legs is increased simultaneously at an increment of 100 vph to see its effect on the delay to the entering traffic (E.B traffic).

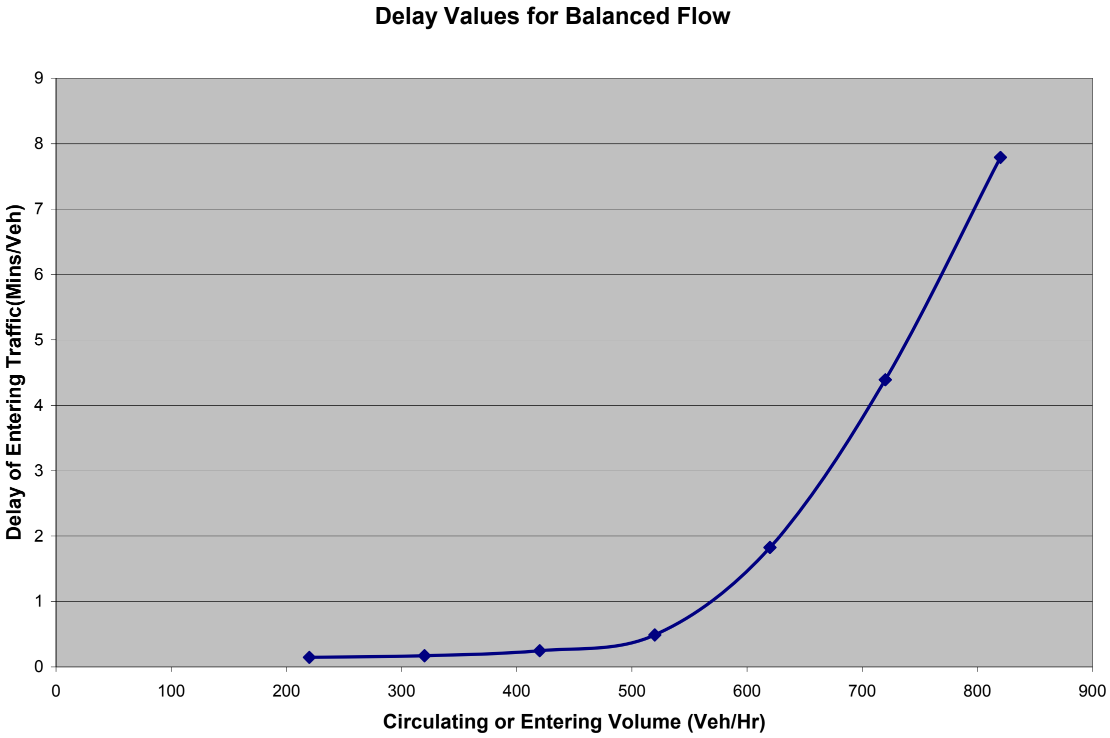

Figure C.3: Delay values for a balanced flow situation

As shown above, the delay of entering traffic increases with the increase in traffic volumes. The increase in delay is more pronounced beyond the volume of 600 vph. Using Figure C.3, the volume of traffic that can cause a certain amount of delay can be determined. For example, the graph shows that 770 vph circulating traffic and 770 vph cause a 4 minutes per vehicle delay.

C.4.2. Case ii: Constant Circulating flow

For a fixed value of circulating flow, the delay of entering traffic should increase as entry volume increases. In case ii, several circulating volumes were selected. For each circulating volume, the entering volume was changed and delay to entering traffic was computed. Figure C.4 shows the relationship between entry delay and entry volume for different values of circulating flow.

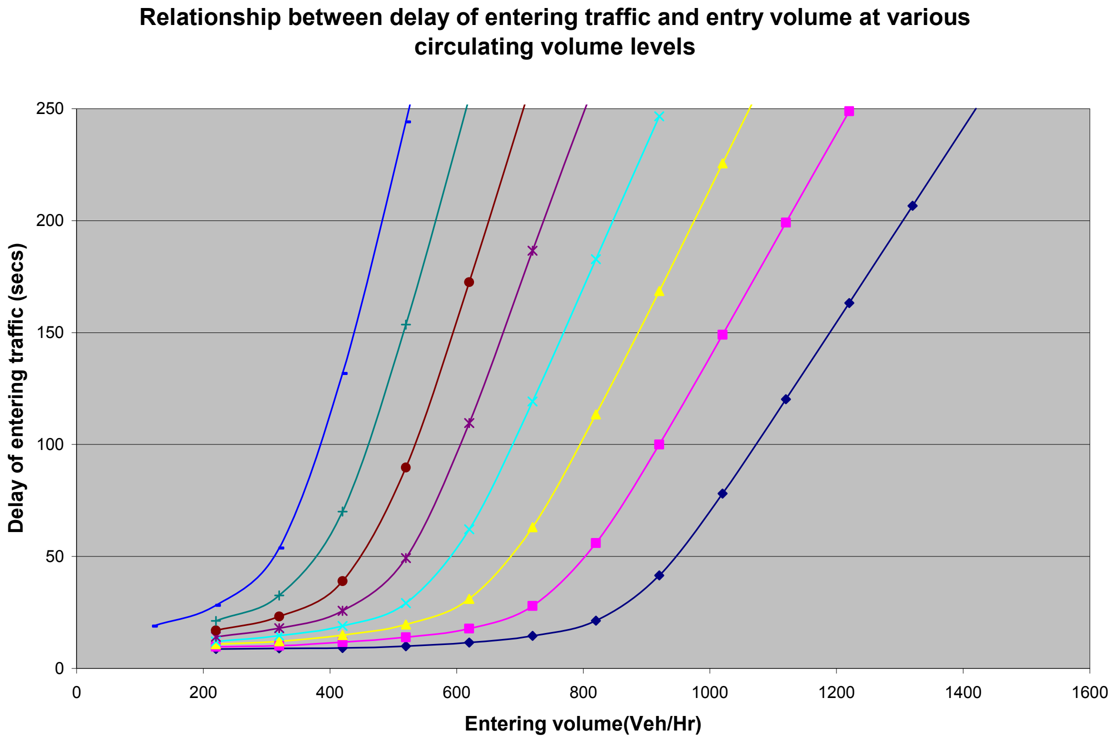

Figure C.4. Relationship between delay of entering traffic and entry volume at various circulating volume levels.

All the curves follow a similar trend. The curves show higher delays when the entering volume increases. This is reasonable as it becomes much more difficult for the vehicles to enter the roundabout if the number of vehicles entering is higher, for a fixed circulating volume.

C.4.3 Case iii: Variable Circulating Flow

In this case, the entry flow was kept at a certain values and he circulating flow was varied. The delay of entering flow versus the volume of circulating traffic is shown in Figure 5.5 for various entering flows.

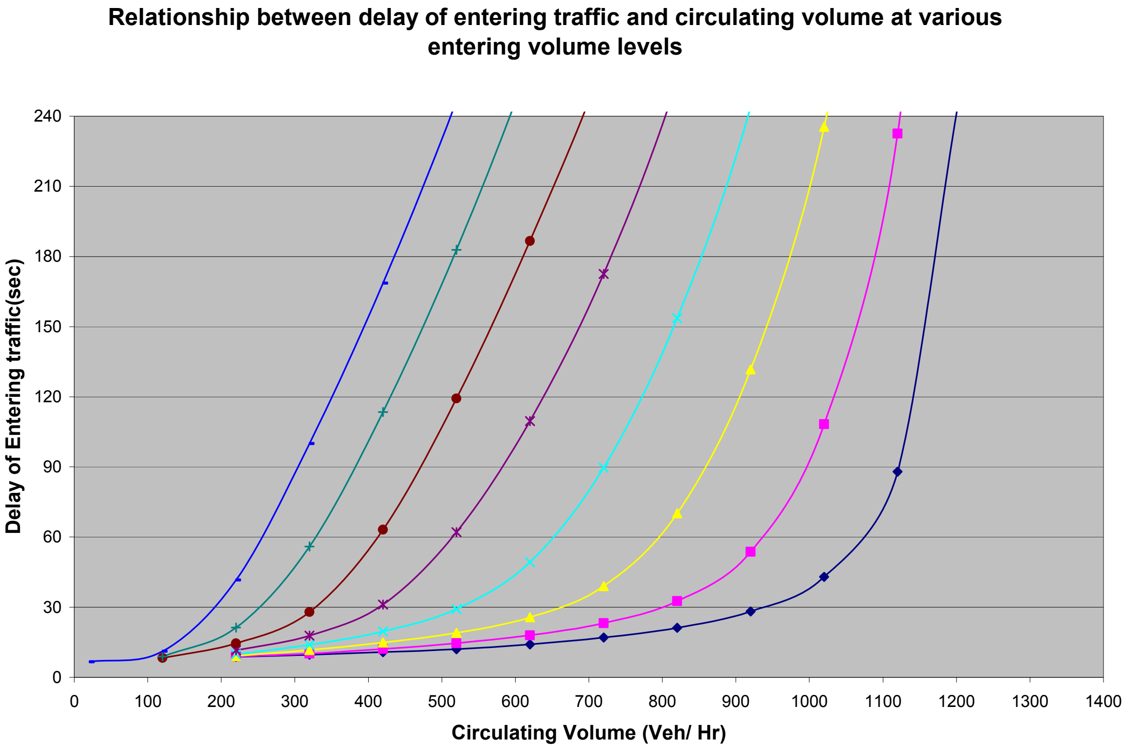

Figure C.5. Relationship between delay of entering traffic and circulating volume at various entering volume levels.

As Figure C.5 shows, initially, the delay of entering traffic increases with the increase in the circulating traffic but after a while, the delay reaches a plateau and does not change even with the increase in the circulating volume. This means, that even if the volume of the circulating flow is increased to higher levels, the delay of entering flow will not be affected after a certain level. This trend does not seem reasonable.

C.5 DELAY CURVE

From the above cases, it was observed that with the increase in the circulating traffic, the entering flow delay increases. Also, the delay of the entering flow increases due to the increase in the entering volume. Thus, a set of curves can be plotted to show points of equal delay for different combinations of circulating and entering flows. Such curves would help determine the number of entering and circulating traffic that yields in a given delay. Alternatively, for a given value of delay one can determine the combinations of entering and circulating volumes that produce such a delay. These curves are shown in Figure C.6

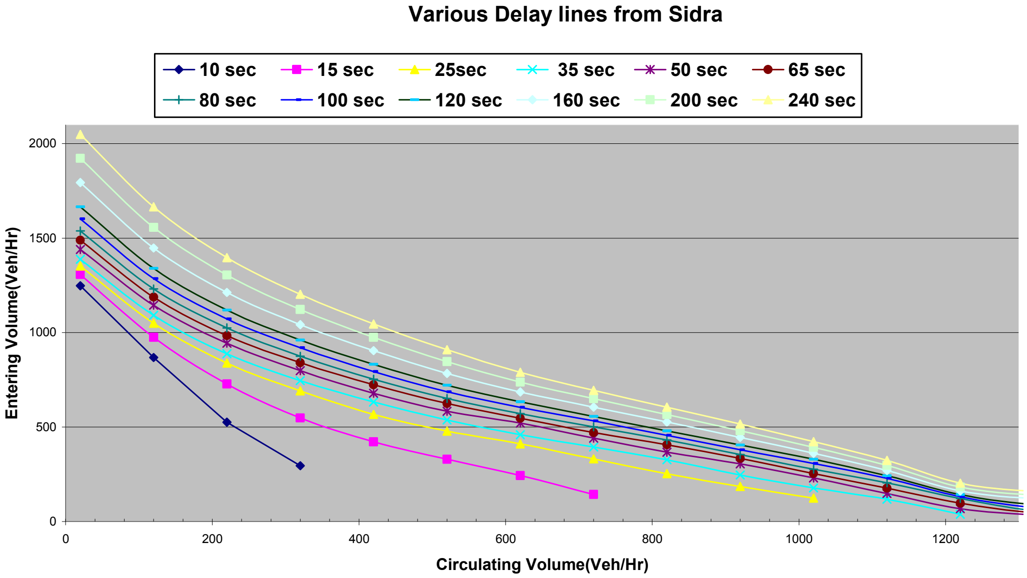

Figure C.6. Various Delay lines from aaSIDRA.

As shown in the graph, for a known delay, one can determine the possible combinations of entering and circulating volumes. These curves will assist in estimating of the number of vehicles that can be processed by the roundabout.

APPENDIX D: REPORT ON RODEL SOFTWARE

D.1 INTRODUCTION

The RODEL software was developed in the United Kingdom, and it is based on empirical regression equations developed by Kimber (1980). The empirical equations are formulated using data from roundabouts in United Kingdom. RODEL can be used to determine the delay for a given roundabout geometry and traffic condition. In addition, when the maximum delay is specified for a given traffic volume, the software gives the geometry that is best suited for the situation. Seven categories of input variables influence the RODEL's output

D.2 INFLUENCING FACTORS

The influential factors that affect RODEL's output are:

i. Geometry
ii. Period of data collection
iii. PCU or vehicle composition
iv. Volume of traffic/ turning flows
v. "Confidence Level"
vi. Flow ratios
vii. Flow times

D.2.1 Geometry

The basic geometric factors that can influence the capacity and delay at the roundabout are:

a. Entry width, E, (ft)
b. Flare length, L', (ft)
c. Approach width (in RODEL is called "Half width"), V, (ft)
d. Entry radius, R, (ft)
e. Entry angle, 2Φ, (degrees)
f. Inscribed circle diameter, D, (ft)
g. Grade separation (Either at grade or not), G.S (0 or 1)

These factors are shown in Figure D.1

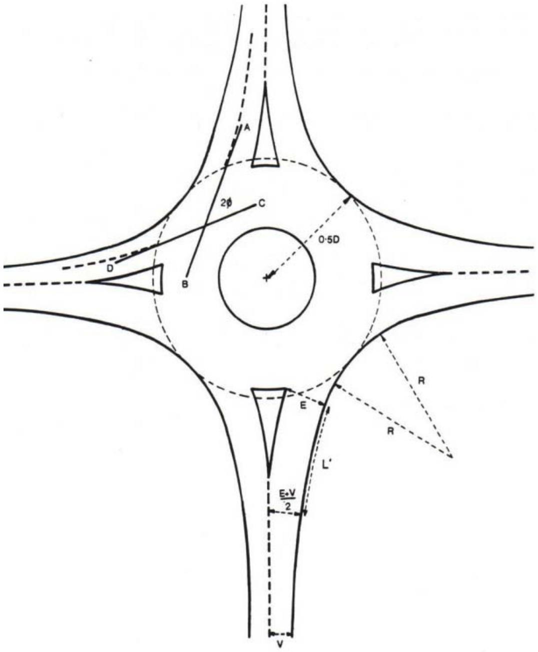

Figure D.1. Geometric Factors used in RODEL (Source: RODEL model (RODEL Software Ltd and Staffordshire County Council))

D.2.2 Period of Data Collection

This is the time spent in the field collecting the data.

D.2.3 PCU

A passenger car unit or PCU is the relative space required for a particular vehicle when compared to a passenger car. The percentage composition of heavy traffic at that intersection does influence the delay and capacity at that intersection.

D.2.4 Volume of Traffic/Turning Movements

Volume of traffic that was processed by the intersection is used as input. It can be measured in units of vph.

D.2.5 Confidence Level

The V/C (volume/capacity) ratio changes when there is a change in flow or capacity of the lane as shown in Figure D.2.

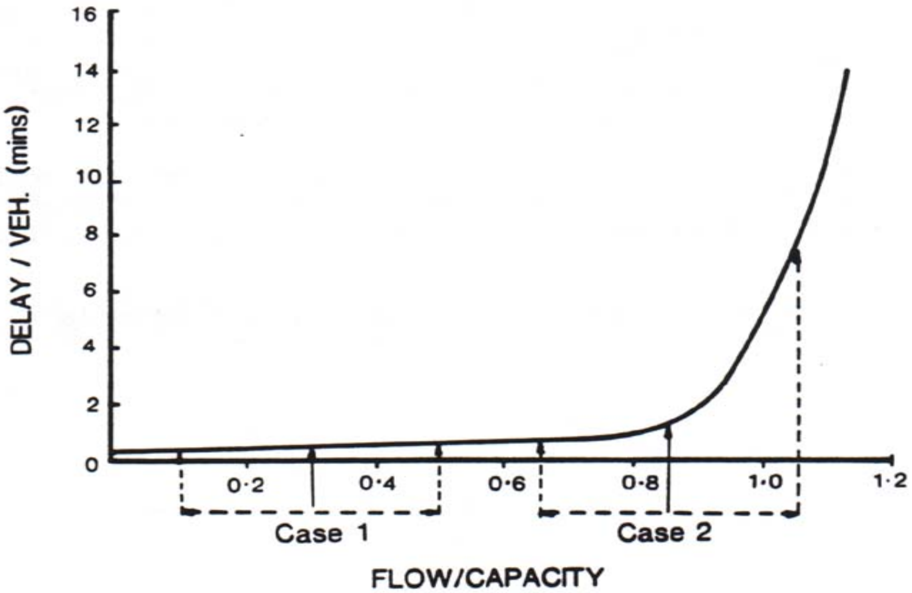

Figure D.2. Delay capacity relationship in RODEL (Source: RODEL model (RODEL Software Ltd and Staffordshire County Council)).

Initially when the flow is less, the V/C ratio does not change much with flow, but after a certain point the curve gets steeper. The per vehicle delay for all V/C ratios at intervals of 0.2 is known. If the V/C falls in between two V/C ratios, the delay corresponding to the V/C left of the value is the minimum delay and that to the right is the maximum delay. For this case when V/C falls in between two known V/C values, two approaches can be used:

1. Arithmetic average of minimum and maximum
2. A weighted average

In terms of “Confidence Level”, a term used in RODEL, approach 1 is “Confidence Level 50%” and approach 2 can have “Confidence Level from 50% to 95%”. As “Confidence Level %” increases, the values of delay get closer to the maximum delay possible (value to the right). The difference between the two approaches is not much when the V/C ratios are small, but for higher V/C ratios the values are different for each approach. By default, RODEL uses arithmetic average (approach 1).

D.3 SCENARIO

The roundabout considered has four entries, and at each entry, the entering traffic conflicts with the circulating traffic. The magnitude of the conflict depends on the volume of circulating traffic and the entering traffic. Four locations within a roundabout can have such conflicts, and one of them would be more critical than the others. The roundabout was tested assuming the critical point is created by the eastbound entry. It would be same for any other entry for the same circulating and entry traffic. Hence a situation was assumed where the traffic is high in just two of the directions and the remaining directions have traffic at a minimum value of 10 vph. As shown below, the southbound through and the Eastbound through are the major movements.

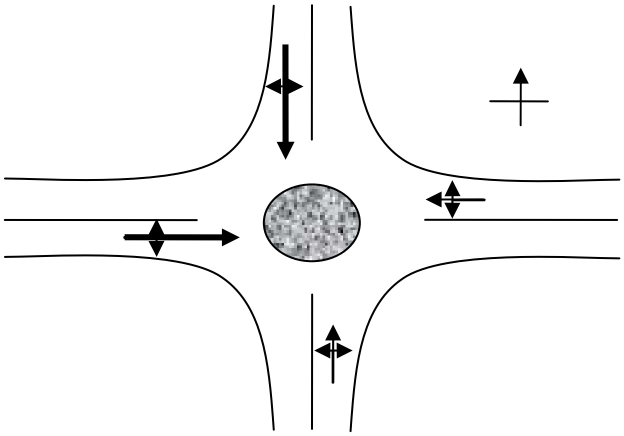

Figure D.3. Main flows are eastbound and southbound.

D.4 VALUES USED

For the analysis purpose, the selected values represent a typical urban compact roundabout.

D.4.1 Geometry

The following values were used for the “typical” roundabout. These values were taken from a general type of roundabout that is used in NCHRP 365.

Table D.1. Geometrical inputs used for RODEL

Geometrical Variables	Assumed values
Entry width (E)	13 ft.
Flare length (L')	40 ft.
Half width (V)	10 ft.
Entry radius (R)	75 ft.
Entry angle (2Φ)	34 degrees
Diameter (D)	100 ft.
Grade separation (GS)	0 (At grade intersection)

D.4.2 Period of Data Collection

Data was collected for 60 minutes.

D.4.3 PCU

It was assumed that there are no heavy vehicles going through the roundabout. Hence PCU = 1.

D.4.4 Turning Flows

In all the scenarios, it was assumed that the traffic is heavy in just two of the movements, the southbound through and the eastbound through. All the other movements were given a minimum value of 10 PCU each.

D.4.5 “Confidence Level”

“Confidence Level” was assumed 50% for the experimental purpose in order to have a perfect correlation between RODEL and aaSIDRA when they are compared. This is because aaSIDRA does not have this option of changing the “Confidence Level” and the default value is 50%.

D.4.6 Flow Ratios

All the flow ratios were assumed unity. This assumption ascertains that there is no fluctuation in the flow.

D.5 EFFECT OF CHANGING VARIABLES

The main goal of the experiment was to determine the effect of circulating traffic at a roundabout on the delay of the entering traffic. A situation was assumed in which all the movements at the roundabout had 10 vph except for the through traffic in the eastbound and southbound approaches. This assumption allows for examination of the effect of circulating flow. This can be done using any corner of a roundabout. In this case, the circulating flow is the southbound through traffic and the entering flow is the eastbound though traffic. The right turning traffic does not often create a critical point.

The following volume combination cases were examined:

Case i: Both the heavy traffic-carrying movements are equal.

Case ii: Constant circulating flow (in our case, increasing entering traffic).

Case iii: Variable Circulating flow (i.e. increasing circulating flow).

Case i: Balanced flow

Case i occurs when both entering and circulating traffic volumes are the same. The volume on both legs is increased simultaneously at an increment of 100 vehicles per hour to see its effect on the delay to the entering traffic (E.B traffic).

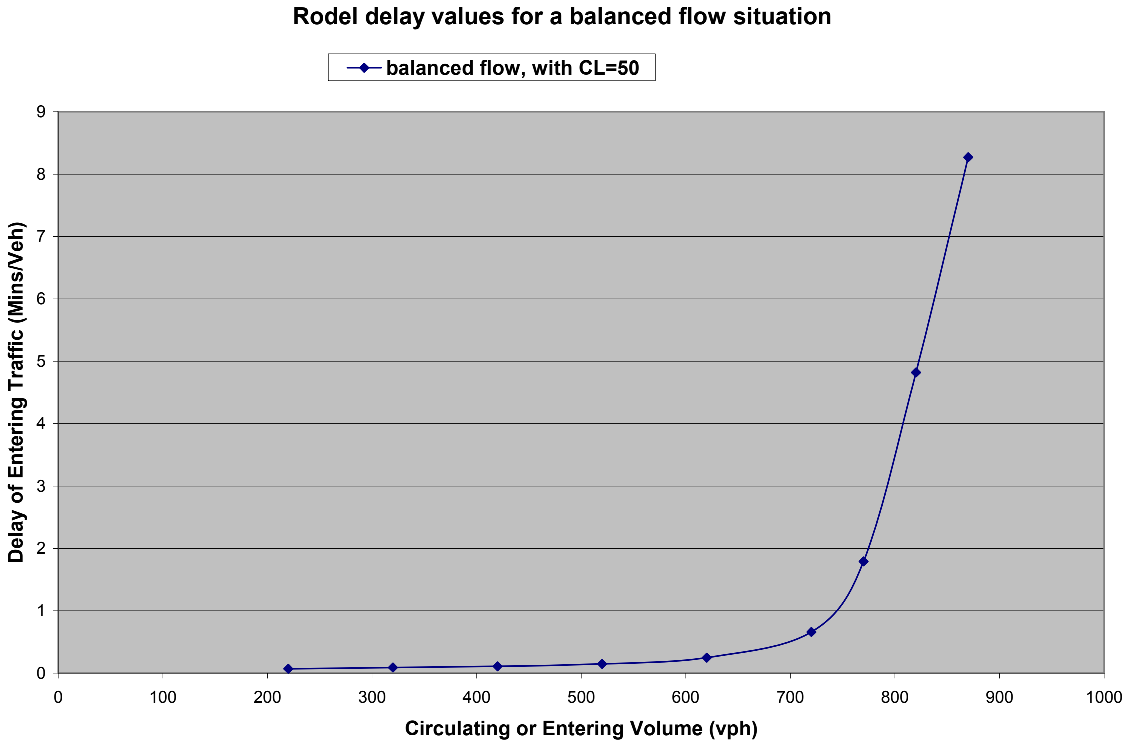

Figure D.4. Delay values for a balanced flow situation.

As shown above, the delay of entering traffic increases with the increase in traffic volumes. The increase in delay is more pronounced beyond the volume of 600 vph. Using this figure, one can determine the volume of traffic that can cause a certain amount of delay. For example, the graph shows that 770 vph circulating traffic and 770 vph cause a 2 minutes per vehicles delay.

Case ii: Constant Circulating Flow

For a fixed value of circulating flow, the delay of entering traffic should increase as entry volume increases. In case ii, several circulating volumes were selected. For each circulating volume, the entering volume was changed and delay to entering traffic was computed. Figure D.5 shows the relationship between entry delay and entry volume for different values of circulating flow.

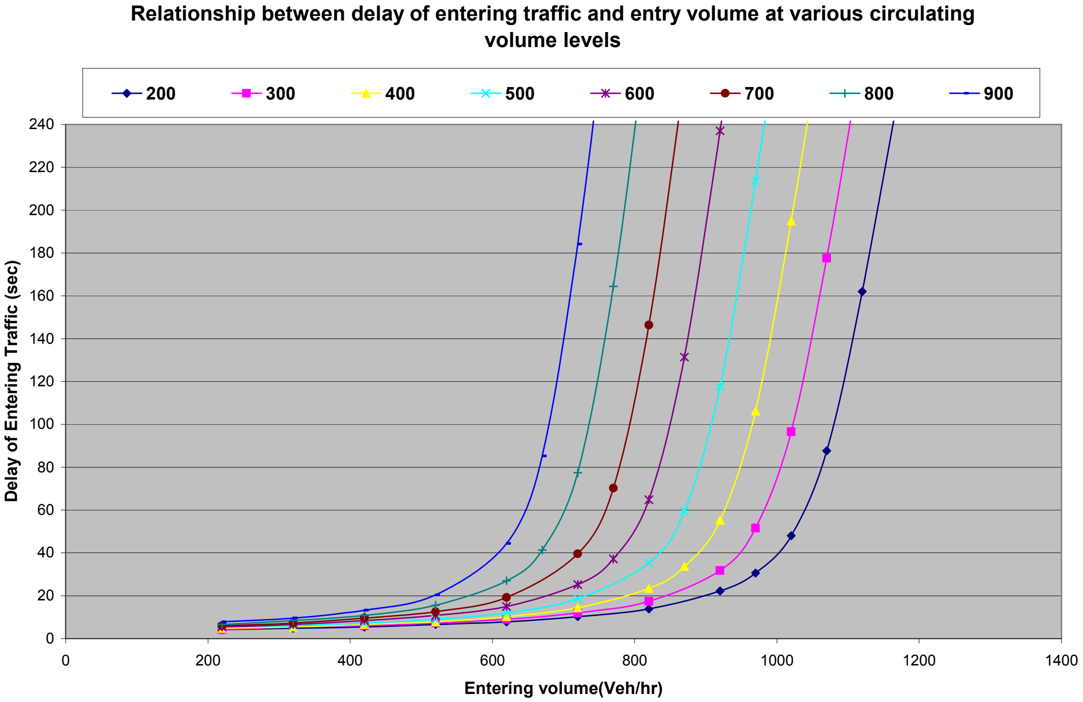

Figure D.5. Relationship between delay of entering traffic and entry volume at various circulating volume levels.

All the curves follow a similar trend. The curves show higher delays when the entering volume increases. This is reasonable as it becomes much more difficult for the vehicles to enter the roundabout if the number of vehicles entering is higher, for a fixed circulating volume.

Case iii: Variable Circulating Flow

In this case, the entry flow was kept at a certain values and the circulating flow was varied. The delay of entering flow versus the volume of circulating traffic is shown in Figures D.6 and D.7 for various entering flows.

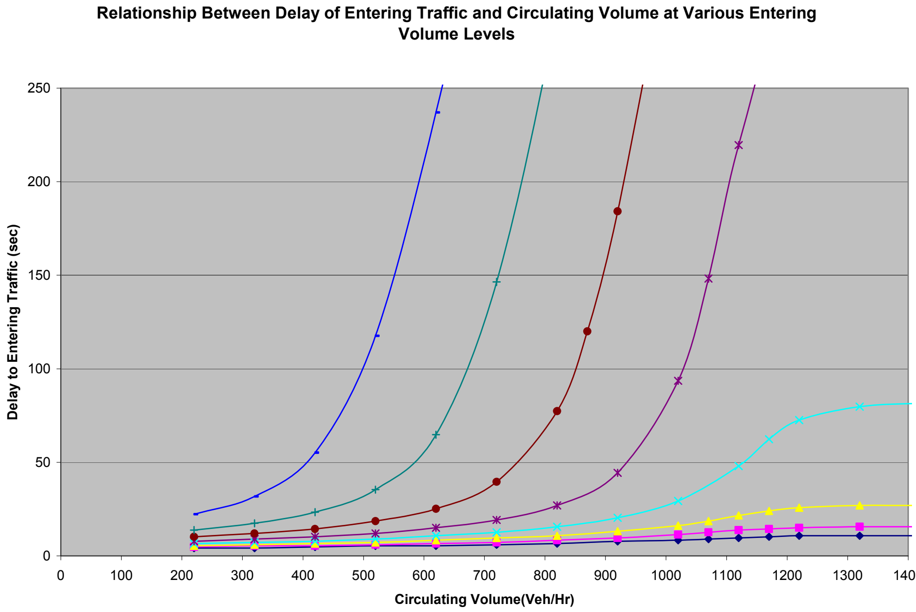

Figure D.6. Relationship between delay of entering traffic and circulating volume at various entering volume levels.

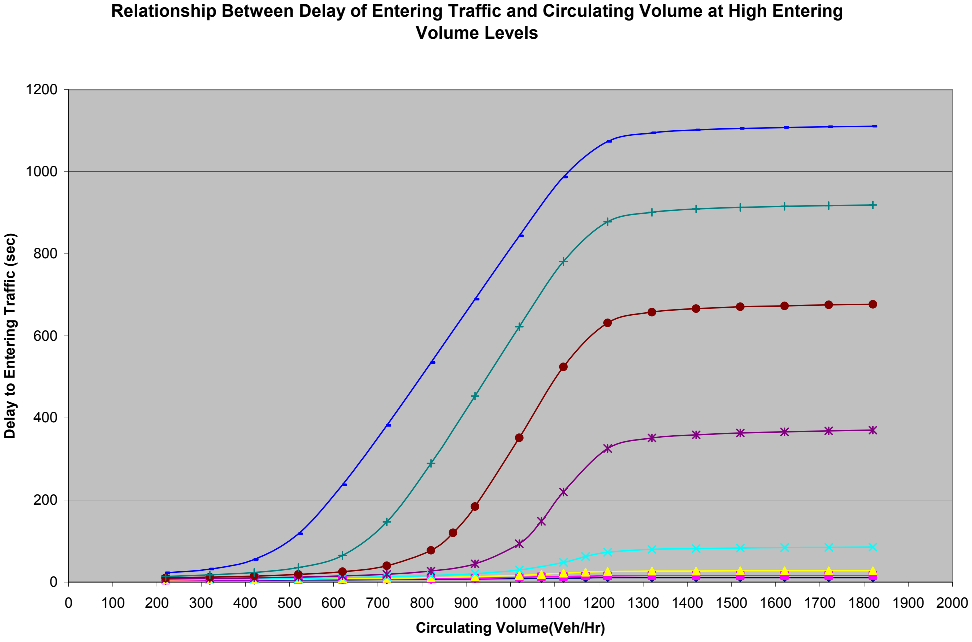

Figure D.7. Relationship between delay of entering traffic and circulating volume at high entering volume levels.

As shown in Figures D.4.6 and D.7, initially the delay of entering traffic increases with the increase in the circulating traffic, but after a while, the delay reaches a plateau and does not change even with the increase in the circulating volume. This means, that even if the volume of the circulating flow is increased to higher levels, the delay of entering flow will not be affected after a certain level. This trend does not seem reasonable.

D.6 DELAY CURVE

From the above cases, it was observed that with the increase in the circulating traffic, the entering flow delay increases. In addition, with the increase in the volume of entering traffic, the delay of the entering traffic increases. Thus, a set of curves can be plotted that show points of equal delay for different combinations of circulating and entering flows. Such curves would help to determine the number of entering and circulating traffic that yields in a given delay. Alternatively, for a given value of delay one can determine the combinations of entering and circulating volumes that produce such a delay. These curves are shown in Figure D.8.

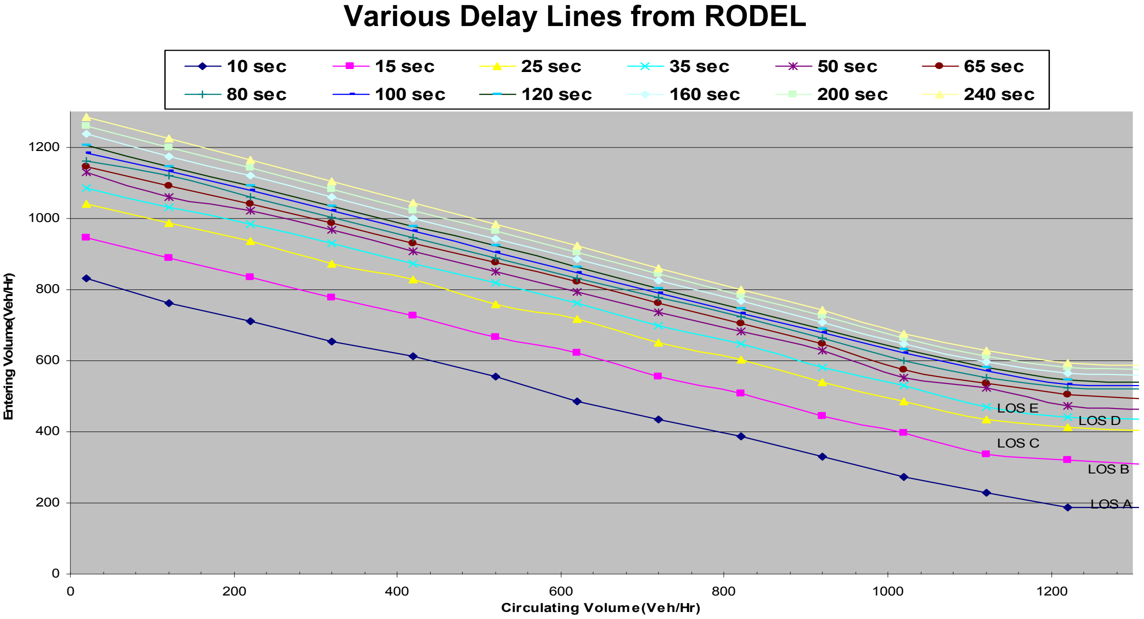

Figure D.8. Various Delay lines from RODEL.

As shown in the graph, for a known delay, one can determine the possible combinations of entering and circulating volumes. These curves will assist in estimating of the number of vehicles that the roundabout can process.

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