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Best Practices for Roundabouts on State Highways

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JOINT TRANSPORTATION RESEARCH PROGRAM

INDIANA DEPARTMENT OF TRANSPORTATION
AND PURDUE UNIVERSITY

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16. Abstract

This report presents a series of research findings from an investigation into roundabout operations. This includes a comparison of several analysis tools for estimating roundabout performance (the Highway Capacity Manual, SIDRA, ARCADY, VISSIM, and SimTraffic); a measurement of rejected headways for the purpose of analyzing critical headway; a review of roundabout lighting practices; and a review of considerations for roundabout site selection. It was found that VISSIM and SIDRA provided the most reliable predictions of roundabout performance for the test site analyzed herein. Additionally, the critical headways measured at this site were significantly lower (at a median value of 2.2 seconds) than other values published in the literature, with driving populations less acquainted with roundabouts. Additionally, a site selection procedure is developed based on a survey of peer agency practices and a checklist is provided for assisting in the determination of whether roundabout control is a feasible alternative for a location. Finally, based upon a review of the literature and practices commonly followed by peer states, we recommend that roundabouts be lighted.

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EXECUTIVE SUMMARY

BEST PRACTICES FOR ROUNDABOUTS ON STATE HIGHWAYS

Introduction

Roundabouts have been increasingly used at intersections in the US over the past 10 years. The benefits of roundabouts include reduced crash severity and improved operations under low to moderate vehicle volumes with balanced demand. Because of these benefits, INDOT policy has been evolving to incorporate roundabouts into its portfolio of options for intersections on state highways. This research project investigated several considerations relevant to agency practice. Various operational analysis tools, including the Highway Capacity Manual methodology and the most commonly used software packages, were compared to see which ones best estimated the actual delay at a real-world roundabout. Gap rejection times were also measured at this roundabout to investigate whether the typical design values for roundabout operational analysis are representative of how traffic actually performs at roundabouts in Indiana. Finally, reviews of peer state practices on roundabout lighting and decisions on intersection treatments were conducted in order to recommend practices for use in Indiana.

Findings

The performance of a real-world roundabout (Spring Mill Road and 106th Street in Carmel, Indiana) was investigated in detail. Several different technologies were deployed at this intersection in order to analyze traffic performance. Bluetooth MAC address sensors were used to measure travel times across the four legs of the intersection, enabling the measurement of delay for each movement. Wireless magnetometers were installed at the approaches and in the circulating roadway of the roundabout in order to measure gaps and the behavior of drivers at the yield lines.

The delay measurements were used to compare several different analysis methodologies for estimating roundabout performance. VISSIM, SIDRA, ARCADY, SimTraffic, and the Highway Capacity Manual (HCM) were the methodologies under comparison. It was found that VISSIM and SIDRA yielded the most reliable results, while ARCADY had a tendency to slightly underestimate the delay, and SimTraffic and the HCM did not yield realistic delay estimates for the peak periods.

Over 45,000 rejected gaps were measured using the wireless magnetometer detector configuration. The observed headways were found to be substantially lower than the suggested values of critical headways that have been observed at a national headway. While these results are based on a single roundabout and a broader set of observations would be needed to make more general conclusions, the results suggest that critical headways are likely reduced as driving populations become more accustomed to roundabouts. For performance analyses intended for 20-year horizons, it is questionable whether longer headways based upon relatively new roundabouts with unfamiliar driving populations are the best representation of how motorists will drive the roundabout throughout its design life.

Fourteen states were identified as having explicitly stated lighting policies for roundabouts available in policy documents that were available online. Of these, nine states required roundabout lighting, four recommended it, and one stated that lighting was "warranted." Based upon these findings, it is clear that the consensus among peer state agencies is that roundabouts should be lighted.

Finally, a review of peer state practices on site selection for roundabouts was conducted. Based upon a review of the criteria or considerations mentioned in the policy documentation and/or guidelines published by these peer states, a checklist of considerations was developed for use in the state of Indiana. This checklist is set up to identify favorable or unfavorable circumstances for roundabout deployment, and to encourage mitigation of problematic factors as early as possible in the planning process.

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1. PROJECT OVERVIEW

1.1 Introduction

The use and acceptance of roundabouts has increased substantially in the US over the past decade. Roundabouts are known to decrease crash severity and under low to moderate volumes often have less control delay than other types of intersection control. Because of these benefits, INDOT policy is evolving to consider roundabouts as a default option for intersection control when an intersection warrants control beyond traditional signs or flashers. This research project was initiated to improve agency understanding of roundabout operations and the set of tools available to estimate roundabout performance for planning and design, as well as to develop a mechanism for determining when roundabouts are an appropriate control mechanism for an intersection.

1.2 Research Results Dissemination

During the course of this research, five presentations, papers, and/or technical memoranda were produced. This final report is a synthesis of these individual findings. The source materials have been included as five appendices to this report:

- **Appendix A:** Hainen, A. M., et al. "Analysis of Roundabout Analytical Models During Unbalanced Flows Using Bluetooth MAC Address Matching." Presented at the Third International Conference on Roundabouts, Carmel, Indiana, May 19, 2011.
- **Appendix B:** Hainen, A. M., A. D. Davis, S. M. L. Hubbard, T. Wei, C. M. Day, and D. M. Bullock. "Field Validation of Roundabout Delay Models Using Probe Data." Working Paper. August 1, 2011.
- **Appendix C:** Hainen, A. M., E. M. Rivera-Hernandez, C. M. Day, M. T. McBride, G. Grimmer, A. J. Loehr, and D. M. Bullock. "Roundabout Critical Headway Measurement Based on High-Resolution Event-Based Data from Wireless Magnetometers." Transportation Research Board Annual Meeting, Paper No. 13-3316, 2013.
- **Appendix D:** "Roundabout Lighting Review." Technical Memorandum, September 21, 2012.
- **Appendix E:** "Roundabout Site Selection." Technical Memorandum, February 14, 2013.

2. PROBLEM STATEMENT

In recent years, roundabouts have been increasingly used for intersection control in the US. A number of benefits of roundabouts are now widely recognized, including their ability to reduce accident severity and to improve intersection performance in the appropriate volume regime, especially as an alternative to four-way stop control (4WSC) or high-accident signalized intersection control. However, engineering experience with roundabouts in the US is still developing and there are several areas where more knowledge is needed.

- There has not been enough time for engineers to develop substantial experience with modeling and simulation software to understand the accuracy with which they can predict roundabout performance. There is, for example, an ongoing debate on whether a British model, based upon regression analysis of several decades of data, or an Australian model, based upon traffic flow theory, produces "better" results. The arguments in this debate are mostly opinion-driven and insubstantial.
- Delay prediction accuracy in relation to volume-to-capacity ratio is a concern. The values of delay or LOS obtained vary significantly depending on the analysis tool utilized.
- The gap-acceptance values for analyzing roundabout performance, as would be used in certain analysis models and in simulation programs, are largely based upon relatively new roundabouts in population areas where the concept of a roundabout is relatively new. There has been little data collected from the perspective of a motorist population that is familiar with driving roundabouts as in Carmel, Indiana.
- The existing literature on roundabouts overwhelmingly focuses on the benefits of roundabout control. The types of traffic conditions wherein roundabouts are unlikely to work well are not well characterized.

The purpose of this research project is to develop a knowledge base for the planning and operation of roundabouts in the State of Indiana. In this project, the above mentioned gaps in the knowledge have been explored and some new results generated that would have interest to the greater transportation engineering community. To accomplish this, new data sets were leveraged that, at the inception of this project, had never before been used in a roundabout context. These technologies are Bluetooth MAC address matching for measuring travel times and the use of wireless magnetometers to measure gap acceptance.

3. SUMMARY OF FINDINGS

Several findings were obtained during this research project, which are organized here according to the instrument where they were disseminated. This section provides an overview of the findings while more detailed results can be found in the five appendices at the end of the report.

3.1 Analysis of Roundabout Analytical Models During Unbalanced Flows Using Bluetooth MAC Address Matching

In May 2011, the Third International Conference on Roundabouts (organized by the Transportation Research Board) was held in Carmel, Indiana. This conference occurred shortly after the beginning of the research project and was an opportunity to share early research results and interact with the international research community. As of May, early field data collection activities consisted of the collection of travel times using Bluetooth MAC address matching (*1*) across the four approaches at Spring Mill Road and 106th Street in Carmel, Indiana (Figure 3.1). In this study, four data recorders (Figure 3.2) were located at

Figure 3.1 Aerial view of Spring Mill Road and 106th Street. (Source: Google Earth.)

the four approach legs of the intersection to read the MAC addresses of cell phones or other Bluetooth-enabled electronic devices being carried in vehicles. The travel time from one location to another was then extracted by comparing the log times at each data collector. From this it was possible to calculate the delay experienced for each movement at the intersection. Five days of data were obtained from five consecutive weekdays. At the same time, vehicle volumes were obtained from tube counters on the approaches. Turning movement volumes were developed based on the proportion of turns observed in the travel time data, and were balanced to match the approach volumes obtained from the tube counters on the approaches.

This data was used to compare against the 2010 Highway Capacity Manual (HCM) (*2*) delay estimates based upon the volume data. These results are shown in Figure 3.3. During most of the day, delay at the roundabout is rather low. However there are rather significant delays during the AM and PM peaks for different movements. The HCM model provided a reasonable estimate for the northbound delay (Figure 3.3a), while the others were either overestimated (Figure 3.3c) or underestimated (Figure 3.3d). Some of this error may have been due to the unbalanced flow characteristics of the intersection, but the HCM also notes specifically on page 21-5 that their observed data was immature and insufficiently assessed the relationship with driver familiarity. The results suggest a need for refinement of the HCM model or closer examination of more field observations, especially where experienced drivers exist, as later conducted in this study.

The presentation given at the conference is included in Appendix A.

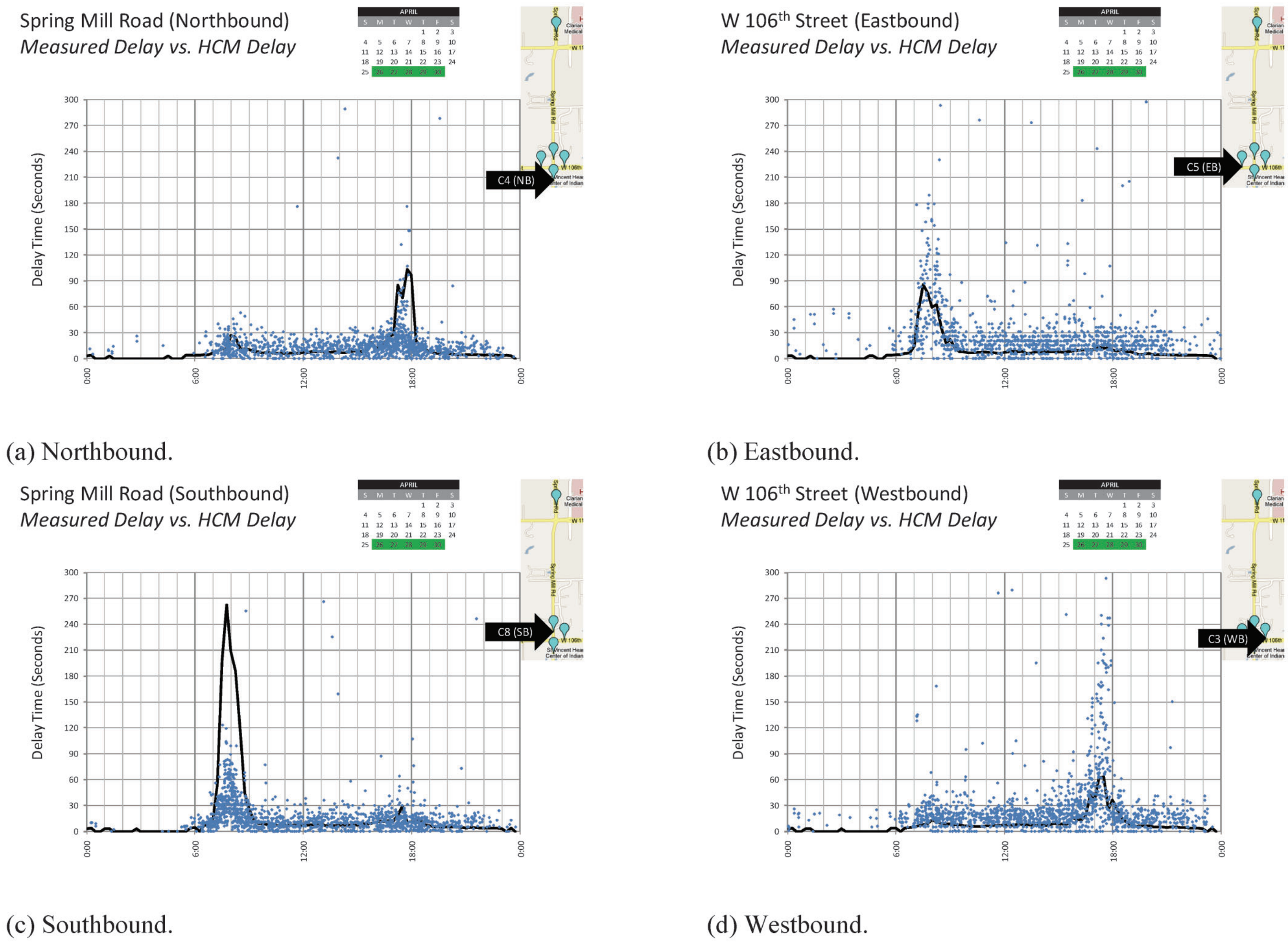
Figure 3.2 Portable Bluetooth cases.

3.2 Field Validation of Roundabout Delay Models Using Probe Data

Using the same data set as presented at the conference, several additional roundabout analysis tools were tested to find how well they predicted the delay experienced at the roundabout:

- The 2010 Highway Capacity Manual (HCM);
- SIDRA Intersection, an intersection analysis software package marketed by Akcelik & Associates (Australia);
- ARCADY, a roundabout analysis software package marketed by TRL (UK);
- VISSIM, a microscopic simulation software package marketed by PTV (Germany); and
- SimTraffic, a microscopic simulation software package marketed by TrafficWare (US).

15-minute volumes obtained from the procedure described in the previous section were entered into these



(a) Northbound.

(b) Eastbound.

(c) Southbound.

(d) Westbound.

Figure 3.3 Measured versus modeled delay at Spring Mill Road and 106th Street.

software programs and compared against the median 15-minute measured delays. Sample results are shown for the southbound approach in Figure 3.4 and for the eastbound approach in Figure 3.5. A glance at the results from these two figures reveal that most of the analysis tools are more successful for one of the approaches and less successful for another. The overall results are shown in Figure 3.6.

During the off-peak periods, each model successfully predicted the lack of delay. This is of course unsurprising; the peak periods are where the discrepancies appear. Peak hour accuracy is paramount, as design projects are typically developed via peak hour analysis results. The VISSIM model had perhaps the best performance during the peak periods, with the exception of the AM peak period for the Eastbound approach (Figure 3.5). SIDRA also had only one substantial outlier, the Southbound approach (Figure 3.4). The other software programs performed less well. ARCADY tended to underestimate delay; the results for the HCM were similar to those explored in the previous study; and SimTraffic tended to either greatly overestimate the delay or completely miss the peaks.

The complete results of the study are available in Appendix B.

3.3 Roundabout Critical Headway Measurement Based on High-Resolution Event-Based Data from Wireless Magnetometers

This study used detailed detector data to investigate the "critical headway" for gap acceptance, a value that is important for roundabout design. The intersection of Spring Mill Road and 106th Street was instrumented with a series of wireless magnetometers (Figure 3.7) that were installed at locations shown in Figure 3.8. Arrays of detectors were used to measure vehicles arriving and departing on the four approaches; detectors were used at the yield lines and in the circulating roadway to measure vehicle gaps and to tell whether each gap was accepted or rejected. Video was recorded during the study period to validate the gap measurement methodology. Full details are contained in Appendix C.

This study involved an unprecedented amount of data for gap measurement. Over 260,000 entering

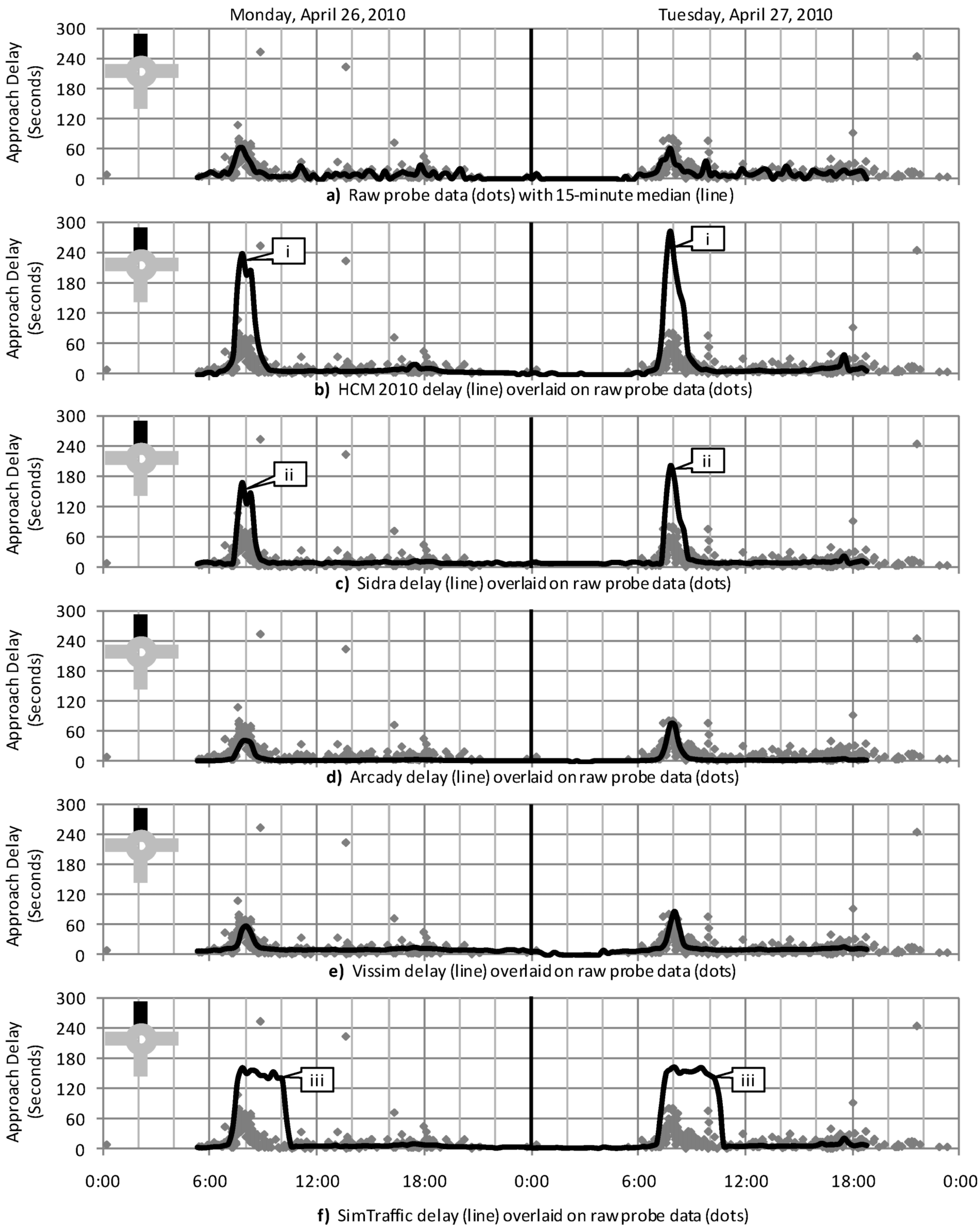


Figure 3.4 Comparison of field measured data and model prediction for 15-minute delay periods for Ssouthbound approach.

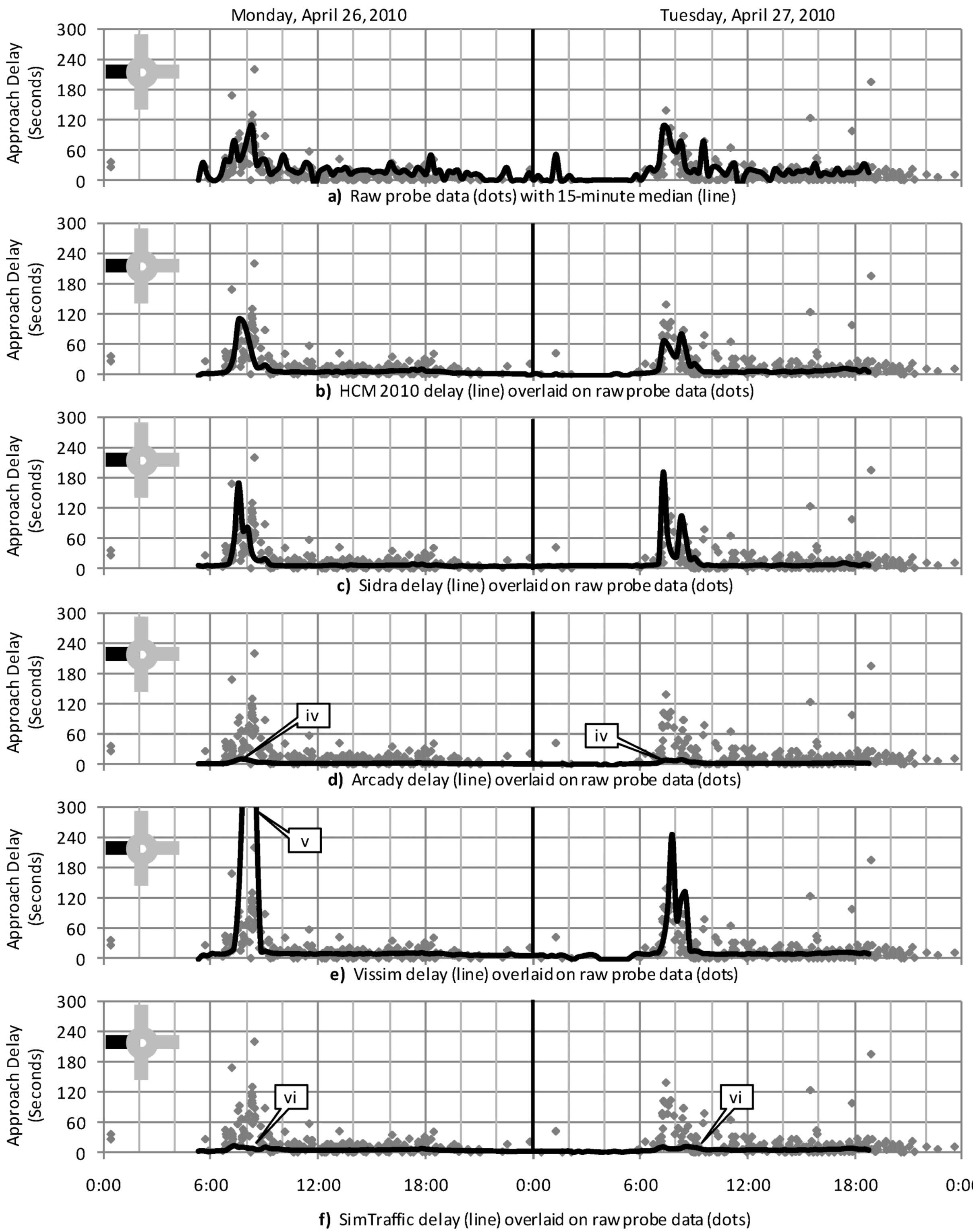


Figure 3.5 Comparison of field measured data and model prediction for 15-minute delay periods for eastbound approach.

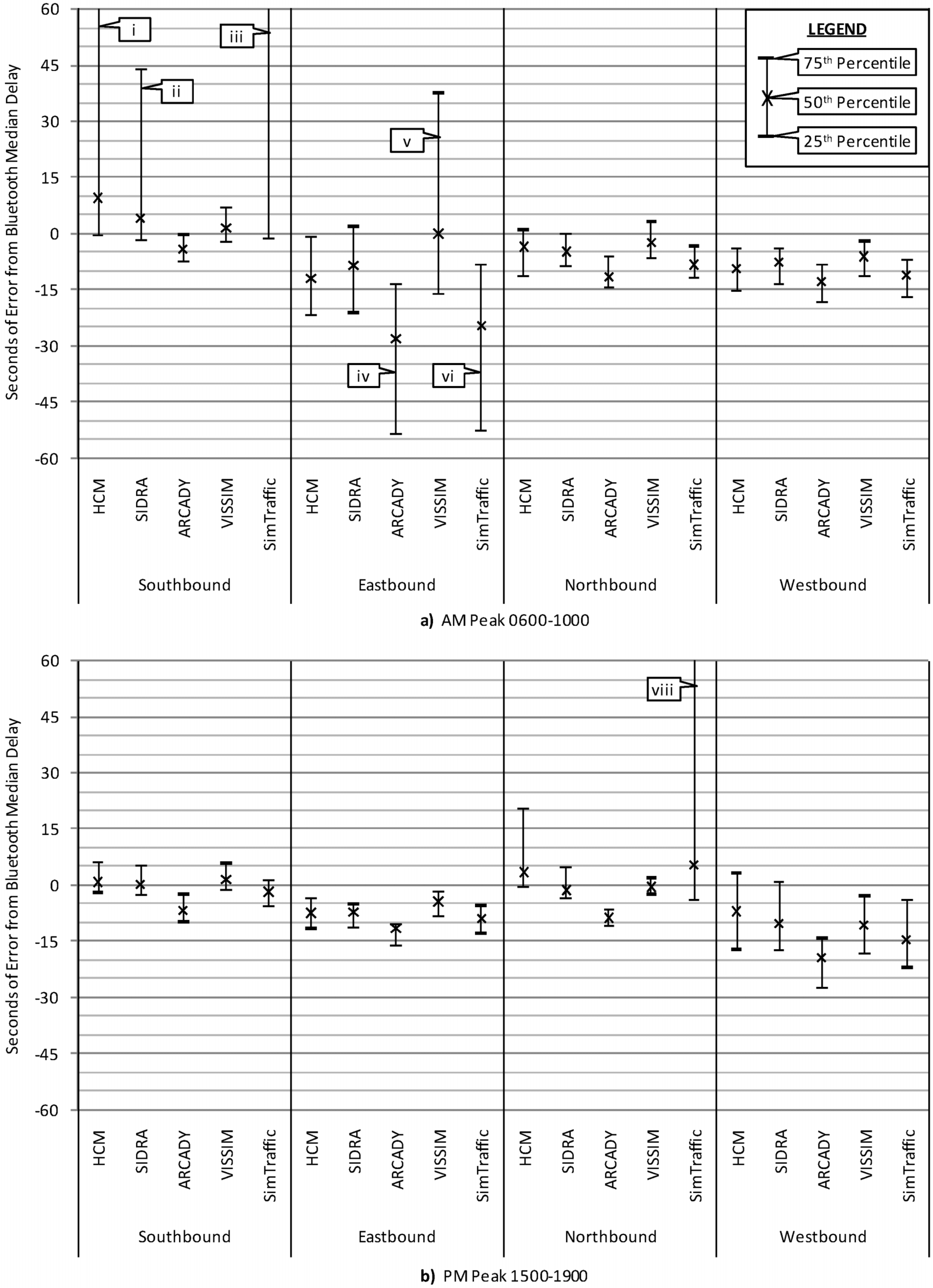


Figure 3.6 Quartile difference in time for peak periods between median of measured field delay and predicted delay from models.

(a) Core drill the hole for the sensor
(b) Clear the hole and remove asphalt core
(c) Remove debris
(d) Torch dry the hole for epoxy
(e) Place the magnetometer and epoxy in place
(f) Finished installation at yield line

Figure 3.7 Installation of wireless magnetometer for entering vehicle.

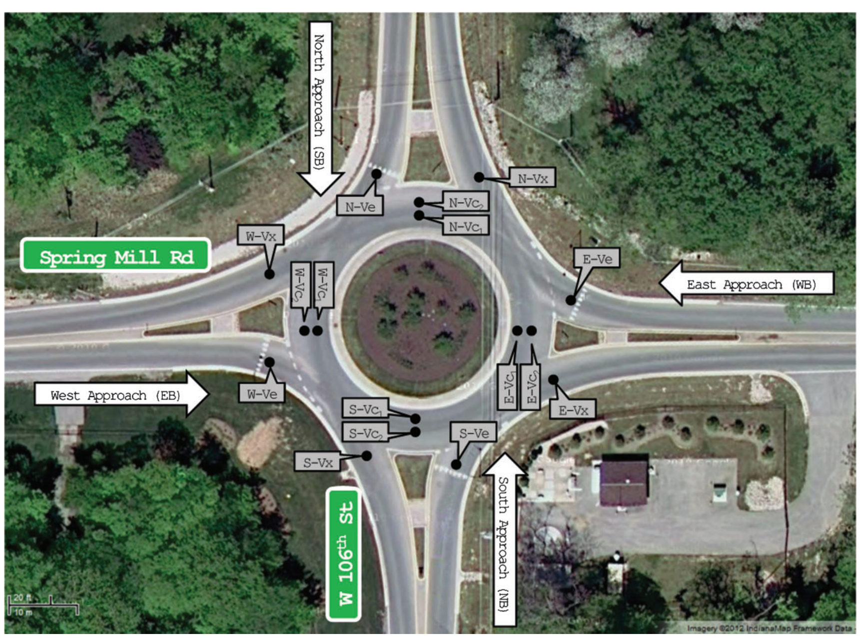
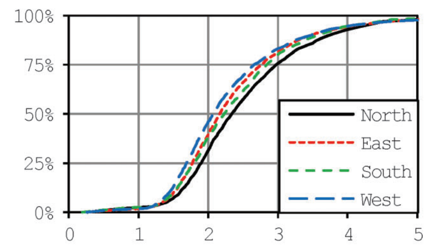
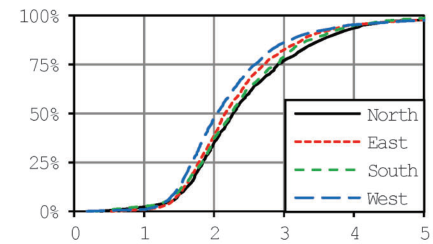


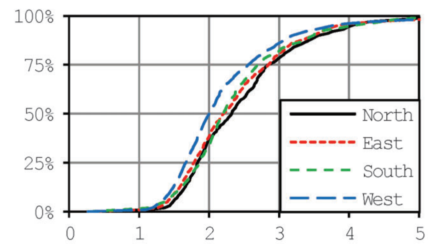
Figure 3.8 Installation of wireless magnetometers at Spring Mill Road and 106th Street.



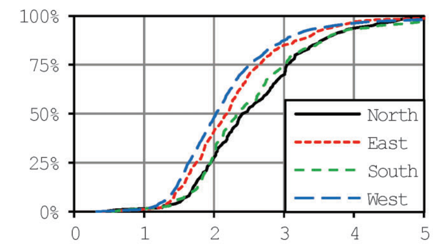
(a) Headway 2 rejection times (sec)



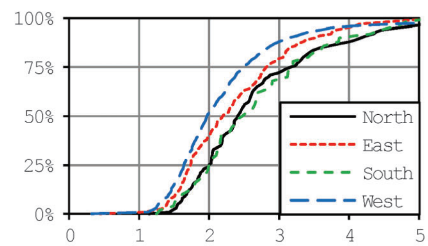
(b) Headway 3 rejection times (sec)



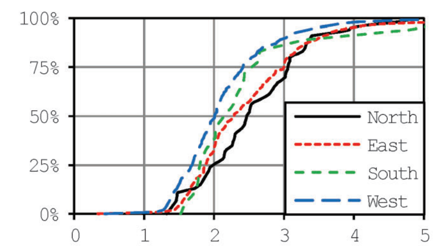
(c) Headway 4 rejection times (sec)



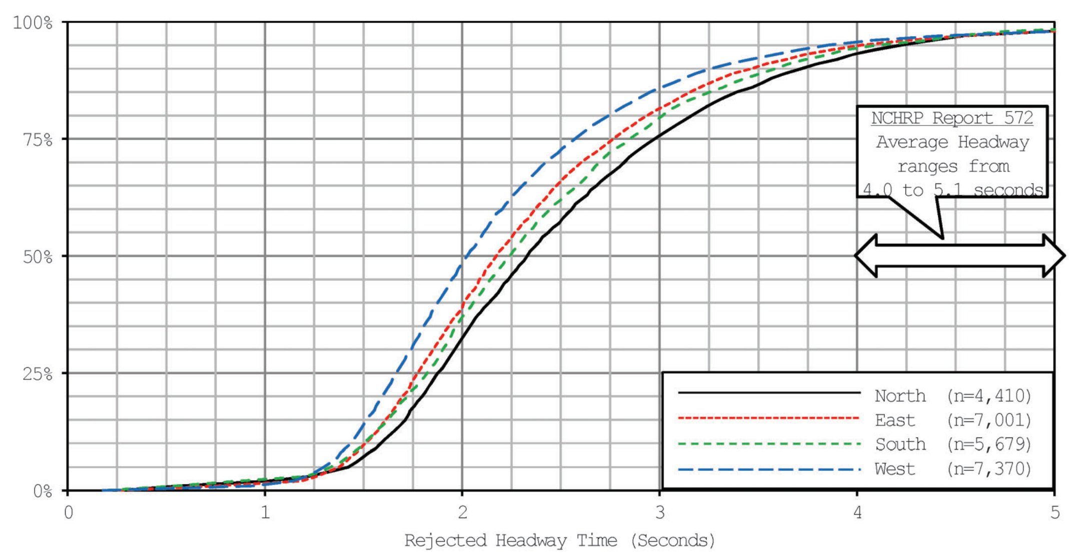
(d) Headway 5 rejection times (sec)



(e) Headway 6 rejection times (sec)



(f) Headway 7 rejection times (sec)



(g) Headway 2 through headway *n*

Figure 3.9 Distribution of headway rejection times.

vehicles were observed, and over 45,000 rejected headways were analyzed. A headway was rejected when a vehicle was stopped at the yield line and had to wait for multiple vehicles in the circulating roadway. Each rejected gap (*i.e.*, where the stopped vehicle did not proceed) between vehicles was measured from the difference between the time of detection between the two vehicles defining the beginning and end of the gap. 75% of the rejected headways were less than 3 seconds, which is substantially less than the recommended critical headway values reported in the literature (*3*). At the test intersection, which is located in a community with experienced roundabout drivers, the median critical headway was 2.2 seconds and the 75th percentile was 2.8 seconds. Cumulative frequency diagrams of the rejected gaps are shown by approach in Figure 3.9. The results also show that, as the number of subsequently rejected headways increases, the more likely a driver is to accept a smaller gap. This is as expected—the longer a motorist waits, the less patient they become.

The results of this study are significant because the observed critical headways were much lower than the numbers that would typically be used for default designs. The 20-year design life being analyzed for a roundabout feasibility study will probably operate under similar conditions, as the population will likely become accustomed to roundabout driving during the design life. Although additional measurements should probably be taken at other locations to account for the impact of approach geometry (particularly multi-lane roundabouts), the results suggest that the critical headway values used for design purposes should be reevaluated.

3.4 Roundabout Lighting Review

During interactions with INDOT engineers and others during the course of this research, the question was raised what the consensus was on the lighting requirement for roundabouts. To discover whether there was such a consensus, a review of state practice with regard to roundabout lighting was conducted. An attempt was made to find a lighting policy from every state. In total, 14 states had explicitly stated policies existing in design manuals, lighting manuals, or other such policy documents that were available for download on the internet. Of these, nine states *required* lighting, another four *recommended* it, and one states that lighting was *warranted.* From this, it is concluded that the consensus on this topic is that roundabouts should be lighted. The results are shown in Table 3.1; further details can be found in Appendix D.

TABLE 3.1
US States with roundabout lighting policies found in this search

State	Roundabout Lighting Practice
Colorado	Warranted
Delaware	Required
Florida	Required
Georgia	Required
Illinois	Recommended
Kansas	Required
Kentucky	Required
Maryland	Required
Michigan	Recommended
Minnesota	Recommended
New Hampshire	Required
New York	Recommended
Washington	Required
Wisconsin	Conditionally required

3.5 Roundabout Site Selection

One of the desired outcomes from this research study was to develop a method for determining whether roundabout control is a feasible option for a site. A list of considerations was developed based on input from INDOT engineers during a workshop and in a review of the state of the practice from a survey of national and state level guidance documents. From this, a variety of site selection criteria were developed and organized into various categories. Table 3.2 shows the list of criteria. Each row represents a set of site conditions that belong under a particular category, the type of data needed to perform the analysis, and whether those conditions are favorable or unfavorable for roundabout control.

From this table, a checklist was developed for site analysis (Figure 3.10) that incorporates the site considerations and a comparison to control alternatives. The philosophy behind this checklist is the construction of a roundabout should be based on some circumstances that are favorable to its deployment. There should also be no unfavorable circumstances, or these should be mitigated, and the need for such measures should be incorporated into the roundabout design at the planning stage. The checklist takes both life cycle costs and construction costs into consideration. If there is not sufficient budget to construct the roundabout, then its construction is not considered feasible. Life cycle costs, including user benefits of all modes, maintenance, energy cost, and so forth are considered in the consideration of alternatives.

For example, many intersections on state highways have neighboring driveways that may have to be removed or relocated for the implementation of a roundabout; this factor would be taken into account first when considering the *functionality* of the roundabout (e.g., whether the driveway can be feasibly accommodated), as well as the *constructability* of the roundabout (e.g., whether driveway relocation introduces considerable cost).

Appendix E provides additional details on the site selection procedure.

TABLE 3.2
Synthesis of selection criteria

	Data Required	Favorable Conditions for Roundabouts	Unfavorable Conditions for Roundabouts
Safety	Intersection/roadway crash history Approach speeds Roadway geometry Local traffic characteristics	History of safety problems On problematic roadway alignment and cannot be relocated Transition between two different speed zones is desired	High pedestrian or bicycle traffic Hearing or visually impaired pedestrian traffic Railroad crossings are in close proximity Intersection skew will produce poor roundabout geometry and additional ROW to improve alignments cannot be acquired
Functionality	Proposed site terrain Local land use Distances to neighboring intersections Roadway geometry, locations of bridges Local traffic characteristics	Low truck traffic Traffic calming is desirable Transition between two different types of land-use areas is desired Will provide a desired community "gateway" Will replace AWSC (crossing roadways have similar priority/functional class) Heavy left turns or U-turns are anticipated Simplifies complex intersection geometry (4+ approaches, etc.) There is an access management need on the roadway(s)	High truck traffic Steep grade or difficult terrain Reversible lanes are used Adequate geometry for circulating roadway and approaches cannot be provided One crossing roadway has very heavy traffic compared to the other (dissimilar priority/ functional class) Nearby intersections will generate queues that would spill into the roundabout In the middle of a coordinated signal system Existing site features transit facilities, parking, or driveways that cannot be relocated
Performance of Roundabout	Design period volume Growth factors for 20-year horizon Pedestrian and bicycle volumes (if applicable) Performance analysis	Roundabout does not suffer undesirable capacity deficiencies over the design life (20 year horizon) Roundabout level of service/delay performance is satisfactory	Roundabout suffers undesirable capacity deficiencies over the design life (20 year horizon) Roundabout level of service/delay performance is unsatisfactory
Performance of Alternatives	(Same data as above step) Performance analysis of roundabout and alternative intersection designs	Roundabout provides better performance (life cycle cost) than alternatives	Roundabout does not provide better performance (life cycle cost) than alternatives
Maintenance	Site characteristics Agency maintenance contracts or procedures	Existing power facilities exist to provide for lighting Existing contracts or procedures exist to provide for landscape maintenance	Terrain problematic for adequate drainage of circulating roadway Difficulty in obtaining power to provide lighting Difficulty in obtaining landscape maintenance
Cost/Constructability	Sketch design Knowledge of right-of-way and utilities impacted Historical unit costs Desired budget for intersection improvement	Construction cost is feasible	Construction cost is unfeasible (e.g., substantial ROW acquisition costs, utility relocation, driveway relocation, earth movement, etc.)

Roundabout Planning Checklist

		Favorable Conditions		Unfavorable Conditions
Safety	☐	History of safety problems	☐	High pedestrian or bike traffic
	☐	Problematic roadway alignment	☐	Impaired pedestrians
	☐	Transition between speed zones	☐	Railroad crossings in close proximity
			☐	Unsatisfactory approach geometry
Functionality	☐	Low truck traffic	☐	High truck traffic
	☐	Traffic calming desired	☐	Steep grade
	☐	Transition between land use areas	☐	Reversible lanes
	☐	Replacement of AWSC	☐	Difficult terrain for geometry
	☐	Heavy left turns or U-turns	☐	Dissimilar functional class roadways
	☐	Simplifies intersection geometry	☐	Nearby intersection queues
	☐	Access management	☐	Amid coordinated signal system
			☐	Problematic site features
Roundabout Performance	☐	Satisfactory v/c ratio	☐	Unsatisfactory v/c ratio
	☐	Satisfactory delay performance	☐	Unsatisfactory delay performance

Comparison with Alternatives	Alternative	Life Cycle Benefit-Cost Ratio
	Existing Intersection (Do-Nothing)	
	Roundabout	

	☐	Satisfactory comparison	☐	Unsatisfactory comparison
Maintenance	☐	Existing power	☐	Power can not be provided
	☐	Existing maintenance contracts	☐	Maintenance cannot be provided
			☐	Drainage problems anticipated

Cost and Constructability		
	Estimated Construction Cost	
	Estimated Construction Budget	

Notes

If no favorable conditions are found, are there any mitigating circumstances that would warrant the installation of a roundabout at this location?

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If unfavorable conditions are found, how will these be mitigated?

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Figure 3.10 Proposed roundabout selection checklist.

4. SUMMARY OF IMPACT

Although the results of this research study have only recently been released, some of the findings may have substantial impact on practice in Indiana and beyond.

- Based on the analysis of operations at Spring Mill Road and 106th Street, the comparison of software packages suggests that VISSIM and SIDRA provide reliable results for estimating single-lane roundabout performance (Figure 3.6). The HCM procedure and SimTraffic did not reliably predict the delay during peak periods, while ARCADY had a tendency to underestimate the delay.
- From the measurement of 45,000 rejected gaps at Spring Mill Road and 106th Street, the observed critical headways for a single-lane roundabout were found to be substantially lower than the values observed at a national level (*3*). Although it is perhaps premature to reduce critical headways based upon a single site, the results suggest that as driving populations become accustomed to roundabouts, critical headways are reduced. Therefore, for performance analyses for 20-year life cycle studies, it is questionable whether relatively long critical headways based upon rather new roundabouts in new regions are the best representation of how motorists will be driving the roundabout throughout its design life.

Clearly, roundabout performance characteristics and modeling practices are continuing to evolve and mature in the US. With regard to values such as critical headway, we can draw parallels with the evolution of saturation flow rate—a nominal value of 1800 veh/h (two seconds per vehicle) was used from about the time of Bruce Greenshields' work in the 1940s (*4*), up until the 1980s when a default value of 1900 began to be used. As driver experience with roundabouts in the US continues to increase, there will be a need to update performance models accordingly.

Future work would include the investigation of how headway acceptance changes during different weather conditions, as well as to investigate alternative site geometries to assess the impact of geometric design. The performance of multi-lane roundabouts and roundabouts with high-speed approaches also would be desirable to assess. Finally, it would be worthwhile to assess operations in different communities to fully determine whether differences in driver behavior translate into operational effects.

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APPENDIX A. ANALYSIS OF ROUNDABOUT ANALYTICAL MODELS DURING UNBALANCED FLOWS USING BLUETOOTH MAC ADDRESS MATCHING

http://docs.lib.purdue.edu/cgi/viewcontent.cgi?filename=0&article=3035&context=jtrp&type=additional

APPENDIX B. FIELD VALIDATION OF ROUNDABOUT DELAY MODELS USING PROBE DATA

http://docs.lib.purdue.edu/cgi/viewcontent.cgi?filename=1&article=3035&context=jtrp&type=additional

APPENDIX C. ROUNDABOUT CRITICAL HEADWAY MEASUREMENT BASED ON HIGH-RESOLUTION EVENT-BASED DATA FROM WIRELESS MAGNETOMETERS

http://docs.lib.purdue.edu/cgi/viewcontent.cgi?filename=2&article=3035&context=jtrp&type=additional

APPENDIX D. ROUNDABOUT LIGHTING REVIEW

http://docs.lib.purdue.edu/cgi/viewcontent.cgi?filename=3&article=3035&context=jtrp&type=additional

APPENDIX E. ROUNDABOUT SITE SELECTION

http://docs.lib.purdue.edu/cgi/viewcontent.cgi?filename=4&article=3035&context=jtrp&type=additional

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On March 11, 1937, the Indiana Legislature passed an act which authorized the Indiana State Highway Commission to cooperate with and assist Purdue University in developing the best methods of improving and maintaining the highways of the state and the respective counties thereof. That collaborative effort was called the Joint Highway Research Project (JHRP). In 1997 the collaborative venture was renamed as the Joint Transportation Research Program (JTRP) to reflect the state and national efforts to integrate the management and operation of various transportation modes.

The first studies of JHRP were concerned with Test Road No. 1—evaluation of the weathering characteristics of stabilized materials. After World War II, the JHRP program grew substantially and was regularly producing technical reports. Over 1,500 technical reports are now available, published as part of the JHRP and subsequently JTRP collaborative venture between Purdue University and what is now the Indiana Department of Transportation.

Free online access to all reports is provided through a unique collaboration between JTRP and Purdue Libraries. These are available at: http://docs.lib.purdue.edu/jtrp

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