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FINAL REPORT

A STUDY OF THE EFFECT OF ADA ACCESSIBILITY ON KANSAS ROUNDABOUTS

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November 2008

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16 Abstract

The Access Board, with authority to enforce provisions of the American Disabilities Act (ADA), initially determined that roundabouts are not accessible by blind pedestrians and drafted proposed guidelines to require pedestrian signals at all roundabouts. More recently, the Access Board proposed final guidelines requiring pedestrian signals at all roundabouts with two or more lanes. It is possible that if these guidelines become Federal regulations through the Federal rule making process, and low-cost pedestrian signals are not developed, the growth of roundabouts could diminish greatly throughout Kansas and the USA. This will, in effect, deny motorists and public transportation organizations a safe, cost-effective means of intersection traffic control which potentially could result in many lives not saved and injuries not prevented. It has been projected that when stop controlled and signal controlled intersections are replaced by roundabouts there is a 76% reduction in injury crashes and a projected 90% decrease in fatalities. Kansas has been a national leader in design and construction of roundabouts and Kansas motorists would suffer a loss of these safety benefits if roundabout growth were slowed or halted. Roundabouts also have proven benefits in reduction of intersection delay and stopping as well as reduction in air pollution. These benefits could be lost or diminished as well.

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A Report on Research Sponsored By

THE KANSAS DEPARTMENT OF TRANSPORTATION
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PREFACE

The Kansas Department of Transportation's (KDOT) Kansas Transportation Research and New-Developments (K-TRAN) Research Program funded this research project. It is an ongoing, cooperative and comprehensive research program addressing transportation needs of the state of Kansas utilizing academic and research resources from KDOT, Kansas State University and the University of Kansas. Transportation professionals in KDOT and the universities jointly develop the projects included in the research program.

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EXECUTIVE SUMMARY

Due to the extensive nature of the material and range of topics covered, the executive summary is broken down by chapters.

This report consists of eight chapters:

1. Accessibility Laws.
2. Public Right-of-way; Accessibility Guidelines and Roundabouts.
3. Overview of Accommodating all Roundabout Users.
4. Research on Pedestrian Accessibility and Accessible Roundabouts.
5. Pedestrian and Motorist Intersections at Two Kansas Roundabouts.
6. Local Roundabout Acceptance.
7. Safety Analysis of Kansas Roundabouts.
8. Conclusions and Recommendations.

Chapter 1: Accessibility Laws

Accessibility laws traces the history of United States laws that deal with accessibility; namely, the Architectural Barriers Act (ABA) of 1986; the Rehabilitation Act (RA) of 1973; and, American's with Disabilities Act (ADA) of 1990. It also covers the role of the Access Board in its responsibility for developing accessibility guidelines under several federal laws. It points out that the process of developing enforceable, accessibility standards starts with Access Board guidelines, known as ADA Accessibility Guidelines (ADAAG). The two-step process is as follows:

1. The Access Board develops *minimum* guidelines for the ABA and ADA, then,

2. Federal departments adopt the guidelines *enforceable* standards that are consistent with the Access Board's guidelines – the Department of Justice (DOJ) and Department of Transportation (DOT) under the ADA.

This chapter makes it clear that the Access Board is responsible for and has the authority under U.S. federal laws to develop guidelines to enforce the ADA in the area of accessibility and the Access Board guidelines are usually adopted as enforceable standards through the federal rule making process.

Chapter 2: Public Right-of-Way; Accessibility Guidelines and Roundabouts

This chapter covers the development of the Access Board's Public Right-of-Way Accessibility Guidelines (PROWAG). The Access Board's ADA Accessibility Guideliness (ADAAG) focused mostly on facilities and sites. The board has been working on the PROWAG since 1992 and revised the initial draft in 1994. In response to transportation industry comment on this draft showing a misunderstanding of the role of accessibility guidelines and standards, the Access Board embarked on a program of education and outreach. Basically, they sought to clarify the role of design and construction standards under the ADA, noting that it required that all new and altered facilities must be accessible to and usable by people with disabilities. They also convened a federal advisory committee, the Public Right-of-Way Advisory Committee (PROWAC). The PROWAC report, Building a True Community, became the basis of the Access Boards' advance draft of PROWAG, published in the Federal Register on June 17, 2002. The draft PROWAG contained guidelines for all accessibility related issues within transportation facilities rights-of-way.

Only a short section of the PROWAG dealt with roundabouts. One statement caused considerable discussion in the transportation community:

> 1105.6.2 – Signals. A pedestrian activated traffic signal complying with 1106 [another section of the guidelines] shall be provided for each segment of the crosswalk, including the splitter island.

The above language would require pedestrian signals on *all* legs of *all* roundabouts. After much discussion and some research, in November 2005, the Access Board issued substantial revisions to the draft guidelines. The change most directly related to roundabout accessibility: (page 4 Draft PROWAC)

> …limited pedestrian signalization at roundabouts and channelized turn lanes to pedestrian crossings [to the splitter island] of two-lanes of traffic or more.

As of today, this provision that would require pedestrian signals at all pedestrian crossings at two or more lane roundabouts is expected to remain in the final guidelines (expected Summer 2008) and eventually become an enforceable standard, e.g., analogous to the way curb cuts on sidewalks became standards in the 1990's.

Chapter 3: Overview of accommodating all Roundabout Users

This chapter discuses worldwide and U.S. research experience and statistics regarding the safety, operation and environmental effects of roundabouts on motor vehicles, pedestrians and bicycles. Literature review shows that roundabouts significantly reduce motor vehicle crashes, is safer for able bodied pedestrians, but the safety of bicyclists needs more study. It discusses the specific issues with blind pedestrians, and summarizes research on blind pedestrian challenges at roundabouts.

The general conclusion of several studies reviewed is that blind pedestrians are at greater risk at roundabouts than traditional intersections.

This chapter concludes with a brief overview of a major, ongoing NCHRP study (NCHRP 3-78A) whose objective is to research and recommend a range of geometric designs, traffic control devices and other treatments that all make pedestrian crossings at roundabouts usable (accessible) by pedestrians with vision impairment.

At this time, NCHRP 3-78A is underway and no conclusions are available. However, preliminary findings are showing good results with a device commonly known as a HAWK beacon, [FHWA recently proposed calling it a hybrid signal] a pedestrian activated beacon, similar to a traditional traffic signal but with significant benefits in reduced delay to motor vehicles and reduced, negative impact on congestion in the roundabout. Chapter 3 presents an overview and detailed discussion of NCHRP 3-78A is contained in Chapter 4 and subsequent chapters.

Chapter 4: Research on Pedestrian Accessibility and Accessible Roundabouts

This chapter gets into more detail on pedestrian issues, challenges for blind pedestrians and recent research on pedestrians and on roundabout accessibility. The material in this chapter on accessibility and challenges of blind pedestrians at roundabouts is excerpted from the Access Board website: “Pedestrian Access to Modern Roundabouts: Design and Operational Issues for Pedestrians who are Blind.” An accessible roundabout is defined as follows:

> “an accessible roundabout will provide non-visual information about crosswalk and splitter island location, crossing direction and safe crossing opportunities.”

The chapter goes on to review current pedestrian crossing research. The most recent research concludes that a red signal or beacon is far better for driver stopping compliance than any other system. The chapter also details research related to pedestrian challenges and possible solutions for increasing accessibility at roundabouts, including details of NCHRP 3-78A.

The NCHRP 3-78A team developed the following list of considerations for improved accessibility:

- decrease in the time it takes the pedestrian to 'locate the crosswalk'
- increased availability of crossable gaps (natural or 'created')
- increased pedestrian ability in correctly identifying 'crossable gaps'
- decreased likelihood of a pedestrian taking a 'risky' gap
- increased likelihood of drivers yielding to pedestrians
- increased pedestrian ability to detect yielding vehicles
- reduction in the overall delay experience by a blind pedestrian in crossing the facility, and
- accomplish goal without significant disruption to overall vehicle/system delay.

The research team has been looking at relocating the crosswalk, sound strips, ped-activated flashing yellow beacons, raised crosswalks and a pedestrian activated HAWK beacon. (Name recently changed to pedestrian hybrid signal.)

In regard to crosswalk location, the research team is looking at two locations: close to the roundabout, typically one car back from the circular roadway, to mid-block crossings. The crossings close to the roundabout, the "normal" location sometimes referred to as the "Splitter Island Location" by the NCHRP 3-78A research team, have been called “proximal” and those at mid block have been called “distal”. Offset design will be incorporated as follows: (email from Ron Hughes, March 4, 2008)

> “Our notion of the proximal/offset approach is to leave the entry lane crosswalk in its current location; offset the crosswalk to the left along the median to a point (distance to be defined) distal to the circulating lane – for the purpose of creating sufficient storage for vehicle queues having the potential of otherwise backing up into the circulating lane.”
>
> “The proximal/offset application can be difficult if one intends to utilize a HAWK beacon (or whatever we are calling it now) – the problem coming from the close proximity of the ‘signal’ and the vehicle yield line prior to the circulating lane. Where that is determined to be a problem (as was suggested by Kittelson in the process of their doing the plans for the HAWK application in Golden) the solution would be to relocate the entry lane crosswalk distal to the circulating lane so that the entry and exit lanes are equidistant from the circulating lane (i.e., a straight across path). That obviously results in a case of a purse ‘distal’ application.”

The Table below summarizes the treatments being researched at multilane roundabouts.

Treatment "Package" Recommendations for Multilane Roundabouts

	Treatment	Splitter Island Location	Offset Design	Distal Crosswalk
Baseline	None			
Package 1	Sound Strips	N/A	N/A We have no reason to believe that the multiple threat problem gets any better.	N/A We have no reason to believe that the multiple threat problem gets any better.
Package 2	Ped-actuated flashing yellow beacon	Yes	Yes	Yes
Package 3	Ped-actuated beacon plus sound strip	N/A	Yes	Yes
Package 4	Raised crosswalk	Yes	Yes	Yes
Package 5	HAWK beacon	Yes	Yes	Yes

The chapter contains several diagrams of crossing treatments at both non-roundabout locations and roundabouts.

Chapter 5: Pedestrian and Motorist Intersections at two Kansas Roundabouts

This chapter reviews literature on existing studies and reports on observational studies of pedestrian – vehicle interaction at two Kansas roundabouts. One is in Lawrence near a grade school; the other in Olathe near a high-school.

As part of NCHRP project 3-65, Harkey and Carter performed observational studies of pedestrian – vehicle interactions at 10 approaches at 7 roundabouts in a number of states. They defined pedestrian actions as:

- Normal
- Hesitant
- Retreats
- Runs

They defined motorist actions as:

- Active yield
- Passive yield
- Did not yield

They separated pedestrian crossings as “start on entry leg” and “start on exit leg” of both roundabout entry legs and exit legs.

Harkey and Carter looked at “conflict” as a surrogate variable for pedestrian safety. They defined a conflict as:

> “…an interaction between a pedestrian and a motorist in which one of the parties had to suddenly change course and/or speed to avoid a collision.”

In the study, only four conflicts were observed out of 769 pedestrian crossings.

With the above definition, the study found that the conflict rate was 2.3 conflicts per 1000 opportunities.

Harkey and Carter concluded that:

> “……the overwhelming majority of the roundabouts in the observational study showed very few problems for crossing pedestrians.”

Harkey and Carter further concluded that the conflict rate of 4 conflicts out of 769 crossing events (0.5 percent) confirms the overall findings of the NCHRP 3-65 study in which data collected from 39 roundabouts in several states found 5 pedestrian crashes with no fatalities, a rate of 0.01 pedestrian crashes per year.

Harkey and Carter made the following conclusions: (paraphrased)

- Exit legs appear to place crossing pedestrians at greater risk than entry legs (based on [overall average] driver yielding percentages of 38 percent vs.. 23 percent).
- Two-lane approaches are more difficult for crossing pedestrians than one-lane approaches. This was based on driver overall, average, non-yielding percentages of 17% at one lane crossings and 43% at two-lane crossings. However, it was pointed out that this could be a reflection of overall, average pedestrian hesitation behavior: 33% at two-lane crossings vs. 25% at one lane crossings.
- Roundabouts result in the type of behaviors expected when compared to other types of intersections and levels of traffic control. Roundabouts, which are under yield control, produced motorist and pedestrian behaviors that were between the behaviors observed at crossings with no traffic control and those observed at crossings with signal or stop-control.

They also commented that bicyclists appear to have very few problems interacting with vehicles in roundabouts. The problems with bicycles they identified in the study were the result of inappropriate behavior on the part of the bicyclists.

The Kansas studies followed the Harkey and Carter study as closely as possible. At the Lawrence roundabout, near a public grade school, the overall observation from watching 10 days of videotapes of children crossing the roundabout legs was that drivers were extremely cautious. There was never a case of “did not yield” and in all cases, yielding included when pedestrians were waiting at the curb or, in many cases, *nearing the curb*. Most drivers stopped some distance from the crosswalk. At this particular site, where pedestrians were obviously young children, motorist behavior could only be described as exemplary. The author concluded that the presence of the roundabout at this location in no way increased the risk of the crossing students compared to traditional school zone crossings and it is possible that the low-speed environment created by the roundabout possibly added to or enhanced the positive driver behavior. It should be noted that 100% of the young pedestrians stayed within the crosswalk.

At the Olathe roundabout it was a different environment. Although there were no conflicts, as defined above, drivers stopped only when the pedestrians were in the street. None were observed stopping for pedestrians at the curb. It was also noted that 30% of the pedestrians, assumed to be almost entirely high-school students, paid no attention to the marked crosswalk boundaries. A few walked within the circulatory roadway as part of a “short cut”, straight path.

The final, overall conclusion from observation at the Olathe high school site was as follows: In all cases observed, pedestrians waited for reasonable gaps and once they were in the street (whether in or out of the marked crosswalks) vehicles slowed or yielded and no close calls were observed that required any sudden, evasive action(s).

Although conjecture, the author believes it is likely that the presence of the roundabout on a busy arterial, creates an environment where drives are slowed, and as a result pedestrians are at less risk.

Chapter 6: Local Roundabout Acceptance

This chapter discusses some of the opposition to roundabouts and suggests a program to answer negative community sentiment. Most of the suggestions in the chapter come from interviews and correspondence with a sample of transportation engineers whose job it is to answer public and/or political oppositions to roundabouts.

An employee of the state of Washington DOT who deals with local government problems and is an enthusiastic promoter of roundabouts provides the following general observation and some specific suggestions for states:

1. The state DOT should identify an individual with knowledge and passion for promoting the benefits of roundabouts. Preferably it should be someone who really wants to do this.
2. Roundabout “selling”/promoting is about good public speaking and communication, i.e., the person doing the presentations should have good public speaking skills. Specific facts should be presented, e.g., a roundabout at “x” location should reduce injury crashes by 4 per year, reduce delay to each vehicle by 24 seconds on average, reduce pollution by 16%--less stopping, waiting, maintenance costs, etc. Successful examples from other cities and key research results should be cited. A power point presentation with lots of photos or video should back up facts presented.

3. Be prepared to be constantly on the offensive, giving out information and anticipating questions. Use your factual knowledge to combat emotional language, irrational opposition or myths.
4. Where possible, tour existing roundabouts with community leaders or any interested groups whenever possible. Even if the main purpose of the tour has nothing to do with roundabouts, per se, lead the group through any in the area when it is easy to do so.

One Kansas City traffic engineer made the following suggestions: (see full report for more detail)

- Get the facts, i.e. an engineering study of safety, capacity, cost and esthetics.
- Stress safety
- Get administrator “buy in”
- Involve the public

In another Kansas city success was achieved by educating the city council and governing body. Where they proposed one near schools they set up a full-size model in a school gym and had a consultant explain the operation to students, administrators and parents.

This chapter also presents the findings of a major study of public opinion of roundabouts by a consultant hired by the city of Olathe. It was found that the overall satisfaction with roundabouts is very high, residents think roundabouts have decreased travel time, and residents think the city should continue developing roundabouts and residents prefer roundabouts over other traffic control options.

City of Olathe personnel made the following suggestions. First and foremost, support from upper management is critical. This support begins with the Public Works Director, then goes up to the City Manager and finally the City Council. Also, educate and garner support from fire, medical and police operations – as one should in traffic calming programs.

More specific suggestions are: (details in the full report)

- Solid upfront planning and buy in
- A good roundabout design
- Well managed roundabout construction
- Consistent traffic enforcement and project follow up

Chapter 7: Safety Analysis of Kansas Roundabouts

This chapter starts with a review of the safety chapters of NCHRP Report 572, the recently published final report from NCHRP project 3-65, Roundabouts in the United States (US). This study produced a number of major safety findings; such as:

- Intersection level prediction models (Safety performance Functions (SPFs)) for prediction of the overall safety performance of roundabouts and several traditional intersection types.
- An updated comparison of the performance of roundabouts to other forms of traffic control, in several different environments, e.g. urban, suburban, rural, etc.

It is stressed that before using any of the models developed in the study, a local jurisdiction should confirm that the models adequately represent the jurisdiction or can be recalibrated using data from the jurisdiction.

The report also discusses the proper procedures to conduct before – after crash studies, i.e., state-of-the-art, Emperical Bayes (EB) techniques. A proper before – after study statistically adjusts values for regression to the mean and the fact that it is impossible to control all factors that could change in the before – after time period. It is naïve to believe that the only change in a before – after time period is some treatment, e.g. building a roundabout, is the only change during this period. Therefore, such an analysis – subtracting crashes for some period after an improvement from crashes that occurred during a similar before period – is a "naïve" before – after study.

In the report proper, the state-of-the-art approach, (EB approach) is discussed. In the EB approach the crashes after some treatment (such as constructing a roundabout) are subtracted from the expected crashes that would have occurred if the treatment had not been implemented. To calculate the expected crashes, SPFs that are appropriate to the jurisdiction are needed. These equations give a "P" value of expected crashes that are then combined statistically with actual, observed crashes to calculate site specific expected before crashes. This is an EB estimate from which actual, observed, after crashes are subtracted. Examples are presented in the full report. (See Table 7.1 of this report for SPF equations used in the NCHRP 3-65 study.)

NCHRP Report 572 provides updated values of safety reduction, i.e. reduced crashes that result from conversion to a roundabout. These are presented in the following Table: (Table 7.1 from the full report)

Results for before-after analysis by logical group.(From NCHRP Report 572, Table 27)

Control Before	Sites	Setting	Lanes	Crashes recorded in after period		EB estimate of crashes expected without roundabouts		Index of Effectiveness θ (standard error) & Point Estimate of the Percentage Reduction in Crashes	
				All	Injury	All	Injury	All	Injury
All Sites	55	All	All	726	72	1122	296.1	0.646 (0.034) 35.4%	0.242 (0.032) 75.8%
Signalized	9	All	All	215	16	410.0	70.0	0.522 (0.049) 47.8%	0.223 (0.060) 77.7%
	4	Suburban	2	98	2	292.2	Too Few	0.333 (0.044) 66.7%	Too Few to estimate
	5	Urban	All	117	14	117.8	34.6	0.986 (0.120) 1.4%	0.399 (0.116) 60.1%
All-Way Stop	10	All	All	93	17	89.2	12.6	1.033 (0.146) -.3.3%	1.282 (0.406) -28.2%
Two-Way Stop	36	All	All	418	39	747.6	213.2	0.558 (0.038) 44.2%	0.182 (0.032) 81.8%
	9	Rural	1	71	16	247.7	124.7	0.285 (0.040) 71.5%	0.127 (0.034) 87.3%
	17	Urban	All	102	6	142.7	31.6	0.710 (0.090) 29.0%	0.188 (0.079) 81.2%
	12		1	58	5	93.7	22.5	0.612 (0.101) 39.8%	0.217 (0.100) 80.3%
	5		2	44	1	48.9	Too few	0.884 (0.174) 11.6%	Too few to estimate
	10	Suburban	All	245	17	357.2	57.0	0.682 (0.067) 31.8%	0.290 (0.083) 71.0%
	4		1	17	5	77.1	21.8	0.218 (0.057) 78.2%	0.224 (0.104) 77.6%
	6		2	228	12	280.1	35.2	0.807 (0.091) 19.3%	0.320 (0.116) 68.0%
	27	Urban/ Suburban	All	347	23	499.9	88.6	0.692 (0.055) 30.8%	0.256 (0.060) 74.4%
	16		1	75	10	162.8	44.3	0.437 (0.060) 56.3%	0.223 (0.074) 77.7%
	11		2	272	13	329.0	44.3	0.821 (0.082) 17.9%	0.282 (0.093) 71.8%

Available Accident Summary reports were obtained from KDOT for intersections where there was at least two or three years of crash history after a roundabout was built. The author believes that as a whole, this body of data are insufficient to make any statistically defensible analysis such as the state-of-the-art EB analysis. The necessary data are not available or beyond the scope of this project. One void is in the lack of SPFs for crash prediction. However, even with a naïve analysis on limited data the results show that the overall trend is definitely positive, i.e., Kansas roundabouts generally decrease crashes. The results are shown below in Table 7.9 from the full report.

Simple, Uncorrected, Before – After Compared To NCHRP 572, Table 28

Control Before	Percent Crash Reduction			
	NCHRP 572		KDOT	
	All	Injury	All	Injury
Various – All Sites	35.4 %	75.8%	-25.8% [1]	54.2 %
Signalized – Urban	1.4%	60.1%	-36.8% [1,2]	-150% [1,2]
Two-way stop Urban – all	29.0%	21.2%	31.3%	84.6%
All-way Stop	-3.3% [1]	-28.2% [1]	-83.3% [1,3]	33.3% [3]

[1] A minus indicates an increase
[2] Data are too limited for meaningful results
[3] Values would be -14.3, for all and +50% for injury without #7 from Table 7.7 which appears to be an “outlier”, which should flag the roundabout for an engineering study.

Roundabouts decrease high angle crashes, e.g. “T-bone”, right angle or close to right angle. Even though the KDOT crash summaries do not indicate the angle, the author believes the reduction of all angle crashes as shown in Table 7.10 below from the full report.

Summary of Sites with Recorded “Angle” Crashes

Condition	**Before Number**	**After Number**	**Decrease**	**Percent Decrease**
All Sites	90	74	16	17.8%
All Sites excluding Sheridan, Ridgeview, and Rogers (4-way) [1]	83	43	40	48.2%
All Signal Sites [1]	15	14	1	6.7%
All 2-way Stop Sites	61	25	35	57.4%
All 4-way Stop Sites	14	35	-19 (increase)	-135.7% (increase)
All 4-way stop excluding Sheridan, Ridgeview, and Rogers [2]	7	4	3	42.9%

[1] Very limited data.
[2] Sheridan, Ridgeview and Rogers appears to possibly have (or had) design or operational problems.

SUMMARY OF PROPOSED RESEARCH

General Research Problem Statement

The Access Board, with authority to enforce provisions of the American Disabilities Act (ADA), initially determined that roundabouts are not accessible by blind pedestrians and drafted proposed guidelines to require pedestrian signals at all roundabouts. More recently, the Access Board proposed final guidelines requiring pedestrian signals at all roundabouts with two or more lanes. It is possible that if these guidelines become Federal regulations through the Federal rule making process, and low-cost pedestrian signals are not developed, the growth of roundabouts could diminish greatly throughout Kansas and the USA. This will, in effect, deny motorists and public transportation organizations a safe, cost-effective means of intersection traffic control which potentially could result in many lives not saved and injuries not prevented. It has been projected that when stop controlled and signal controlled intersections are replaced by roundabouts there is a 76% reduction in injury crashes and a projected 90% decrease in fatalities. Kansas has been a national leader in design and construction of roundabouts and Kansas motorists would suffer a loss of these safety benefits if roundabout growth were slowed or halted. Roundabouts also have proven benefits in reduction of intersection delay and stopping as well as reduction in air pollution. These benefits could be lost or diminished as well.

Background Overview

“To ensure that buildings and facilities are accessible to and usable by people with disabilities, the ADA establishes accessibility requirements for State and local government facilities, places of public accommodation, and commercial facilities. Under the ADA, the Access Board has developed and continues to maintain design guidelines for accessible buildings and facilities known as the ADA Accessibility Guidelines (ADAAG).” (Access Board Website)

The Access Board has undertaken rulemaking to supplement its ADA and ABA accessibility guidelines, which primarily cover facilities on sites, by adding new proposed provisions specific to public rights-of-way.

The guidelines would not require alterations to existing public rights-of-way, but would apply where a pedestrian route or facility is altered as part of a planned project to improve existing public rights-of-way.

On June 17, 2002, the Access Board released draft guidelines that were available for public comment. The Board published a rule based on review of the comments in 2006.

The guidelines cover access to sidewalks and streets, including cross walks, curb ramps, street furnishings, parking, and other components of public rights-of-way.

One section of the draft guidelines (1105.6) covers roundabouts. It states that the absence of stopped traffic at roundabouts presents a problem for pedestrians with vision impairments and puts them at a particular disadvantage. Thus the draft guidelines propose:

> “To provide safer crossing at roundabouts, the draft guidelines would require pedestrian activated crossing signals at each roundabout crosswalk, including those at splitter islands.” (Access Board Website)

This has caused considerable concern among roundabout advocates who promote their growth because of their many advantages for moving traffic through intersections safely and efficiently.

ORIGINAL WORK PLAN

Research Objective

The main objective was to analyze types of pedestrian/vehicle conflicts at Kansas roundabouts. A secondary objective was to document factors that are beneficial or detrimental to roundabout growth in Kansas and recommend approaches for promoting the benefits of roundabouts.

Tasks

1. Investigate and make recommendations for a sustainable program to monitor safety records of all Kansas roundabouts.
2. Identify the key stakeholders in the process of getting support and approval for roundabouts in local communities and interview a sample to determine their viewpoints and/or concerns.
3. Conduct pilot field research monitoring driver/pedestrian interaction at a number of roundabouts by videotaping crosswalks, and as the budget permits, test one or more simple countermeasures that may make drivers more aware of pedestrians.
4. Keep current on national research and Access Board Guidelines on accessibility of roundabouts and summarize the results as they affect roundabout growth.

5. Investigate and report on strategies used in other states for promoting the benefits of roundabouts.
6. Write a final report documenting the findings of the study and recommending actions that will continue roundabout growth in Kansas.

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CHAPTER 1 - ACCESSIBILITY LAWS

1.1 Overview

There are three primary laws that deal with “accessibility”:

1. Architectural Barriers Act (ABA) (1968)
2. Rehabilitation Act (RA) (1973)
3. Americans with Disabilities Act (ADA) (1990)

The Architectural Barriers Act (ABA) of 1968 (“An Act to ensure that certain buildings financed with Federal Funds are so designed and constructed as to be access to the physically handicapped”) was the first measure taken by the US Congress to “ensure access to the built environment.” (Access Board website, accessed 7/15/06) The ABA requires access to facilities built, altered or leased with Federal funds. This law includes facilities such as post offices, social security offices, prisons, national parks and a wide range of other facilities. (Access-Board Websites, 1 & 2, accessed 7/15/06.) Facilities that existed prior to the ABA are generally not covered; however, “alterations or leases undertaken after the law took effect can trigger coverage”. (Access Board Web Site 1, accessed 7/15/06)

The Rehabilitation Act of 1973, as amended in 1992 and 1998, is Federal legislation that authorizes grant programs of vocational rehabilitation, supported programs, independent living and client assistance and training and service grants administered by the Rehabilitation Services Administration. The Act includes provisions focused on rights, advocacy and protections for individuals with disabilities. (Ed. Gov Web Site, accessed 7/15/06.) Section 504 of the Rehabilitation Act covers programs and design and construction of Federally-funded facilities, such as schools, roadways, and transit. Section 508 of the Rehabilitation Act requires Federal acquisition of equipment and technology to meet certain accessibility standards. The Rehabilitation Act, as amended, and the American with Disabilities Act (ADA) of 1990, (discussed below) together constitute the principal civil rights protections for individuals with disabilities.

Two sections of the Rehabilitation Act (RA) stand out as of particular importance – sections 502 and 504. Section 502 established the Architectural and Transportation Barriers Compliance Board (Access Board) and Section 504 defines the concept of program accessibility.

> "It [Section 504] prohibits discrimination on the basis of disability by the federal government, federal contractors and by recipients of federal financial assistance. Organizations that receive federal funds are required to make their programs accessible to individuals with disabilities" (PACER Center website, accessed 7/15/06).

The Civil Rights Restoration Act of 1987 makes it clear that discrimination is prohibited throughout an entire agency if any part of the agency receives Federal financial assistance, for any program.

Enforcement of Section 504 is the responsibility of each Federal agency providing funds. Section 504 was an important model for the landmark ADA legislation, whose title II applies similarly to discrimination in state and local government programs. Thus, between the two laws, government programs at all levels are covered, regardless of funding.

The Americans with Disabilities Act (ADA) of 1990 is an Act to establish a clear and comprehensive prohibition of discrimination on the basis of disability.

The purpose of the ADA is:

§2(b)(1) to provide a clear and comprehensive national mandate for the elimination of discrimination against individuals with disabilities;

§2(b)(2) to provide clear, strong, consistent, enforceable standards addressing discrimination against individuals with disabilities;

§2(b)(3) to ensure that the Federal Government plays a central role in enforcing the standards established in this Act on behalf of individuals with disabilities; and

§2(b)(4) to invoke the sweep of congressional authority, including the power to enforce the fourteenth amendment and to regulate commerce, in order to address the major areas of discrimination faced day-to-day by people with disabilities. (Access Board Web Site 3, p. 9)

The ADA is much broader then the ABA as it does not require a link to federal funds. The ADA has five titles, i.e., discrete parts of the larger document. They are:

- Title I/Employment
- Title II/Public Service

    Subpart A: Covers State and Local Government generally

    Subpart B: Applies to most public transportation systems

- Title III/Public Accommodations and Services (including transportation) operated by Private Entities
- Title IV/Telecommunications
- Title V/Miscellaneous Provisions

The objectives of the ADA are accomplished through rulemaking by four Federal agencies: Equal Employment Opportunities Commission (EEOC), Department of Justice (DOJ), Department of Transportation (DOT) and the Federal Communications Commission (FCC) with rulemaking responsibility divided as follows:

- Title I/EEOC
- Title II, Subtitle A/DOJ
- Title II, Subtitle B/DOT
- Title III/DOJ (DOT for vehicles)
- Title IV/FCC

By law, the standards adopted by the four Federal standard-setting agencies must be consistent with the Access Board guidelines, which themselves were derived in part from voluntary standards first published in 1961 by the American National Standards Institute (ANSI). (Known today as ANSI A117.1) Standard on Accessible and Usable Buildings and Facilities, provides the accessibility criteria for the International Building Code (IBC), adopted by many States.

1.2 The Access Board

The Access Board is an independent federal agency responsible for developing accessibility guidelines under several Federal laws. The board operates with a staff of about 30 and a governing board of representatives from federal agencies/departments and public members appointed by the president. (Access IT website, accessed 7/15/06). The Access Board was created in 1973 as the Architectural and Transportation and Transportation Barriers Compliance Board in accordance with Section 502 of the Rehabilitation Act of 1973. The Access Board was charged with ensuring compliance of Federal Agencies to the Architectural Barriers Act (ABA) of 1968 and proposing solutions to barriers addressed by the ABA. (Access IT web site, accessed 7/15/06). Subsequent legislation, most notably the American with Disabilities Act (ADA) of 1990, and amendments to the Rehabilitation Act of 1973 greatly expanded the Access Board's mandate, which also includes the Telecommunications Act of 1998, transit vehicle accessibility, and access to communications and information technology under section 508 of the Rehabilitation Act, as amended, for Federal purchase of electronic and information technology, The Board is currently developing accessibility guidelines for outdoor developed areas and trails, passenger vessels, and public rights-of-way.

The ADA standards are adopted and enforced by the Federal rulemaking agencies (as discussed above); the building/facility standards in titles II and III and the vehicle standards in title II are based upon the guidelines developed by the Access Board. The EEOC and FCC develop their own standards.

The Access Board guidelines for accessible buildings and facilities are known as the ADA Accessibility Guidelines (ADAAG). When adopted by DOJ as the Standards for Accessible Design, they establish the minimum requirements for accessibility to building and facilities and in transportation vehicles subject to title II and III of the ADA. (Access Board Bulletin 5, August 2003). Title II entities (State and Local Governments) may choose either ADAAG or the Uniform Federal Accessibility Standards (UFAS, 1984) until the Access Board completes Title II rulemaking (in progress as discussed below). A draft of the ADAAG was first published in the Federal Register 1991 as a Notice of Proposed Rulemaking (NPRM). After a 60-day comment period it was revised and published as a Final rule on July 26, 1991. On that date, ADAAG was adopted through the Federal rulemaking process by both DOJ and DOT; the DOT adopted the rule as “Transportation for Individuals with Disabilities.” The current ADA standard is still the 1991 ADAAG.

Developing enforceable standards is generally a two-step process: 1. the Access Board develops *minimum* guidelines for the ABA and ADA; 2. Federal departments adopt *enforceable standards that are consistent with the Access Board’s guidelines* – DOJ and DOT under the ADA and DOD, and GSA, HUD, DOD and USPS under the ABA.

Details of the Access Board’s establishment, mandate, functions, etc. are contained in Title 29, Chapter 16, Subchapter 5 section 792 of the US Code. The section on functions is quoted below:

1.3 Access Board Functions Details

Several Federal laws govern the functions of the Access Board; they include responsibilities to: (Cornell Law School website, Accessed 7/15/06)

(1) ensure compliance with the standards prescribed pursuant to the Act entitled “An Act to ensure that certain buildings financed with Federal funds are so designed and constructed as to be accessible to the physically handicapped”, approved August 12, 1968 (commonly known as the Architectural Barriers Act of 1968; 42 U.S.C. 4151 et seq.) (including the application of such Act to the United States Postal Service), including enforcing all standards under such Act, and ensuring that all waivers and modifications to the standards are based on findings of fact and are not inconsistent with the provisions of this section;

(2) develop advisory information for, and provide appropriate technical assistance to, individuals or entities with rights or duties under regulations prescribed pursuant to this subchapter or titles II and III of the Americans with Disabilities Act of 1990 (42 U.S.C. 12131 et seq. and 12181 et seq.) with respect to overcoming architectural, transportation, and communication barriers;

(3) establish and maintain –

a. minimum guidelines and requirements for the standards issued pursuant to the Act commonly known as the Architectural Barriers Act of 1968;
b. minimum guidelines and requirements for the standards issued pursuant to titles II and III of the Americans with Disabilities Act of 1990;
c. guidelines for accessibility of telecommunications equipment and customer premises equipment under section 255 of title 27; and
d. standards for accessible electronic and information technology under section 794d of this title;

(4) promote accessibility throughout all segments of society;

(5) investigate and examine alternative approaches to the architectural, transportation, communication, and attitudinal barriers confronting individuals with disabilities, particularly with respect to telecommunications devices, public buildings and monuments, parks and parklands, public transportation (including air, water, and surface transportation, whether interstate, foreign, intrastate, or local), and residential and institutional housing;

(6) determine what measures are being taken by Federal, State, and local governments and by other public or nonprofit agencies to eliminate the barriers described in paragraph (5);

(7) promote the use of the International Accessibility Symbol in all public facilities that are in compliance with the standards prescribed by the Administrator of General Services, the Secretary of Defense, and the Secretary of Housing and Urban Development pursuant to the Act commonly known as the Architectural Barriers Act of 1968;

(8) make to the President and to the Congress reports that shall describe in detail the results of its investigations under paragraphs (5) and (6);

(9) make to the President and to the Congress such recommendations for legislative and administrative changes as the Access Board determines to be necessary or desirable to eliminate the barriers described in paragraph (5);

(10) ensure that public conveyances, including rolling stock, are readily accessible to, and usable by, individuals with physical disabilities; and

(11) carry out the responsibilities specified for the Access Board in section 794d of this title.

1.4 Additional Functions, transportation barriers and housing needs, transportation and housing plans and proposals

The Access Board shall also:

(1) a. determine how and to what extent transportation barriers impede the mobility of individuals with disabilities and aged individuals with disabilities and consider ways in which travel expenses in connection with transportation to and from work for individuals with disabilities can be met or subsidized when such individuals are unable to use mass transit systems or need special equipment in private transportation, and

b. consider the housing needs of individuals with disabilities;

(2) Determine what measures are being taken, especially by public and other nonprofit agencies and groups having an interest in and a capacity to deal with such problems,

a. to eliminate barriers from public transportation systems (including vehicles used in such systems), and to prevent their incorporation in new or expanded transportation systems, and

b. to make housing available and accessible to individuals with disabilities or to meet sheltered housing needs; and

(3) Prepare plans and proposals for such further actions as may be necessary to the goals of adequate transportation and housing for individuals with disabilities, including proposals for bringing together in a cooperative effort, agencies, organizations, and groups already working toward such

goals or whose cooperation is essential to effective and comprehensive action.

1.5 Additional Functions; Compliance

In addition to the above, the Access Board conducts investigations, holds public hearings and issues orders as it deems necessary to ensure compliance with the provisions of the ABA.

"……and an order of compliance issued by the Access Board shall be a final order for purposes of judicial review." (US Code Title 29, Chapter 16, Subchapter V, paragraph 792, e (1))

The authority of the Access Board to enforce provisions of the ABA are clearly stated in the above document: (Cornell Law School website accessed 7/15/06)

(2) The executive director is authorized, at the direction of the Access Board –

(a) to bring a civil action in any appropriate United States district court to enforce, in whole or in part, any final order of the Access Board under this subsection; and

(b) to intervene, appear, and participate, or to appear as amicus curiae, in any court of the United States or in any court of a State in civil actions that relate to this section or to the Architectural Barriers Act of 1968 [42 U.S.C. 4151 et seq.].

1.6 Accessibility Standards Overview

Accessibility standards cover the scoping (how many and under what conditions) and the technical features of such things as walks, ramps, curb ramps, entrances, elevators, rest rooms, etc. Standards are referenced as a measure of the accessibility required under law and as a safe harbor for covered entities. Before 1984 the standards required by the ABA and enforced by the Access Board as specified by the Rehabilitation Act, were developed independently by four agencies – the General Services Administration (GSA), Department of Defense (DOD), Department of Housing and Urban Development (HUD) and the U.S. Postal Service (USPS). In August 1984 these four agencies jointly issued the Uniform Federal Accessibility Standards (UFAS) to serve as ABA and Rehabilitation Act standards for Federal and Federally-aided design and construction. (The Architectural Barriers Act and other Access Laws, http://www.makoa.org/gov/g15.htm)

1.7 ADA Accessibility Guidelines (ADAAG) History

As discussed above, the Access Board was formed by the Rehabilitation Act of 1973 to enforce compliance with the ABA of 1968. The ADA of 1990 expanded the Access Board's Mandate to develop accessibility guidelines to include guidelines for buildings, facilities, and transit vehicles covered by titles II and III of the ADA and to provide related technical assistance and training on the guidelines. ADAAG serves as the basis for standards issued by DOJ and DOT to enforce the law. (The Americans with Disability Act of 1990, on Access Board website.) The Access Board "Guidelines" do not in themselves directly affect the public but instead serve as the basis of enforceable standards issued by DOJ and DOT. (Board Rulemaking, Access Board website, accessed 7/15/06.) The Access Board initially issued the Americans with Disabilities Act Accessibility Guidelines (ADAAG) on July 26, 1991 (CFR 1191 Appendix A) (Building a True Community, 2001). ADAAG 1991 consists of general sections 1 to 4 that apply to all types of buildings and facilities; and sections 5 to 10 that contain additional requirements for specific types of buildings and facilities (section 10 and the vehicle guidelines were added in September 1991). Rulemakings in 1998 and 2000 added sections 11 and 12 to ADAAG, and in 2004 the Board completed a wholesale revision of the guidelines which are now being reviewed by DOJ for adoption as new ADA standards. Two of the ABA rulemaking agencies, GSA and USPS, have adopted the revision as new ABA standards.

1.8 ADAAG for Public Rights of Way (PROW)

A Notice of Proposed Rulemaking first published in 1992 included 4 sections (11-14) that were to be added to the 1991 ADAAG to provide more definition for Correctional Facilities (11), Judicial Facilities (12), Housing (13) and Public Rights-of-Way (14). An Interim Final Rule was issued in 1994. In a 1998 rulemaking, sections 13 and 14 were reserved. Section 14, Public Rights of Way, is of particular importance to the transportation community. Public comments on section 14 suggested that public works agencies, transportation departments and traffic consultants misconstrued the role of standards under the ADA, and believed that section 14 would require extensive rebuilding of existing, developed rights-of-way. It was clear that most agencies did not understand that the obligation to design and construct new and altered facilities that were “accessible to and usable by” people with disabilities was imposed by the ADA implementing regulations – titles II and III – and that the guidelines were developed only to provide a measure of compliance for that requirement. Thus, when the Access Board published final rules for state and local governments in 1998, section 14 was “reserved” for future rulemaking. At that time, the Board made a decision to separate rights-of-way rulemaking from the building and facility rulemaking in ADAAG.

1.9 Updated ADAAG (2004)

On July 23, 2004, the revised ADA and ABA Accessibility Guidelines (ADA/ABA-AG) were published. During the development of the revised guidelines, the Board decided to publish the Public Rights of Ways Accessibility Guidelines (PROWAG), technically a part of ADAAG, as a separate and stand-alone document for the convenience of its transportation industry users. Accordingly, that document is proceeding on a separate rulemaking timeline.

The ADA requires the DOJ to publish regulations that include accessibility standards that are consistent with the Access Board Guidelines. (Proposal to Issue Revised ADA Design Standards, DOJ Homepage, Accessed 7/15/06). In 2005 the DOJ published an Advance Notice of Proposed Rulemaking (ANPRM) in the process of revising the Departments ADA regulations.

The ANPRM is the first of three steps in the Federal regulatory process. This will be followed by a Notice of Proposed Rulemaking (NPRM) and a final rule. The final rule will indicate when the new standards take effect, which is likely to take two or three years. Until that time existing ADA standards continue to apply.

In 2006 the DOT issued a notice to amend its ADA regulations for transit facilities. The notice seeks to clarify the responsibility of transportation providers to make reasonable modifications to their policies and practices to ensure program access (Access Currents, Vol. 2, No. 1, January/February 2006). This notice was available for comment until April 6, 2006 and is available on the DOT website at http://dms.dot.gov. (Note: PROW guidelines are not included.) DOT is currently working to update their vehicle guidelines under the ADA.

In updating ADAAG, the Access Board sought to reconcile differences from model building codes including the International Building Code (IBC) which contains provisions for accessibility and references the technical criteria of the ANSI A117.1-2003 standard. (A side by side comparison of the 2004 ADA/ABA-AG with ADAAG and the IBC provisions is available at http://www.access-board.gov/ada-aba/comparison/index.htm. (Access Currents, January/ February 2006)

In regard to "when" the revised guidelines will take effect, the responsible agencies are on separate tracks and progress is varied. In 2006, both the GSA and USPS adopted the revised guidelines as their ABA standard. Until the adoption process is complete, however, the current standards maintained by the various agencies must be followed. The 2004 Access Board Accessibility Guidelines (ADAAG) are the baseline for new standards, but by themselves are not enforceable. (Update of ADA and ABA standards, Access Board website, accessed 7/15/06).

The process of developing guidelines for Public Rights of Way (PROWAG) is still in progress. The PROWAG guidelines are discussed in the next chapter.

CHAPTER 2 - PUBLIC RIGHTS OF WAY ACCESSIBILITY GUIDELINES AND ROUNDABOUTS

2.1 Public Rights-of-Way Accessibility Guidelines (PROWAG)

A brief summary and review of the background of PROW follows:

The current ADA standards, the Access Board's 1991 guidelines, focus mainly on facilities and sites. They do include some features relating to sidewalks, curb ramps, accessible routes, surfaces, etc. However, many features of the accessible route required on a site were not applicable to sidewalks and other pedestrian facilities. The Access Board felt further guidance was necessary to address conditions unique to PROW.

The Access Board first proposed PROWAG in 1992 and revised those guidelines in 1994. In 1995, in response to transportation industry comment that revealed a substantial misunderstanding of the role of accessibility and civil rights guidelines and standards, the Board embarked on an ambitious program of education and outreach to the transportation industry. This included a series of videotapes, an accessibility checklist, a synthesis of pedestrian signals and a design guide on accessible public rights-of-way. (Building a True Community, 2001) The Board also sought to clarify the role of design and construction standards under the ADA, noting that the ADA's implementing regulations (titles II and III) required that all newly-constructed or altered facilities (and parts of facilities) must be 'accessible to and usable by' people with disabilities. The Board's guidelines are intended to provide a measure of compliance for this requirement and a safe harbor for designers and agencies. Without standards, covered entities must determine on their own what comprises compliance in the right-of-way. A number of court cases have resulted.

In 1999, the Access Board convened a Federal advisory committee to develop recommendations for guidelines for accessibility for public rights-of-way, establishing the Public Rights-of-Way Access Advisory Committee (PROWAAC) late that year. The committee was made up stakeholders affected by the rulemaking, including persons with disabilities, Federal, state and local public works and transportation agencies; organizations representing design professionals; pedestrian and bicycle organizations; standard-setting organizations and disability advocates.

The PROWAAC was guided by the belief that accessibility standards for pedestrian facilities should follow these basic principles: (Building a True Community, 2001)

- provide for equal opportunity,
- maximize accessibility for all users,
- be reasonable,
- be clear, simple and understandable,
- be enforceable and measurable,
- be constructible and maintainable within today's technological capabilities,
- address safety for both pedestrians and motor vehicle operators,
- provide guidance for implementing agencies and the public,
- be flexible enough to include future technologies,
- be consistent with ADAAG, and
- support independent use by persons with disabilities.

The PROWAAC report, "Building a True Community," (online at http://www.access-board.gov/prowac/commrept/index.htm) proposed accessibility provisions for new and altered facilities in the public rights-of-way covered by the ADA. Their recommendations were presented to the Access Board in January 2001 in a Special Report at the TRB Annual Meeting in January 2001. The report provided scoping and technical criteria for new and altered pedestrian facilities in the public rights-of-way. Proposed in the Report proposals considered the latest available ROW information and design and construction practices (Building a True Community, 2001).

After reviewing the PROWAAC recommendations, Board members developed draft PROW accessibility guidelines (PROWAG). Because the draft differed from the PROWAAC report in several areas the Access Board decided to make an *advance* draft available for public comment.

Notice of availability of the advance draft was published in the Federal Register on June 17, 2002. (It is available at http://www.access-board.gov/news/archive/prow-release.htm) Comments were solicited and over 1400 comments were received. The comments are also available on the Access Board website. (http://www.access-board.gov/prowac/comments/index.htm)

From the comments, several key issues were identified for detailed study. Among the issues were roundabouts and roundabout signalization.

In November 2005 the Access Board released a second and revised draft of the PROWAG to facilitate its work in preparing cost/benefit analysis – a necessary step in the Federal rulemaking process. After the Access Board completes its cost analysis, the Board will issue a notice of proposed rulemaking (NPRM) seeking public comment prior to issuing a final rule. (Access Board website, News, January-February 06).

2.2 Roundabouts and Accessibility

The PROWAAC report incorporated the industry definition of a roundabout:

Roundabout: a distinctive circular roadway with the following three critical characteristics: 1) a requirement to yield at entry which gives a vehicle on the circular roadway the right-of-way; 2) a deflection of the approaching vehicle around the central island; and 3) a widening of the approach to match the width of the circular roadway. Typically has raised splitter islands at the approaches. Usually used at arterial or collector intersections rather than local streets. (Building a True Community, 2001, pg 28)

The PROWAAC report made several recommendations specific to roundabouts, distinguishing between a roundabout (as defined) and a neighborhood traffic circle – typically a small raised circle installed within an intersection for traffic calming, i.e., slowing traffic. The following are of particular significance to accessibility of blind and low-vision pedestrians – a critical issue that needs to be addressed (paraphrased):

(A) **Separation.** Continuous shrubbery, planters, landscaping, guardrails or other barriers shall be provided along the street side of the public sidewalk where pedestrian crossing is prohibited. Where railings are used they shall have a bottom rail no more than 15 inches (380 mm) above the pedestrian access route so as to be detectable by cane in time to prevent street entry.

(B) **Cues.** A cue shall be provided to allow blind and visually impaired pedestrians to locate each crosswalk.

Advisory: The locator tone of an accessible pedestrian signal may be used to indicate the presence of the crosswalk.

(C) **Signals.** A pedestrian actuated traffic signal (APS) shall be provided for each segment of the crosswalk, including at the splitter island. Signals shall clearly identify which crosswalk segment the signal serves.

Advisory: If allowed by MUTCD, the signal system may provide for permissible crossings without activating the signal and without violating a DON'T WALK pedestrian signal. In addition, the accessible symbol shown in proposed ADAAG may be displayed on the activation button to discourage use by pedestrians not needing the additional protection. (Building a True Community, 2001, p 112, paraphrased)

In their discussion, the PROWAAC points out that although the roundabout generally controls and slows the traffic flow, the absence of the sound of regular surges from stop-and-go traffic, e.g., at a signal or stop sign, "….presents a major problem for blind and visually impaired pedestrians when crossing" (Building a True Community, 2001, p 113) because there is little useful information available that would enable the pedestrian to recognize and choose a gap to cross with confidence of safety.

The PROWAAC states that pedestrians report that vehicles do not stop for them at roundabouts (and free flow, right slip lanes) and other non-signalized crosswalks (no references presented, although this is confirmed by the 2000 Bureau of traffic Safety study, ‘Freedom to Travel’) and pedestrians with disabilities are particularly vulnerable in these situations. In addition, they point out that:

> “People who are blind or visually impaired are unable to make eye contact with drivers – making it impossible to ‘claim the intersection.’ The driver’s view of people using wheelchairs is often blocked by other vehicles. Pedestrians with slower than normal mobility may hesitate when entering the street.” (Building a True Community, 2001, p 113)

For the above reasons they conclude that pedestrians with disabilities must have the ability to reliably stop traffic in order to afford them opportunity to cross safely. They suggest the use of pedestrian activated pedestrian signals that only stop traffic when pedestrians are crossing or in the crosswalk, and further, that an accessibility symbol displayed on the signal activation button may discourage use by pedestrians not needing the signal. (Building a True Community, 2001)

In addition, since roundabout crosswalks are one or two car lengths back from the circular roadway, the PROWAAC report recommended barriers be provided where crossing is prohibited and cues to guide blind and visually impaired pedestrians to the crosswalk. (Building a True Community, 2001)

In summary, the PROWAAC concluded:

- "Barriers must be provided where pedestrian crossings are prohibited.
- A cue must be provided to locate the pedestrian crossing.
- A pedestrian activated traffic signal must be provided at pedestrian crossings."

  (Building a True Community, 2001, p. 20)

2.3 Proposed PROWAG

The advance draft PROWAG report published on June 17, 2002 for public comment addressed roundabouts. In a discussion section of the draft guidelines (preamble) it was stated that because of the "continuous flow" nature of roundabouts, the absence of usable sound cues presents a problem for pedestrians with vision impairments. Therefore, to provide information about and an opportunity to cross, the guidelines would require pedestrian activated crossing signals at each roundabout crosswalk including those at the splitter islands. The Access Board indicated they were not aware of alternatives [to signals] "that would allow safe passage for pedestrians with disabilities." (Access Board Draft Guidelines, on Accessible Rights-of-Way, June 17, 2004, p. 13)

Two items were addressed in the text: Separation and Signals:

"**1105.6.1 Separation.** Continuous barriers shall be provided along the street side of the sidewalk where pedestrian crossing is prohibited. Where railings are used, they shall have a bottom rail 15 inches (380 mm) maximum above the pedestrian access route.

> **1105.6.2 Signals.** A pedestrian activated traffic signal complying with 1106 [another section of the guidelines] shall be provided for each segment of the crosswalk, including the splitter island. Signals shall clearly identify which crosswalk segment the signal serves." (Access Board, Draft Guidelines on Accessible Rights-of-Way, June 17, 2002, p. 26)

Signals would be required to comply with section 1105.6 which essentially sets for the requirements for Accessible Pedestrian Signal (APS) Systems consistent with the MUTCD, i.e., systems that, where provided, would include a locator tone and both audible and vibrating indications of the "walk" interval. Pedestrian signals would also be required at channelized right turn lanes. (A section on APS research will follow below.)

Although the section on Roundabouts in the advance draft guidelines constituted only a very small portion, it caused considerable concern among roundabout advocates, particularly traffic engineering and transportation professionals. By the time this advance draft language was published, roundabouts were rapidly gaining acceptance as being superior for intersection traffic control for vehicle safety, although there were few data on pedestrian use, and none at all on use of roundabouts without visual cues. Roundabouts had a proven record of safety, particularly in reduction of motorists' death and injury; reduced delay, stopping, and queuing; and lowered vehicle emissions. There was a fear that signal requirements could be costly to the point of making the roundabout options for intersection safety improvement unacceptable from an economics standpoint.

One of the "arguments" for installing roundabouts in lieu of, or to replace signals, was that their life cycle costs, considering installation and maintenance, were generally less than signals. One could argue that a significant barrier to the growth of roundabouts in the USA could mean forfeiting the lives of motorists who could have been saved by a roundabout. Civil rights provisions intended to provide equal opportunity for people with disabilities were also raised, with advocates noting that the “over accommodation” of vehicle travel had profoundly affected the independence of children, elders, and people who have vision loss, who are highly pedestrianized segments of our population. Spirited discussion and debate of these issues continues today, as does research attempting to find acceptable (“accessible”) low costs solutions that will not significantly affect the growth of roundabouts and negate the potential reduction of motorists’, intersection deaths. Albeit “dramatic,” these are the type of arguments that are presented, usually passionately. (Discussed further in Chapter IV.)

In November 2005, the Board issued substantial revisions to the draft guidelines in response to public and industry comments. (The comments may be read on the Access Board Website (http://www.access-board.gov/prowac/comments/index.htm))

The revised draft guidelines were re-formatted to use transportation metrics and language and was better coordinated with transportation industry standards and documents, particularly the MUTCD. Also, the June 17, 2002 advance draft guidelines had been formatted to supplement the ADA and ABA guidelines; the revised draft is formatted as a stand alone document.

From the comments received on the advance draft, ten key issues were identified for detailed analysis:

- crosswalk width,
- on-street parking,
- walking speed and pedestrian signal phase timing,
- elevators at pedestrian overpasses and underpasses,
- same-side alternate circulation routes,
- cross slope in crosswalks,
- detectable warnings,
- accessible pedestrian signals,
- roundabouts and roundabout signalization, and
- and alterations.

(Access Board, Revised Draft Guidelines for Accessible Public Rights-of-Way, November 23, 2005, p. 3)

The text regarding roundabouts was revised as follows:

2.3.1 Roundabouts

The change most directly relating to roundabout accessibility:

> "--Limited pedestrian signalization at roundabouts and channelized turn lanes to pedestrian crossings (to the splitter [island]) of two lanes of traffic or more." (Access Board, Revised Draft Guidelines for Accessible Public Rights-of-Way, November 23, 2005, p. 3 of 49, pdf version)

In their discussion of the change, the Access Board noted that research and comments received from both industry and consumers confirmed concerns about the usability (accessibility) of pedestrian crossings at roundabouts and channelized turn lanes. However, the revised draft went on to note:

> "- - access to additional data has indicated that well-designed roundabouts and channelized turn lanes with single-lane crossings can provide cues that make non- visual use possible." (Access Board Revised Draft Guidelines, for Accessible Public Rights-of-Way, November 23, 2005, p. 7, pdf version)

The revised sections dealing with roundabouts regarding "Separation" and "Signals" now read:

"R305.6.1 Separation. If walkways are curb-attached, there shall be a continuous and detectable edge treatment along the street side of the walkway wherever pedestrian crossing is not intended. Where chains, fencing, or railings are used, they shall have a bottom element 38 cm (15 in) maximum above the pedestrian access route."

"R305.6.2 Signals. At roundabouts with multilane crossings, a pedestrian activated signal complying with [ADAAG Section] R306 (Section R306 specifies Activated Pedestrian Signals (APS)) shall be provided for each segment of each crosswalk, including the splitter island. Signals shall clearly identify which crosswalk segment the signal serves." (Access Board Revised Draft Guidelines, for Accessible Public Rights-of-Way, November 23, 2005, p. 31 of 49, pdf version)

Another new feature in the revised draft is “Advisory” sections. Advisory notes, for informational purposes only, (similar to “Support” sections in the MUTCD) were added throughout the draft: The advisory note on separation and signals provide relevant information and, perhaps, insight into the Access Board’s current (as of November 23, 2005) “thinking” on satisfying the requirements of R305.6.1 Separation and R305.6.2 Signals.

“Advisory R305.6.1 Separation. Because the pedestrian crossings are located off to the side of the pedestrian route around the street or highway and noise from continuously circulating traffic may mask useful audible cues. Carefully delineated crosswalk approaches with plantings, low enclosures, curbs, or other defined edges can be effective in identifying the crossing location(s). European and Australian roundabout intersections extend a 6- cm (24-inch) width of tactile surface treatment from the centerline of the ramp or blended transition across the full width of the sidewalk to provide an underfoot cue. Several manufacturers make a surface of raised bars for this use. The detectable warning surface should not be used, since it indicates the edge of a street or highway.”

“Schemes that remove cyclists from the circulating street or highway by means of a ramp that angles from the curb lane to the sidewalk and then provides re-entry by means of a similar ramp beyond the pedestrian crossing may provide false cues about the location of a crossing to pedestrians who are using the edge of the sidewalk for wayfinding. Designers should consider ways to mitigate this hazard.”

"Advisory R305.6.2 Signals. There are many suitable demand signals for this application. Crossings at some roundabout intersections in Australia and the United Kingdom incorporate such systems, in which the driver first sees a flashing amber signal upon pedestrian activation and then a solid red while the pedestrian crosses to the splitter island (there is no green). These types of signals are also used in some U.S. cities at pedestrian crossings of arterial street or highways. The pedestrian pushbutton should be identifiable by a locator tone, and an accessible pedestrian signal incorporated to provide audible and vibrotactile notice of the gap created by the red signal. If properly signed, it need only be used occasionally by those who do not wish to rely solely on visual gap selection."

"Roundabout intersections with single-lane approach and exit legs are not required to provide signals." [emphasis added] (Access Board Revised Draft Guidelines, for Accessible Public Rights-of-Way, November 23, 2005, p. 31 of 49)

As discussed previously the Access Board has published a notice of proposed rulemaking (NPRM) in the Federal Register. After the guidelines are published as proposed rulemaking, the public may comment on them. Then they will be finalized and submitted to OMB for review. Once cleared by OMB the guidelines will be published in final form. Other Federal departments that are responsible for enforcing ADA and ABA must then modify their standards so that they are consistent with the final guidelines.

CHAPTER 3 - OVERVIEW OF ACCOMMODATING ALL ROUNDABOUT USERS

3.1 Introduction

3.1.1 With regard to motor vehicles.

The safety, operational, environmental, and economic benefits of modern roundabouts are well-established abroad and are beginning to be well documented in the United States (US).

3.1.2 With regard to pedestrians.

The author believes that increased safety of pedestrians has been adequately documented internationally; although US experience and studies have been limited. Some international practitioners believe that roundabouts are not appropriate where pedestrian usage is high. The usability of roundabout crossings by blind and low-vision pedestrians has been questioned by the US Access Board, orientation and mobility professionals, and advocates for blind and low-vision pedestrians in the US.

3.1.3 With regard to bicycles

Research on the safety of bicyclists traveling through roundabouts has been generally acceptable in foreign countries but needs additional study, particularly in the US. For example, the use of bicycle ramps onto the sidewalk in advance of the circulating roadway to permit cyclists to cross as pedestrians, a common design practice, could give a dangerous message to blind pedestrians.

Roundabout advocates in the traffic engineering community have been challenged to find ways to design roundabouts so they can provide usable gaps -- and information about when those gaps exist -- to pedestrians who don't use visual cues to travel. Audible information from vehicle passage through and around roundabouts has not proved useful (as it is at traditional crossings). The alternative or default for not doing so can be found in the discussion accompanying the draft guidelines for public rights-of-way published in June 2002:

> "To provide safer crossings at roundabouts, the draft guidelines would require pedestrian activated crossing signals at each roundabout crosswalk, including those at splitter islands." (Access Board, June 2002)

Motor Vehicles

3.1.4 Safety.

The author believes the greatest benefit promoting the growth of the modern roundabout is motor vehicle safety. Studies are available that document their great potential for decreasing intersection crashes, injuries, and fatalities. Although too easily accepted and shrugged off, the author believes that the numbers of persons killed and injured on US highways is a national tragedy. Earliest estimates for 2003 report 43,220 persons killed and 2,819,000 injured (NHTSA, 2003). A large component of these numbers is the numbers killed or injured in intersection crashes – 9,410 intersection related deaths in 2003 (NHTSA, 2002). From red light running alone 800 to 1,000 persons are killed annually. In 2002, 207,000 intersection crashes, 178,000 injuries and about 920 deaths were attributed to red light running (FHWA, Safety-Stop Red Light Running Facts, http://safety.fhwa.dot.gov/intersections/redl_facts.htm). Each year stop sign violations are associated with about 200 fatal crashes and 17,000 injury crashes. A study of stop sign violations examined the frequency of driver compliance with stop signs at non-signalized marked and unmarked pedestrian crosswalks near schools. Thirty-seven percent rolled through the crosswalk. Seven percent did not even slow down (National Safe Kids Campaign). There is a relatively simple traffic control “device” or system to dramatically reduce crashes, injury and death US intersections – the modern roundabout.

Numerous studies from the United Kingdom, Europe, Australia, New Zealand and other countries with thousands of modern roundabouts report significant decreases in vehicle crashes, injuries, and deaths at roundabouts, compared to traditional forms of intersection traffic control. In the US roundabouts are relatively new, and before and after crash data are limited. One study funded by the Insurance Institute for Highway Safety (IIHS) studied crashes before and after roundabouts had replaced signals at 24 intersections in the US. The study used state-of-the-art statistics and data from seven states and found a 39 percent decrease in all crashes, a 76 percent decrease in injury crashes and predicted a 90 percent decrease in fatal crashes (Persaud, Retting and Garder, 2001).

Maryland is a leading state in constructing modern roundabouts on state highways. They have eight that have been in use long enough to report reliable before and after crash statistics. Crashes per year dropped from 4.98 to 1.8, a 64% reduction. Injury crashes per year dropped from 3.0 to 0.5, an 83% reduction. Crash rates dropped from 1.53 per MEV to 0.97 per MEV. Injury crash rates dropped from 0.48 per MEV to 0.11 per MEV (Maryland, SHA, 2001).

Using the IIHS study results and NHTSA 2002 statistics, if there had been modern roundabouts at all US intersections in 2002, there would have been a potential for up to 8,469 fewer deaths and tens of thousands fewer injury crashes. Roundabouts at all intersections are unrealistic; however, the author believes converting just 50 percent of the intersections with crash histories would result in an annual decrease of several thousand motor vehicle intersection crashes.

At a well designed modern roundabout, speeds are low, generally less than 25 mph and deflection and entering angles are such that most crashes that do occur are same-direction sideswipe. The deadly, right angle crashes that occur at intersections with traditional traffic control, many at high speed, are essentially eliminated.

3.1.5 Operations.

Kansas State University (KSU) has been studying the operational effects of 11 roundabouts in Kansas since 1996. These studies have been reasonably consistent in showing decreases in vehicle delay, stopping, queuing, and degree of saturation at all roundabouts studied when compared to stop signs or signals. A summary of the average results from 11 Kansas roundabouts show the following reductions: Average Intersection Delay reduced 65%, Maximum Approach Delay reduced 71%, 95% Queue Length reduced 44%, Proportion of Vehicles Stopped reduced 52% and Degree of Saturation reduced 53%. All reductions were statistically significant (Russell, Mandavilli and Rys, 2004).

3.1.6 Environmental Effects.

Using data available from the Kansas Roundabout Operational studies, the computer program SIDRA was used to theoretically estimate vehicular emissions. In all cases, emissions were significantly reduced. This reduction was not unexpected as vehicular emissions are related to delay (excess idling) and stopping. Results from the KSU emissions studies show the following average results: Hydrocarbons reduced

65%, Carbon Monoxide reduced 42%, Oxides of Nitrogen reduced 47%, Carbon Dioxide reduced 58% (Vedula, 2004).

3.2 Pedestrians

3.2.1 Safety.

In 2003, 4,672 pedestrians -- 10.6 percent of all deaths from motor vehicle crashes in 2003 – were killed in motor vehicle crashes, another “too-high” statistic. About 23% were intersection related (NHTSA, 2003)

There is insufficient US data to make reliable conclusions regarding the safety of all pedestrians crossing at a roundabout. The low vehicular speed of a well designed roundabout -- 15 to 25 mph -- by itself creates a safer condition.

A literature review study of the relationship between vehicle speeds and pedestrian fatalities and injuries found that higher vehicular speeds are strongly associated with both a greater likelihood of pedestrian crash occurrence and more serious injuries. The study authors estimated that 5% of pedestrians would die when struck by a vehicle traveling 20 mph, compared with fatality rates of 40, 80 and nearly 100 at speeds of 30, 40 and 50 mph or more, respectively (Preusser and Leaf, 1999).

Another study concludes that the probability of a pedestrian being killed when hit by a vehicle is 3.5% when the vehicle is traveling at 15 mph but increases more than ten times to 37% at 31 mph and 83% at 44 mph (Limpert, 1994).

Studies have shown that a driver’s field of vision or peripheral vision angle, which spans 150° at 30 mph, decreases two thirds to 50° at 60 mph (Limpert, 1994). What this means is that motorists driving at 25 mph or faster have difficulty perceiving that a pedestrian is waiting to cross a roadway and making the decision to slow down and stop and the typical driver usually speeds up assuming another car will stop (Burrington, et al., 2000).

Also, International experience indicates that modern roundabouts increase pedestrian safety. A German before and after study of 25 intersections that were converted from stop signs or traffic signals to modern roundabouts showed a 75% decrease in average vehicle pedestrian crashes (Brilon, et al., 1993). In the Netherlands a before and after study of 181 intersections converted from stop signs or signals to modern roundabouts showed a 73% decrease in average vehicle – pedestrian crashes. (Schoon and Van Minnen, 1994). In Sweden, researchers compared empirical vehicle-pedestrian crash data from 72 roundabouts with expected values from comparable signalized intersections and concluded that for single lane roundabouts vehicle-pedestrian crashes at the roundabouts were 3 to 4 times lower than predicted crashes at comparable signalized intersections; and for two-lane roundabouts, crash risk was similar to comparable intersections (Brude and Larson, 2000). Researchers in the Netherlands examined the safety changes when 181 intersections (with ADTs from 4000 to 18000) were converted to roundabouts. All pedestrian injury crashes decreased 73% and fatalities decreased 89% (Schoon and van Minnen, 1993). Some critics argue; however, that few studies corrected for changes in volume of pedestrian use, which might be expected to drop.

Baranowski and Waddell reviewed pedestrian crash studies in France, Australia and Great Britain (Baranowski and Waddell, 2003). They cited Guichet (1992) from a study of 202 crashes at 179 urban roundabouts in France.

Table 3.1: Causes of Roundabout Crashes in France (4) (From Baranowski and Waddell, 2003)

Cause of Crash	Percent of Crashes
Entering traffic failing to yield to circulating traffic	36.6%
Loss of control inside the circulatory roadway	16.3%
Loss of control at entries	10.0%
Rear-end crashes at entries	7.4%
Sideswipe, mostly at two-lane exits with cyclists	5.9%
Running over pedestrians at marked crosswalks, mostly at two-lane entries	**5.9%**
Pedestrians on the circulatory roadway	3.5%
Loss of control at exits	2.5%
Head on collision at exits	2.5%
Weaving inside the circulatory roadway	2.5%

The major design recommendations from the Guichet study were: (Baranowski and Waddell, 2003)

- ensure motorists recognize the approach to the roundabout,
- avoid entries and exits with two or more lanes except for capacity requirements,
- separate the exit and entry by a splitter island,
- avoid perpendicular entries or very large radii,
- avoid very tight exit radii, and
- avoid oval-shaped roundabouts.

Baranowski and Waddell cited an Australian study by Jordan (1985), which evaluated 31 pedestrian crashes from 1980-83. The study found a roundabout pedestrian crash rate of one pedestrian crash per 100 roundabout years. They cited other statistics from the Jordan Australian study: of crashes that occurred in crosswalks, 78% occurred as the pedestrian began the crossing, with 22% as they left the splitter island. Of all pedestrian crashes, 39% were on entries, 35% were on exits, 16% were on the circulating roadway and 10% other. (Baranowski and Waddell, 2003)

They presented (paraphrased) several recommendations from the Jordan, Australian study: (Baranowski and Waddell, 2003)

- reduce vehicle approach speeds by providing adequate deflection on each approach,
- provide splitter islands as large as the site allows,
- provide clearly defined carriage and splitter island crossings,
- prohibit parking on approaches to improve visibility of pedestrians,
- assure street lighting illuminates the roundabout and the approaches,
- locate signs so users perceive an easily recognizable intersection layout, and
- locate signs and landscaping so that signs, pedestrians and bicyclists are not hidden.

Another Australian study by Tumber (1997) was also reviewed by Baranowski and Waddell (2003). They report that Tumber studied 64 pedestrian crashes at Melbourne roundabouts from 1987 to 1994. The study found 45 percent of the crashes were at roundabout entries; 27 percent were at exits, 17 percent on the circulating roadway; 3 percent on the footpath or splitter island and 8 percent at other locations. Baranowski and Waddell suggest that this analysis means that *speed reduction is nearly twice as important at entries* as it is at exits [emphasis added].

The Tumber study also concluded that pedestrian crashes were more severe at roundabouts than at all other intersection types. They offered six recommendations for pedestrian safety: (Baranowski and Waddell, 2003)

- Assure adequate vehicle speed reduction prior to pedestrian crossings.
- Set pedestrian crossings one to two car lengths back from yield lines so drivers encounter pedestrian and vehicle conflicts as separate tasks.
- Provide space on the splitter island for carriages, wheelchairs, etc., and make crossings flush with the pavement or as low as possible.
- Assure curbs cuts and splitter island crossings are in alignment.
- Assure visibility for pedestrians to see oncoming vehicles from all crossing points, and for drivers to see all crossing points from each approach.
- Use physical measures to discourage inappropriate pedestrian movements and direct pedestrian to crosswalks.

Baranowski and Waddell reviewed two studies in Great Britain – Lalani (1975) and Maycock and Hall (1984). The study by Lalani reported before and after crash experience from 38 intersections converted to roundabouts between 1970 and 1975, with the following results: Pedestrian crashes within 50 meters (165’) of the intersection were included in the study, and these dropped 46.2% after conversion to roundabouts, with fatal and serous pedestrian crashes down 70.0% At mini-roundabouts, pedestrian crashes dropped 37.5%, and fatal/serious pedestrian crashes dropped 60%.

The second study (Maycock and Hall (1984)) evaluated 431 “junction-years” of injury and crash data, including 1,427 crashes at 84, four-leg roundabouts. Pedestrian crashes (78) were 5.5 percent of the total. This study found no significant relationship between geometry and pedestrian crashes, and they developed the following formula:

$$A=.029(Q_V Q_P)^{0.5} \quad \text{Equation 3.1}$$

Where:

A = Annual Pedestrian Injury Crashes for a Roundabout Leg

Q_V = Entering + Exiting vehicle ADT (in thousands)

Q_P = Average Daily Pedestrian Crossing Volume (in thousands)

Baranowski and Waddell (2003) made the following conclusions:

- Tight-exit design shows little benefit for pedestrians by reducing speed and, in some cases, may endanger them by limiting sight-distance for drivers.
- Studies in both Australia and France show that most pedestrian crashes occur at roundabout entries, not exits.
- No relationship has been reported between pedestrian crashes and exit radius.
- Both British and Australian roundabout accident studies show significant reduction in pedestrian accidents after roundabouts are installed. Pedestrian accident rates increase with traffic volumes and pedestrian volumes. As pedestrian/vehicle crossing conflicts increase, crosswalk treatments should be improved accordingly and may warrant grade separation for some roundabout locations.
- Designed correctly, easy roundabout exits can improve roundabout capacity and reduce vehicle crashes, without increasing exit speeds or harming pedestrians.

3.3 Bicycles

Considering the low volume of bicycle traffic in the US plus the fact that roundabouts are relatively new, there is no reliable US data on the effect of roundabouts and bicycle travel. In countries such as Sweden and the Netherlands where bicycle travel is extensive, special provisions for bicycles are common. In the Netherlands, Schoon and Minnen studied bicycle safety and concluded the safest approach was to construct separate bike paths so that the bicycles crossed the path of vehicles outside of the roundabouts--usually yielding to motor vehicles (Schoon and Minnen, 1994). Because most Dutch people are cyclists, drivers there may be unusually compliant with yield-to-cyclist laws.

In the U.S., the primary recommendation is to not have bicycle lanes run through a roundabout, but to terminate them some distance prior to the roundabout. At the termination, a bicycle ramp to an adjacent sidewalk is usually provided. Thus, a bicyclist has the option of riding through the roundabout or diverting to the sidewalk via the ramp and riding or walking his/her bicycle through the roundabout on the sidewalk shared with pedestrians. The US Access Board is concerned that a bicycle ramp at the sidewalk edge and in the direction of sidewalk travel offers an ambiguous cue about the location of a pedestrian crossing. Additionally, blindness organizations have expressed concern about the presence of relatively quiet devices, including Segways, scooters, and bicycles, on pedestrian walkways. This issue has come up on the KSU Roundabout listserve (ROUNDABOUTS@LISTSERV.KSU.EDU) and has generated considerable discussion. The bicycle ramp needs to be designed and marked in such a way that blind pedestrians cannot mistake it for an intersection ramp and head out into the roadway traffic lanes.

If riding through the roundabout, bicyclists are advised to ride in the center of a lane, particularly in one-lane roundabouts. They should be able to ride at 15 to 20 mph and safely mingle with traffic. The potential danger of riding on the edge of the roundabout circularatory roadway is that drivers may be tempted to pass them and crowd them off the lane or broadside them when making a turn into the exit leg.

3.4 Accessibility and Usability

Currently, the issue of accessibility may be the most controversial issue surrounding roundabouts. It is an issue that must be resolved. It needs to be satisfactorily resolved in such a way that a balanced solution accommodates all roundabout users and is not detrimental to new roundabout growth. A solution that discourages state and local agencies from constructing roundabouts because of cost or other requirements is one that could have the effect of discouraging an intersection traffic control with the potential of saving lives, thus costing hundreds of thousands of intersection-related motorists' deaths and injuries over time. On the other hand, some associated with the U.S. Access Board, orientation and mobility professionals and advocates for the blind and low-vision pedestrians argue that: if installing hundreds of new roundabouts has the effect of limiting mobility and choice for thousands of Americans who are most often pedestrians and transit users, the social and economic effects of this isolation and loss of independence may not be figured into the budget analysis that supports roadway design and construction.

3.5 Information for Blind and Low Vision Pedestrians

3.5.1 Background.

The author believes that there is a wide range of knowledge and/or understanding of the accessibility issue and some brief background is beneficial. The

Americans with Disabilities Act (ADA) was passed and signed into law to protect the civil rights of people with disabilities. The legislation authorizing the Access Board to develop guidelines to satisfy ADA and ABA legislation were detailed in Chapters 1 and 2.

The Access Board maintains that roundabouts as currently designed do not provide blind and low-vision pedestrians with the same access to crossing information as sighted pedestrians have. They define an accessible roundabout as one that "…will provide non-visual information about crosswalk and splitter island location, crossing direction, and safe crossing opportunities." (Access Board, August 2003).

3.5.2 Overview of Blind Pedestrian Problems

The most common techniques and cues used by blind peds at traditional intersections are based primarily on the sounds of traffic surges and streams. Pedestrians who are blind align themselves with the sounds of traffic flow parallel to their path and -- at fixed time - actuated signalized intersections -- begin to cross when there is a surge of through traffic next to and parallel to them. (Access Board, updated August 2003.) Also, at a traditional intersection the crossing is typically straight ahead, on the same line as the sidewalk, while roundabout crossings are to the side.

At roundabouts, there are no clear auditory cues that blind pedestrians can align themselves with. The sounds of circulating traffic in the circularatory roadway in the roundabout mask sounds of vehicles approaching the crosswalk. Also, the crossings are generally not in line with the approach sidewalk but one or two car lengths back from the roundabout entry yield line. The following are key roadway crossing tasks for the blind pedestrians at any intersection (Access Board, August 2003):

- detecting the intersection;
- locating the crosswalk and aligning the body in the direction of the crosswalk;
- analyzing the traffic pattern;
- detecting an appropriate time to initiate the crossing (at signalized intersections, determining the onset of the walk interval);
- remaining in the crosswalk during the crossing;
- monitoring traffic during the crossing; and
- detecting the destination sidewalk or median island.

At a roundabout it may be less clear where and when to cross. The key tasks and traffic characteristics specific to a roundabout are:

- finding the crosswalk;
- having sufficient safe crossing gaps in the traffic stream;
- identifying the gaps and or identifying when cars have stopped for the pedestrian;
- estimating the distances and direction to the splitter island and onto the far curb; and
- staying in the crosswalk.

In a response during the comment period for the draft guidelines, Retting pointed out that research by Guth, et al. (2002) determined that at low-volume, single lane roundabouts, pedestrians observed frequent periods of “all quiet” and suggested that this all quiet may be an effective strategy for identifying acceptable gaps, and that blind pedestrians can cross single-lane roundabouts with relatively little difficulty and risk

(Retting, October 25, 2002). The Guth findings and subsequent research indicate that two- and multilane roundabouts pose the greatest barriers.

More detailed information on issues with blind pedestrians follow and current research will be presented in Chapter IV.

3.5.3 Specific Issues with Blind Pedestrians

Bentzen, Barlow and Bond (2004) studied the challenges that blind pedestrians have at unfamiliar intersections. They note that blind and visually impaired pedestrians often travel in areas unfamiliar to them.

In this study, Bentzen et al. (2004), made descriptive analyses on broad measures of safety, orientation and need for assistance in crossing. The study and results were described as follows:

> "In each city, 16 blind participants crossed at unfamiliar, complex signalized intersections without accessible pedestrian signals. Results confirm that blind pedestrians have considerable difficulty locating crosswalks, aligning to cross, determining the onset of the walk interval, maintaining a straight crossing path, and completing crossings before the onset of traffic perpendicular to their path of travel."

Barlow (2004), an orientation and mobility (O&M) specialist, in a paper presented at the ITE Curb Ramp and Intersection Workshop (October 22-23, 2004) pointed out that, based on personal preference, pedestrians who are blind or visually impaired commonly travel to new locations and intersections and "figure them out" by "listening and exploring" and use different travel aids for obstacle and curb detection. Some aids are: (Barlow, 2004)

- long white cane,
- guide dog,
- vision aid, e.g., telescope, or
- electronic travel aid.

Orientation is maintained by a combination of a number of skills and information obtained by the environment in which they are traveling. Some examples are: (Barlow, 2004)

- awareness of slight changes and slopes underfoot, or a detectable change in surface texture,
- sidewalk, grass, or building lines,
- location of poles or trees,
- sound and travel paths of other pedestrians,
- smell/odors,
- knowledge of the area,
- traffic sounds, both parallel to travel path and perpendicular to travel path.

Barlow goes on to enumerate street crossing tasks: (Barlow, 2004)

1. locate edge of the street,
2. determine where to begin crossing (locate crosswalk),
3. establish crossing direction and alignment,
4. determine traffic control and use pushbutton, if necessary,
5. decide when to begin crossing,
6. maintain alignment during crossing,
7. monitor traffic during crossing,
8. recognize end of crossing (other side of the street).

Ashmed, et al. (2005) studied pedestrian behavior at roundabouts. The study involved using six blind and six sighted pedestrians negotiating crossings at a two-lane urban roundabout. In general, the study suggested that blind pedestrians miss more crossing opportunities and make riskier judgments than sighted pedestrians.

Some major conclusions of the study were: (Ashmed, et al., 2005)

- blind pedestrians waited three times longer to cross than sighted participants,
- about 6 percent of the blind participants' crossing attempts were judged dangerous enough to require intervention, compared to none for sighted pedestrians,
- drivers yielded frequently on the entry lanes but not the exit lanes, and
- sighted participants accepted drivers' yields, whereas blind participants rarely do so.

In a similar study, Guth, et al. (2005), described two experiments of street crossings at roundabouts under conditions of free flowing traffic. The first experiment was conducted at three roundabouts of varying size and traffic volume. The experiment was to have six blind and six sighted pedestrians judge whether gaps in traffic were long enough to safety cross. The second experiment evaluated drivers' response to pedestrians with and without such mobility devices as long canes and dog guides.

In the first study, it was found that: (Guth, et al., 2005)

- blind participants were nearly 2.5 times less likely to make correct judgments than sighted pedestrians,
- blind pedestrians took longer to detect crossable gaps,
- blind pedestrians were more likely to miss crossable gaps altogether, and
- these differences were statistically significant only at the two higher volume roundabouts.

In the second study, performed at a single lane roundabout, a mid-block crossing and a two-way stop controlled intersection. It was concluded that site - specific characteristics have a greater impact on drivers' yielding than did a mobility device. (Guth, et al., 2005)

The authors of the study made the following observations: (Guth, et al., 2005)

> "The findings of the first experiment suggest that crosswalks at roundabouts vary widely in the safety they afford to pedestrians. The results of the second experiment suggest that at some roundabouts, hearing-based judgments about when to initiate a street crossing may be more risky and inefficient than vision-based judgments."

The objective of research by Rouphail, et al. (2005) was to capture the gap acceptance behavior for both sighted and blind pedestrians near roundabouts, and integrate this behavior into a simulation model of pedestrian/vehicle operations at roundabouts. The simulation results indicated that: (Rouphail, et al., 2005)

- pedestrian delay increases in a nonlinear fashion as vehicle volume increased,
- the difference in pedestrian delays between crossing entry and exit legs is more pronounced for blind pedestrians, who experienced higher delays on the exit side, and
- placing a pedestrian - actuated, signalized crossing upstream or downstream of the roundabout results in delays to blind pedestrians that are comparable to those experienced by sighted pedestrians that cross at the unsignalized splitter island.

3.6 Moving Toward Solutions

The best hope for an acceptable, balanced solution that will not impede the great safety benefits of modern roundabouts to motorists is a major NCHRP research project (NCHRP 3-78A), which is currently underway. The stated objectives of this research project are as follows:

> "---- to recommend a range of geometric designs, traffic control devices, and other treatments that will make pedestrian crossings at roundabouts and channelized turn lanes useable by pedestrians with vision impairment. These recommendations should be suitable for inclusion in transportation-industry practice and policies, including the *AASHTO Policy on Geometric Design of Highways and Streets* and the FHWA *Manual on Uniform Traffic Control Devices*. Exploration of the proper balance among the needs of

passenger cars, trucks, pedestrians (including pedestrians with vision impairments), and bicycles is central to achieving the objectives of the research." (NCHRP RFP for Project 3-78A from http://www.trb.org/TRBNet/ProjectDisplay.asp?ProjectID=834)

Progress to date and other research will be presented in the next chapter.

Let's hope the above research finds solutions that find a balance acceptable to all users. In the meanwhile, designers should consider the issues identified by the Access Board and address them to the extent feasible in all new roundabout projects.

CHAPTER 4 - RESEARCH ON PEDESTRIANS, ACCESSIBILITY AND ACCESSIBLE ROUNDABOUTS

4.1 Accessibility Design and Operational Issues

The information in this section, unless specifically referenced otherwise, is excerpted from a bulletin on the Access Board website: "Pedestrian Access to Modern Roundabouts: Design and Operational Issues for Pedestrians who are Blind." (Access Board Website, Updated August 2003, accessed 3/28/2005, http://www.access-board.gov/research/roundabouts/bulletin.htm). This publication is important because it summarizes the concerns of the Access Board regarding accessibility of the modern roundabout to mobility challenged pedestrians. Since the Access Board has been designated by Federal legislation – the ABA, RA and revisions and the ADA – as the agency responsible for developing guidelines that will become enforceable standards that must be followed to be in compliance with the ABA and the ADA, understanding their concerns is of the utmost importance. In fact, rulemaking leading to enforceable standards for roundabouts (and numerous other features) as part of Public Rights of Way Accessibility Guidelines (PROWAG) has recently started with a notice of proposed rulemaking (NPR) in the Federal Register.

The bulletin, Pedestrian Access to Modern Roundabouts (Access Board Website, Updated August 2003, accessed 3/28/2005, p. 2)

- summarizes orientation and mobility techniques used by blind pedestrians,
- highlights key differences between roundabouts and traditional intersections,
- suggests approaches that may improve accessibility of roundabouts, and
- encourages transportation engineers and planners to implement and test design features to improve roundabout accessibility.

The Access Board bulletin notes that roundabouts reduce vehicle crashes but maintain that pedestrian safety “is less clear.” One issue that certain board members and blind advocates keep bringing up is the degree to which pedestrian volume may change after a signal installation is converted to a roundabout. They suggest a need for research on this issue. They further maintain that little is known about the use of roundabouts by older pedestrians, children and pedestrians with cognitive disabilities.

The ideal location for pedestrian crossings at roundabouts is not clear at this point in time. They are typically one or two car lengths back from the circular roadway, but there is little or no standardization. Thus, the first difficulty of a blind person is finding the crosswalk location, i.e., “wayfinding.”

The bulletin suggests the following improvements for wayfinding:

- well-defined walkway edges
- separated walkways, with landscaping at street edge to preclude prohibited crossings to the center island
- tactile markings across sidewalks to identify crossing locations
- bollards or architectural features to indicate crossing locations
- detectable warnings (separate from those at splitter islands) at the street edge
- perpendicular crossings; or where angled, use curbing for alignment cues
- high-contrast markings, and
- pedestrian lighting

(Pedestrian Access to Modern Roundabouts, 2005, p. 3)

See Appendix A for the full Bulletin: Access Board Views on Pedestrian Access to Modern Roundabouts: Design and Operational Issues for Blind Pedestrians.

4.2 Differences in Crossing at Roundabouts vs. Traditional Intersections

4.2.1 Traditional Intersections.

At signalized intersections, pedestrians who are blind generally use traffic sounds to align themselves properly for crossing and then cross when they hear a surge of traffic parallel to their direction. The cues they use include: (Pedestrian Access to Modern Roundabouts, 2005, p. 4)

- traffic sounds,
- orientation and slope of curb ramps,
- textural differences between street and sidewalk,
- detectable warnings underfoot,
- locator tones at pedestrian push buttons, and
- audible or vibrotactile information from accessible pedestrian signals (APS).

Key street-crossing tasks for the blind pedestrians include:

- detecting the intersection,
- locating the crosswalk and aligning the body in the direction of the crosswalk,
- analyzing the traffic pattern,
- detecting an appropriate time to initiate the crossing (at signalized intersections, determining the onset of the walk interval),
- remaining in the crosswalk during the crossing,
- monitoring traffic during the crossing, and
- detecting the destination sidewalk or median island.

(Pedestrian Access to Modern Roundabouts, 2005, p. 4)

When there are no sounds on the street parallel to the pedestrians' direction of travel, there are insufficient auditory cues and accessible pedestrian activated signal (APS) systems may be necessary.

4.2.2 Roundabout Intersections.

When traffic signals and stop signs regulate the flow of traffic, the "breaks in traffic flow provide identifiable and predictable periods – gaps – during which pedestrians can cross" (Pedestrian Access to Modern Roundabouts, 2005, p.3). Many blind persons are trained by Orientation and Mobility (O&M) specialists in these recognition techniques.

The bulletin maintains that selection of gaps at some roundabouts is "problematic" because traffic sounds provide ambiguous cues. Circulating traffic sounds can mask the sounds of vehicles near the pedestrian crossings. At the exit it may be particularly difficult to distinguish cues between an exiting vehicle and one staying in the circle. At the entry crosswalk, auditory cues may not make it clear if a driver intends to yield, i.e., stop, for a blind pedestrian or not.

The bulletin notes that although some research has shown that drivers yielding to pedestrian rates increase with low speeds, many drivers do not yield to blind pedestrians at crosswalks. Two other things that pose challenges to blind pedestrians are: 1. The curvilinear layout of roundabouts makes it a challenge to find information about the location and direction of the crosswalk and 2. The ambiguity or absence of traditional intersection traffic sounds makes it difficult to align their body with the crosswalk.

The bulletin does note that some non-visual, traditional street crossing methods may be appropriate at roundabouts, e.g., crossing during periods of “all quiet” that can occur at low-volume roundabouts. The bulletin does bring up a concern that as vehicles become quieter, auditory techniques may become less effective at both traditional intersections and roundabouts.

The bulletin quotes sections from the FHWA, “Roundabouts: An Informational Guide”:

> “It is expected that a visually impaired pedestrian with good travel skills must be able to arrive at an unfamiliar intersection and cross it with pre-existing skills and without special, intersection-specific training. Roundabouts pose problems at several points in the street crossing experience, from the perspective of information access.”
>
> “Unless these issues are addressed by design, the intersection is ‘inaccessible’ and may not be permissible under the ADA…[M]ore research is required to develop the information jurisdictions needed to determine where roundabouts may be appropriate and what design features may be appropriate for the disabled, such as audible signalized crossings.”

The bulletin also points out that Title II of the ADA requires new and altered facilities conducted, “---by, on behalf of, or for the use of state and local government entities are designed to be readily accessible and usable by people with disabilities (28CFR35.151).

The bulletin presents the following as improvements for speed control/yielding:

- “single lane crossings at entrance and exit
- raised crossings, especially at exit
- ‘YIELD-TO-PED’ markings/driver signs/beacons; if pedbutton, need voice message to clarify not a [traditional] RYG signal
- pedestrian lighting, and
- yield cameras”

(Pedestrian Access to Modern Roundabouts, 2005, p. 5)

In regard to design, the bulletin noted that current roundabout design practices “do not yield the same access to crossing information for blind and low vision pedestrians as for sighted pedestrians.” The bulletin goes on to “define” an accessible roundabout:

“An accessible roundabout will provide nonvisual information about crosswalk and splitter island location, crossing direction, and safe crossing opportunities.” (Pedestrian Access to Modern Roundabouts, 2005, p. 7)

Good advice for planners and engineers: The bulletin presents the following “good advice” for planners and engineers in the “business” of promoting and designing modern roundabouts.

“An understanding of the auditory, tactile, and other cues used by blind individuals as they negotiate intersections will aid engineers and planners in designing and building accessible roundabouts. Orientation and mobility (O&M) specialists can aid transportation professionals in understanding the demands of non-visual travel and the strategies that blind people use to successfully meet these demands. Much research and development work is needed to improve the usability of modern roundabouts by persons with blindness and visual impairments. It is essential that transportation engineers and planners involve themselves in this R&D by working to devise, implement and test design features with potential for improving accessibility" (Pedestrian Access to Modern Roundabouts, 2005, p. 7).

4.2.3 Improvements Worth Investigating

The bulletin goes on to suggest "promising avenues" for further investigation in four categories (Pedestrian Access to Modern Roundabouts, 2005, p. 7-9):

1. locating the crosswalk and establishing alignment,
2. detecting when it is appropriate to cross,
3. remaining in the crosswalk, and
4. detecting the destination sidewalk or splitter island

The details of these four categories of needs and potential improvements are reproduced as Appendix A, in this report from the Access Board Bulletin "Design and Operational Issues for Blind Pedestrians."

4.3 Yielding for Pedestrians at Unsignalized Intersections

Texas Transportation Institute, (TTI) conducted a TCRP/NCHRP study to evaluate engineering treatments with potential to increase pedestrian safety at marked crosswalks. (K. Fitzpatrick, et al.., 2005, Turner, et al.., January 2006) Motorist yielding behavior data was collected at several locations (42 sites in 7 different states) using both staged crossings by researchers and observations of the general public.

4.3.1 Background

Turner, et al. noted that many pedestrians find it difficult and feel unsafe crossing busy arterial streets where there is no signal. They cited two studies addressing the issue of marked vs. unmarked crosswalks: (Zeeger, et al., March 2002) and Zeeger, et al., May 2001). In the 2002 report, Zeeger provided recommendations for the use of marked crosswalks for varying street widths and traffic volumes. These recommendations were supported by the 2001 study which showed that, above certain roadway widths and traffic volumes, *unmarked* crosswalks had lower crash rates than marked crosswalks. Many engineers interpreted this result to mean that crosswalks should not be provided on wide arterial streets. However, the 2002 report indicated the roadway and traffic speed at which engineers should consider traffic control devices *in addition to* crosswalks.
(see http://www.walkinginfo.org/pedsafe/moreinfo_crosswalk.cfm)

As additional devices to consider, Zeeger (2002) recommended:

- traffic claming – road narrowing and curb extensions,
- traffic signals with pedestrian signals,
- raised medians, and
- enhanced overhead lighting.

In another report, Lalani (2001) compiled the following inventory of alternate treatments to improve the safety of a marked crosswalk: (Lalani as cited in Turner, et al., 2006)

- supplemental high-visibility signs and markings,
- advance placement of STOP or YIELD limit lines, (Note: 2003 MUTCD calls them Yeild Lines)
- pavement legends for pedestrians,
- overhead and side mounted flashing beacons, lights and signs,
- in-roadway warning lights,
- pedestrian crossing flags,
- innovative traffic signal control strategies,
- median refuge islands,
- traffic calming measures,
- street lighting,
- turn restrictions, and
- miscellaneous other treatments such as curb ramps, tactile surfaces, pedestrian railing, etc.

However, they made no recommendations about where these treatments would be effective.

Turner, et al. (2006) summarized the literature review conducted by the TTI study team. (Turner, et al., 2006) A synopsis of Crossing Treatments is presented below in Table 4.1.

A literature review by the research team found numerous reports and articles evaluating the effectiveness of various pedestrian crossing treatments. Most of the available literature reported effectiveness in terms other than actual crash rate reductions. In many cases, surrogate Methods of Effectiveness (MOEs) for pedestrian safety were used, such as motorist yielding, vehicle-pedestrian conflicts, vehicle braking distance, vehicle speeds, and pedestrian behavior. The most common MOE reported in the literature was motorist yielding (or stopping) where required for pedestrians in crosswalks. Motorist yielding was expressed as the percentage of motorists that yielded when one or more pedestrians were present, as shown below in Table 4.2.

Table 4.1: Synopsis of Crossing Treatments (Table A-3 from TTI Report, Improving Pedestrian Safety at Unsignalized Crossings)

Treatment	Characteristics
Advance Signing	~ Provides additional notification to drivers that a crosswalk is near
Advance Stop Line and Sign	~ Vehicle stop line is moved back from the crosswalk
Median Refuge Island	~ Accessible pedestrian path within a raised median
Raised Crosswalk	~ Crosswalk surface elevated above driving lanes
Curb Extension	~ Curb adjacent to crosswalk lengthened by the width of the parking lane
Roadway Narrowing	~ Reduced lane widths and/or number of vehicle lanes
Markings and Crossing Signs	~ Standard crosswalk markings and pedestrian crossing signs ~ Subject to *MUTCD* requirements
In-Street Pedestrian Crossing Signs	~ Regulatory signs placed in the street ~ Subject to *MUTCD* requirements
High-Visibility Signs and Markings	~ Warning devices placed at or in advance of the pedestrian crossing ~ Subject to *MUTCD* requirements
In-Roadway Warning Lights	~ Amber flashing lights mounted flush to the pavement surface at the crossing location
Pedestrian Crossing Flags	~ Square flags on a stick carried by pedestrians ~ Stored in sign-mounted holders on both sides of the street ~ Experimental; not currently in the *MUTCD*
Overhead Flashing Amber Beacons	~ Mounted on mast arms that extend over the roadway or on signposts at the roadside ~ Pedestrian activated ~ Subject to *MUTCD* requirements
Pedestrian Crossing Signal	~ Standard traffic signal at a pedestrian crosswalk ~ Pedestrian activated
Half Signal	~ Standard traffic signal on major road ~ Experimental; not currently in the *MUTCD*
HAWK Beacon Signal	~ Combination of a beacon flasher and a traffic control signal ~ Dwells in a dark mode; pedestrian activated ~ Used exclusively in Tucson and Pima County, Arizona ~ Experimental; not currently in the MUTCD
Pedestrian Beacon	~ Proposed device; not currently in the *MUTCD* ~ Pedestrian activated
Traffic Signal	~ Standard traffic signal at an intersection or midblock location ~ Pedestrian phase typically activated by a pushbutton ~ Subject to *MUTCD* requirements

Table 4.2: Summary of Motorist Yielding at Innovative Pedestrian Crossing Treatments. (Adapted from Turner, et al., 2006)

Crossing Treatment	Evaluation Studies*	Number of sites	Range in yielding (%)	Average yielding (%)
Half signal	(5)	1	99	99
HAWK signal beacon	(6)	1	93	93
In-roadway warning lights	(7,8,9,10,11)	11	8 to 100	66
Overhead flashing beacon (pushbutton activation)	(5,6,12,13,14)	10	13 to 91	52
Overhead flashing beacon (passive activation)	(15)	not available	not available	74
In-street crossing signs	(13)	7	44 to 97	77
High-visibility signs and markings	(13)	1	52	52

Note: 1. Additional detail for each evaluation study (as well as related literature on pedestrian crossing treatments) can be found in Appendices C and D of the final project report (Fitzpatrick, K. et al., 2005)
Note*: Reference number key: 5. Center for Urban Transportation Research 2000; 6. Nassi, R.B., 2001; 7. Whitlock & Weinburger Transportation, Inc, 1998; 8. Katz, Okitsu & Associates 2000; 9. Godfrey, D. and T. Mazzella, 1999; 10. Malek, M., 2001; 11. Prevedouros, P.D., 2001; 12. Fairfax, B.W., 1999; 13. Huang, H., C. Zeeger and R. Nassi, 2000.

The TTI, TCRP/NCHRP study was to recommend effective pedestrian crossing treatments at marked crosswalks and develop a revised MUTCD warrant for pedestrian traffic signals. Although data on other effectiveness measures was collected, study conclusions were based on motorist yielding compliance. (Turner, et al., 2006)

The research team categorized the crossing treatments into three basic types according to function and design: (Turner, et al., 2006)

1. **Red signal or beacon** – devices that display a circular red indication to motorists at the pedestrian crossing location. Examples (see Figure 4.1) include a midblock traffic signal, half signal, or HAWK signal beacon.
2. **Active when present** – devices that are designed to display a warning only when pedestrians are present or crossing the street. Examples (see Figure

4.2) include in-roadway warning lights, flashing amber beacons, and pedestrian crossing flags.

3. **Enhanced and/or high-visibility** – devices and design treatments that enhance: 1) the ability of pedestrians to cross the street, and 2) the visibility of the crossing location and pedestrians waiting to cross. Warning signs and markings in this category are present at the crossing location at all times. Examples (see Figure 4.3) include in-street pedestrian crossing signs, high-visibility signs and markings, and median refuge islands.

Note: Figures 1, 2 and 3 from the Turner, et al. 2006 paper follow as Figures 4.1, 4.2 & 4.3 respectfully.

4.3.2 Data Reduction and Analysis.

For the TTI TCRP/NCHRP study, motorist yielding compliance was calculated as follows: (Turner, et al., 2006)

$$\text{Motorist yielding compliance (\%)} = \frac{\text{number of motorists yielding to pedestrians}}{\text{total number of motorists that should have yielded}}$$

The researchers found that there was no statistical difference between the crossings staged by the research team and crossings by the general public. Therefore, they used the former because it was larger.

The TTI TCRP/NCHRP research team studied the statistical correlation between yielding behavior and the following site characteristics: (Turner, et al., 2006)

- crossing treatment type,
- speed limit of major street,
- number of lanes crossed,
- presence of parking lane,
- presence of bicycle lane,
- presence of curb extension,
- distance to nearest signal,
- designation as midblock crossing,
- type of crosswalk marking,
- pedestrian crossing volume, and
- peak hour vehicle volume.

The TTI TCRP/NCHRP research team developed the Table 4.3 which summarizes the motorist yielding data they collected from both staged and the general population, as well as a comparison to data available from other studies from the literature. From this table, the research team developed the following conclusions: (Turner, et al., 2006)

- The motorist yielding rates from staged pedestrians and general population pedestrians were in relatively close agreement for most crossing treatments.
- Red signal or beacon treatments consistently perform well, with compliance rates above 94 percent.

- Pedestrian crossing flags and in-street crossing signs also were effective in prompting motorist yielding, achieving 65 and 87 percent compliance, respectively, and
- The measured compliance rates for many crossing treatments varied considerably among sites.

Midblock Traffic Signal

Characteristics

- A midblock signal is a standard traffic signal that is not located at an intersecting cross street.
- The pedestrian phase for a midblock signal is typically activated by a pushbutton and can consist of a steady red indication or a sequence of steady red then flashing red indications.
- A midblock signal typically dwells in steady green (or green arrow).
- A supplemental sign is typically used to indicate the signal is for pedestrians.
- The signal is subject to requirements specified in the MUTCD.

Half signal (Intersection pedestrian signal)

Characteristics

- A half signal is a standard traffic signal (with red, yellow, and green indications) that is located at a minor cross street with STOP sign control.
- The pedestrian phase for a half signal is typically activated by a pushbutton and consists of a steady red indication.
- In the U.S., most installed half signals dwell in steady green, whereas most half signals in British Columbia dwell in flashing green.
- This is an experimental traffic control device that is not currently included in the MUTCD.

HAWK signal beacon

Characteristics

- A HAWK signal beacon resembles an emergency vehicle beacon and only provides yellow and red indications.
- The pedestrian phase for a HAWK signal beacon is typically activated by a pushbutton and provides a sequence of flashing yellow, steady yellow, steady red, and flashing red indications.
- The HAWK signal beacon, used exclusively in Tucson and Pima County, Arizona, dwells in a dark mode.
- This is an experimental traffic control device that is not currently included in the MUTCD.

Figure 4.1: Red signal or beacon devices. (From Turner, et al., 2006, Figure 1)

In-Roadway Warning Lights

Characteristics

- In-roadway warning lights provide amber flashing lights that are mounted flush to the pavement surface at the crossing location.
- The flashing lights can be activated by either a pushbutton or a passive detection technology, such as bollards, video, or microwave sensors.
- This traffic control device is subject to requirements specified in the MUTCD.

Flashing Amber Beacons

Characteristics

- Overhead flashing amber beacons are mounted on mast arms that extend over the roadway at or in advance of the crossing location. Flashing amber beacons can also be mounted on signposts at the roadside.
- The flashing beacons can be activated by either a pushbutton or a passive detection technology, such as bollards, video, or microwave sensors.
- Continuously flashing beacons are not included in this category; they are included in the "Enhanced and/or High-visibility" category.
- This traffic control device is subject to requirements specified in the MUTCD.

Pedestrian Crossing Flags

Characteristics

- Pedestrian crossing flags are square flags (of various colors, typically orange, yellow, or fluorescent yellow-green) mounted to a stick that is held by pedestrians waiting to cross or while crossing the street.
- The flags are typically stored in sign-mounted holders on both sides of the street at crossing locations.
- This is an experimental device that is not currently included in the MUTCD.

Figure 4.2: "Active when present" devices. (From Turner, et al., 2006, Figure 2)

In-Street Pedestrian Crossing Signs

Characteristics

- In-street crossing signs are regulatory signs placed in the street (on lane edge lines and road centerlines, or in medians) to remind road users of laws regarding right-of-way at an unsignalized pedestrian crossing
- This traffic control device is subject to requirements specified in the MUTCD.

High-visibility Signs and Markings

Characteristics

- High-visibility signs and markings are warning devices placed at or in advance of the pedestrian crossing.
- These include fluorescent-yellow green pedestrian crossing signs, other pedestrian crossing signs, high-visibility crosswalk markings, and other devices that attempt to draw attention to the pedestrian crossing.
- Many of these high-visibility signs and markings are included in the MUTCD and are subject to requirements specified in the MUTCD.

Median Refuge Islands

Characteristics

- Median refuge islands are a design treatment that permits pedestrians to cross one direction of street traffic at a time.
- Median refuge islands are typically raised above the roadway surface with an accessible pedestrian path, typically offset to direct the view of crossing pedestrians at the second direction of street traffic.
- Two-way left turn lanes and other median treatments that vehicles routinely enter are not considered appropriate refuge for pedestrians.
- Curb extensions, roadway narrowing, raised crosswalks, and other design treatments or traffic calming elements can also be used to improve the safety of unsignalized pedestrian crossings.

Figure 4.3: "Active when present" devices. (From Turner, et al., 2006, Figure 2)

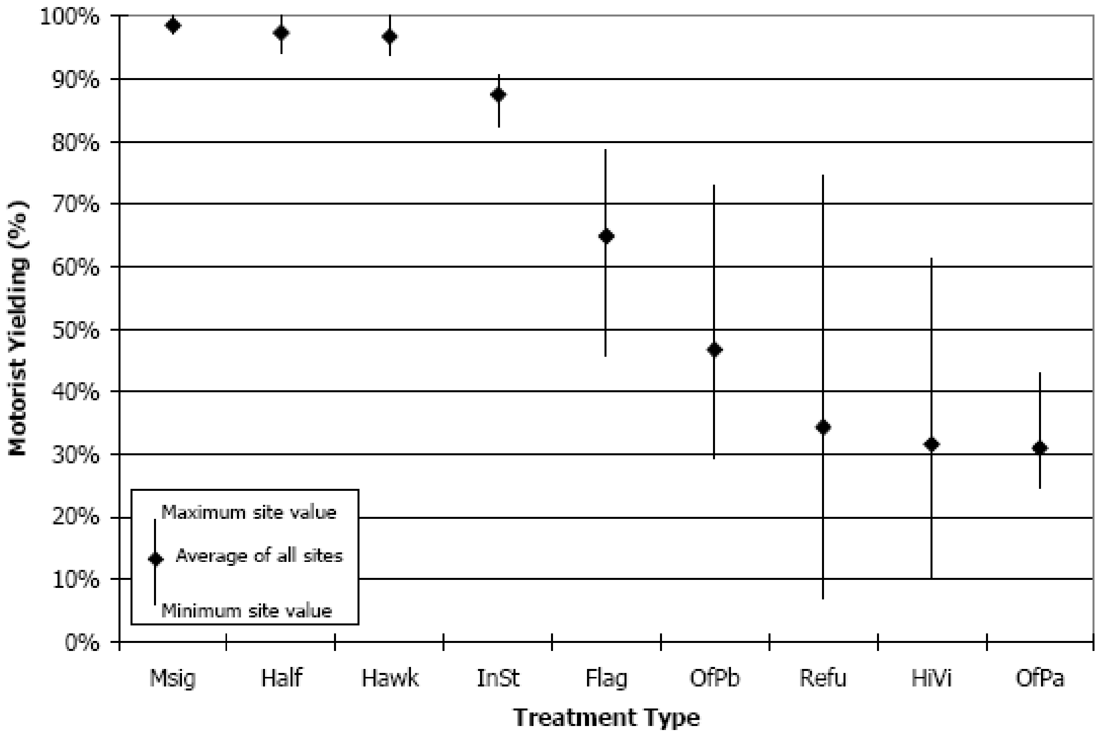
Table 4.3: Summary of Motorist Yielding Compliance from Three Sources, (from Turner, et al., 2006, p. 12)

Crossing Treatment Category	Crossing Treatment	TCRP D-08/NCHRP 3-71 Study: Compliance - Staged pedestrian crossing: # of sites	Range (%)	Average (%)	Compliance – General population pedestrian crossing: # of sites	Range (%)	Average (%)	Other Studies: Compliance – Literature review (from Table 1): # of sites	Range (%)	Average (%)
Red Signal or Beacon	Midblock signal	2	97 to 100	99%	4	91 to 98	95%	n.a.	n.a.	n.a.
	Half signal	6	94 to 100	97%	6	96 to 100	98%	1	99	99%
	HAWK signal beacon	5	94 to 100	97%	5	98 to 100	99%	1	93	93%
Active when Present	In-roadway warning lights	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	11	8 to 100	66%
	Overhead flashing beacon (pushbutton activation)	3	29 to 73	47%	4	38 to 62	49%	10	13 to 91	52%
	Overhead flashing beacon (passive activation)	3	25 to 43	31%	3	61 to 73	67%	n.a.	n.a.	74%
	Pedestrian crossing flags	6	46 to 79	65%	4	72 to 80	74%	n.a.	n.a.	n.a.
Enhanced and/or High-visibility	In-street crossing signs (25 to 30 mph speed limit)	3	82 to 91	87%	3	84 to 97	90%	7	44 to 97	77%
	High-visibility signs and markings (35 mph speed limit)	2	10 to 24	17%	2	4 to 35	20%	n.a.	n.a.	n.a.
	High-visibility signs and markings (25 mph speed limit)	1	61	61%	1	91	91%	1	52	52%
	Median refuge islands	6	7 to 75	34%	7	7 to 54	29%	n.a.	n.a.	n.a.

Notes: "n.a." indicates that data were not collected or available in the literature.
The "Range" column represents the range of motorist yielding for all sites with the treatment.
The "Average" column represents the average value of motorist yielding for all sites with the treatment.
Metric conversion: 25 mph = 40 km/h; 30 mph = 50 km/h; 35 mph = 55 km/h; 40 mph = 65 km/h.

The Turner, et al., paper presented several figures to illustrate yielding compliance of the various treatments. Figure 4.4 below shows the comparison by crossing treatment. The research team also tested statistical differences of compliance rates between crossing rates by two different methods. Their conclusion from this analysis was:

It is clear that the three devices listed as 'red signal or beacon' had statistically similar mean compliance rates – greater than 97 percent – and all of the group were more effective than the other treatments.[Emphasis Added] (Turner, et al., 2006).



Abbreviations: Msig=midblock signal; Half=half signal; Hawk=HAWK signal beacon; InSt=in-street crossing signs; Flag=pedestrian crossing flags; OfPb=overhead flashing beacons (pushbutton activation); Refu=median refuge island; HiVi=high-visibility signs and markings; OfPa = overhead flashing beacons (passive activation)

Figure 4.4 Site average and range for motorist yielding by crossing treatment (from Turner, et al., 2006)

The study made the following conclusions: (Turner, et al., 2006)

- The type of crossing treatment does have an impact on motorist yielding. (These red signals or beacon devices had compliance rates greater than 95 percent and include mid-block signals, half signals and HAWK signal beacons.) Pedestrian flags and in-street signs were effective (65 and 85 percent) on low-volume, two lane roadways.
- The measured motorist yielding for many crossing treatments varied considerably among sites. (Other factors include traffic volume, roadway width, street environment, etc.)

- The number of lanes being crossed can effect the performance of treatments. (The four-lane sites had much lower compliance rates than the two-lane sites.)
- The posted speed limit can affect the performance of treatments (compliance rates for devices on 25 mph streets all were above 60 percent; compliance rates as low as 15 percent were found for streets with a 35 mph speed limit.)

The authors provided the following recommendations: (Turner, et al., 2006)

- *An implementation matrix is needed to assist in the selection of appropriate treatment(s) for pedestrian crossings with known ranges of traffic volumes and road widths.* A draft of this implementation matrix has been developed by the research team and is currently undergoing review by the project panel. This implementation matrix will recommend a specific treatment category (e.g., red signal or beacon, active when present, or enhanced and/or high-visibility devices) when road widths, traffic volumes, and pedestrian volumes are input. Once finalized, this implementation matrix will be published and distributed as a separate document (i.e., *Guidelines for Pedestrian Crossing Treatments*) through the TCRP/NCHRP website.
- *Red signal or beacon devices need to be added to the engineer's toolbox for pedestrian crossings.* The study results indicated that all red signal or beacon devices were effective at prompting high levels of motorist yielding on busy arterial streets. However, only a midblock traffic signal is currently recognized in the MUTCD, and the current pedestrian signal warrant is

very difficult to meet. Thus, in the current situation, engineers are unable to employ those traffic control devices that are most effective for pedestrians on wide arterial streets. The authors have presented information to the National Committee on Uniform Traffic Control Devices (NCUTCD) in an attempt to revise the pedestrian traffic signal warrant as well as recognize a new class of traffic control signals for pedestrians (to include the red signals and beacons evaluated in this study).

- *There is a need to better inform motorists and enforce the right-of-way laws at marked crosswalks.* In most (if not all) states, motorists are required by law to yield or stop for pedestrians in a marked crosswalk.

Additional Information:

The Transportation Research Board recently posted the ITT study report from which the above paper was taken on its website:

http://trb.org/news/blurb_detail.asp?id=6630

TCRP Report 112/NCHRP Report 562: Improving Pedestrian Safety at Unsignalized Crossings is available at:

http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_562.pdf

One of the tools developed in the study can be found in “NCHRP Report 562, Appendix A: “Guidelines for Pedestrian Crossing Treatments.” The Guidelines include procedures to determine what category of pedestrian crossing treatment is recommended, given crossing width, traffic volumes, traffic speed, and other site variables. A paper worksheet is included in the appendix and the authors of NCHRP Report 562 are working on a spreadsheet version as well.

Other research data is available in the NCHRP Report 562 appendices. Appendices B to O are published in a web-only document – "TCRP Web Only Document 30/ NCHRP Web-Only Document 91" at the Transportation Research Board (TRB) website http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_w91.pdf.

Information on three signals used in other countries and experimental in the USA – PELICAN, TOCAN and HAWK – is presented in Appendix B of this report.

4.4 Accessible Pedestrian Signals

There have been a number of studies on accessible pedestrian signals (APS). Access Board Guidelines (ADAAG) recommend APS. A study was conducted in which sixteen blind participants crossed at two complex intersections before and after installation of APS. The analysis included measures of crossing timing, orientation and independence. After installation of APS, delay in beginning crossing was reduced by approximately two seconds and there was significant improvement in beginning to cross during WALK, completing crossings before the onset of crossing traffic “green”, locating the crosswalk, aligning to cross and independence. (Barlow, Bentzen, Bond and Gubbe, 2006)

A similar study (Barlow, Bentzen and Scott, 2006) compared the effect of specific features of pushbutton – integrated APS on blind pedestrian ability to locate and correctly use pushbuttons and cross accurately. Variations in locator tone, pushbutton type, tactile arrow, actuation indicator, response to ambient sound, and vibrotactile WALK indication were studied. It was found that variations in these features made little difference to users familiar with these devices.

It was also concluded that:

“A fast tick WALK signal promoted the fastest onset of crossing, and is the preferred signal. However, speech WALK indications are needed where two APS are mounted on the same pole” (Barlow, Bentzen and Scott, 2006).

Wall, et al. (2003 and 2004) conducted a series of experiments to evaluate factors influencing the effectiveness of APS for visually impaired pedestrians. Participants crossed a 65.6-foot space simulating the width of a four-lane crossing. Their findings: (Wall, et al., 2003)

- the most robust effect was from a far side only audible indication as opposed to both sides simultaneous or alternately,
- providing auditory guidance through the pedestrian clearance phase was beneficial,
- type of signal was not a major factor, however, and
- the placement and alignment of the speaker on the street corner can have a large impact on guiding visually impaired pedestrians across the street and indicating which crosswalk is being signaled.

In response to a previous article on pedestrian clearance intervals that suggested that the pedestrian clearance interval should be lengthened to accommodate blind pedestrians, Wall, et al. (2001) argued that a more appropriate solution would be to provide blind pedestrians with audible information about the status of the light with APS. This would allow them to leave the curb as soon as the onset of the WALK. They also suggest:

> "Communication between the blindness community and traffic engineers, as well as access to updated information, is essential in designing intersections to make them easier for visually impaired pedestrians to use" (Wall, et al. 2001).

4.5 Driver Stopping for Pedestrian Behavior

Harrell (1994) studied factors that influenced 187 Canadian motorists to stop or not stop when blind pedestrians started to cross a busy street. Harrell found that motorists in his study were significantly more likely to stop for blind pedestrians. He also found that motorists were more likely to stop for pairs of pedestrians than for single pedestrians.

In Chapter 3 of the Florida Pedestrian Planning & Design Guide (2004). The guide makes some interesting (to this author) observations (paraphrased below and not listed here in any implied order of significance.)

- as many as 50 to 80 percent of drivers involved in pedestrian or bicycle crashes report that they did not see them until too late and many times they are telling the truth,
- research performed at Ohio State University in the 1970's (no references provided) showed that poorly trained or inexperienced drivers spend much of their time looking straight ahead taking in objects of low importance. Highly skilled drivers spend most of their time keeping eyes in motion, focusing on objects of great importance,
- the speed of the vehicle and driver pedestrian detection are directly correlated,
- when drivers see a pedestrian on or approaching the curb, they have to "predict" the pedestrian action. If the pedestrian is looking at the driver, some drivers would not react; if the pedestrian(s) is not looking while moving forward the driver will likely prepare to brake. However, an inexperienced driver may miss this cue and hit a pedestrian who continues to move forward,
- drivers tend to give various levels of respect to pedestrians based on:
  - the drivers' speed,

- acceptance of a gap when turning,
- competing visual needs,
- ability to deal with complex situations,
- traffic volume, and
- presence and speed of other vehicles, especially those alongside or behind them.

- even though laws in all states generally require a vehicle to stop when a pedestrian in the roadway is about to cross their path, many drivers tend not to yield to pedestrians.

Although stopping for pedestrian behavior of drivers tends to be regional, there is always a tendency to be more or less courteous based on a number of factors. Based on informal observations in a number of cities, the following can be implied about driver behavior. Motorists are likely to stop for a pedestrian when: (Human Factors and the Pedestrian, 2004)

- the motorist's speed is at 20 mph (32 km/h) or less,
- the motorist does not sense the impending danger of a trailing motorist,
- the motorist is not anxious to be somewhere,
- the pedestrian is a uniformed police officer,
- the pedestrian is a child, an older adult, a woman, or has an apparent disability,
- the pedestrian makes it clear that he/she is about to cross by looking at the motorist,

- the pedestrian points (extends an arm) indicating he/she is about to cross, and
- the pedestrian actually enters the street.

Motorists are not likely to stop when:

- the motorist speed exceeds 35 mph (56 km/h),
- a downstream traffic signal is likely to change to red, and
- the pedestrian is not a uniformed police officer.

Motorists rarely stop when:

- speeds are greater than 45 mph (72 km/h),
- a police cruiser is not in sight,
- the motorist fears personal attack from individuals in the area.

Unfortunately, the failure to slow or stop may occur even when the pedestrian is crossing in a crosswalk, and where continued motion of the motorist places the pedestrian in imminent danger. (Human Factors and the Pedestrian, 2004)

Observations of pedestrians in New York City, show that motorists and pedestrians fail to yield with about equal frequency with right turning maneuvers. (Human Factors and the Pedestrian, 2003) With vehicles' left turning movements drivers fail to yield to pedestrians 62 percent of the time, compared to a 38 percent failure rate for pedestrians. (Habib, 1980) There is a natural tendency for drivers to fixate on objects to their right. In a study by Shinar, et al. (1977) it was learned that driver eye fixations were 3.6 degrees to the right on right curves and almost straight ahead on left curves. Left turning vehicles are usually traveling at lethal speeds and older pedestrians are especially at risk. (Human Factors and the pedestrian, 2003)

Sauerburger (2003) presented an overview of drivers' stopping for blind pedestrians in the USA. She starts by making a point that FHWA literature regarding pedestrians seems to imply that the pedestrian is responsible for avoiding pedestrian-vehicle collisions and this is in spite of the fact that every state has laws requiring drivers to yield to pedestrians at crosswalks. She cites the following FHWA "advice" for pedestrians (Sauerburger, 2003):

> "Remember to make eye contact with drivers to ensure they see you. Don't take a walk signal, a green traffic light, or a driver for granted. **Crossing safely is your responsibility. Remember, it's up to you."** [*Emphasis is from original text*]

Sauerburger (2003) cites a study by Geruschat and Hassan (2003) of pedestrian crossings at two roundabouts in Annapolis, MD:

- 10 percent of drivers failed to yield to pedestrians where vehicles' entering speed at one roundabout was an average of 15 mph,
- 32 percent failed to yield where vehicles' entering speed at the other roundabout was an average of 24 mph,
- 46 percent did not yield when drivers exited at an average speed of 16 mph, and
- 80 percent did not yield when drivers exited at an average speed of 17 mph.

Sauerburger, one of several orientation and mobility (O&M) specialists who conducted studies at the Towson, MD roundabout to determine how blind persons could cross safely, found that generally, very few drivers stopped when O&M specialists stepped off a curb with long white canes extended into the street at the roundabouts' exit crosswalks, even though there were also prominent in-street signs reminding drivers to stop for pedestrians.

In a Geruschat and Hassan (2003) study (cited in the Sauerburger (2003) paper), at the Annapolis roundabouts researchers stepped off the curb into the crosswalk with a long white cane extended into drivers' paths. With drivers at an average speed of 24 mph, 63 percent did not yield to subjects with an extended white cane and one foot in the crosswalk – as required by "white cane" laws. It was also noted that drivers' rate of yielding to pedestrians without canes was 10 percent.

Blind pedestrians must determine gaps auditorially. They must be able to "consistently and reliably" hear the sound of approaching vehicles far enough to give them sufficient warning to allow them to complete the crossing. (Sauerburger, 2003) Intersections must have periods of complete quiet for auditory cues to be effective. Competing noises and quieter cars make this very difficult. Also, when drivers do stop for blind people, competing noises and sounds from other vehicles make it very difficult to detect the stopped, idling vehicle.

4.5 Roundabouts: An Informational Guide

In the first significant report on the modern roundabout, (Roundabouts: An Informational Guide) pedestrians were briefly covered. (Robinson, et al., June 2000). The report pointed out that pedestrian crossing locations are a balance of convenience, pedestrian safety, and roundabout operations. Key points made regarding each element were: (Robinson, et al., June 2000)

Convenience: As close to the intersection as possible.

Pedestrian Safety: Minimize crossing distance, take advantage of a splitter island and locate crossings back from the yield line in increments of approximate vehicle length.

Roundabout Operations. A queuing analysis at the exit crosswalk may determine it should be more than one vehicle length away to prevent queuing in the circle. Also, pedestrians may be able to distinguish exiting vehicles better. They point out this latter supposition is not covered by research (at the time of this publication).

With the above "balance" issues in mind, the report set forth the following design guidelines for pedestrian crossings.

> *"Roundabout operations:* Roundabout operations (primarily vehicular) can also be affected by crosswalk locations, particularly on the exit. A queuing analysis at the exit crosswalk may determine that a crosswalk location of more than one vehicle length away may be required to reduce to an acceptable level the risk of queuing into the circulatory roadway. Pedestrians may be able to distinguish exiting vehicles from circulating vehicles (both visually and audibly) at crosswalk location further away from the roundabout, although this has not been confirmed by research." (Robinson, et al., June 2000)

With these issues in mind, pedestrian crossings should be designed as follows:

- “The pedestrian refuge should be a minimum width of 6 ft (1.8 m) to adequately provide shelter for persons pushing a stroller or walking a bicycle.
- At single-lane roundabouts, the pedestrian crossing should be located one vehicle-length (7.5 m [25 ft]) away from the yield line. At double-lane roundabouts, the pedestrian crossing should be located one, two, or three car lengths (approximately 7.5 m, 15 m, or 22.5 m [25 ft, 50 ft, or 75 ft]) away from the yield line.
- The pedestrian refuge should be designed at street level, rather than elevated to the height of the splitter island. This eliminates the need for ramps within the refuge area, which can be cumbersome for wheelchairs.
- Ramps should be provided on each end of the crosswalk to connect the crosswalk to other crosswalks around the roundabout and to the sidewalk network.
- It is recommended that a detectable warning surface, as recommended in the Americans with Disabilities Act Accessibility Guidelines (ADAAG) §4.29 (Detectable Warnings), be applied to the surface of the refuge within the splitter island. Note that the specific provision of the ADAAG requiring detectable warning surface at locations such as ramps and splitter islands (defined in the ADAAG as “hazardous vehicle areas”) was suspended until July 26, 2001 (ADAAG §4.29.5). Current ADAAG should be

followed. Where used, a detectable warning surface shall meet the following requirements:

— The detectable warning surface shall consist of raised truncated domes with a nominal diameter of 23 mm (0.9 in), a nominal height of 5 mm (0.2 in), and a nominal center-to-center spacing of 60 mm (2.35 in).
— The detectable warning surface shall contrast visually with adjoining surfaces, either light-on-dark or dark-on-light. The material used to provide contrast shall be an integral part of the walking surface.
— The detectable warning surface shall begin at the curb line and extend into the pedestrian refuge area a distance of 600 mm (24 in). This creates a minimum 600-mm (24-in) clear space between detectable warning surfaces for a minimum splitter island width of 1.8 m (6 ft) at the pedestrian crossing. This is a deviation from the requirements of (suspended) ADAAG §4.29.5, which requires a 915-mm (36-in) surface width. However, this deviation is necessary to enable visually impaired pedestrians to distinguish the two interfaces with vehicular traffic" (Robinson, et al., June 2000).

4.6 Applying Roundabouts in the United States

This National Cooperative Highway Research Program (NCHRP) project 3-65 had two objectives: (NCHRP 3-65, RFP, website, access 8/2/2006).

1. develop methods of estimating safety and operational impacts of US roundabouts and,
2. refine the design criteria used for them.

Task 8 of NCHRP 3-65 is to develop crash prediction models to estimate total crashes and fatal injury crashes separately. Also, a summary analysis is required to assess collision types and severity of multi-vehicles, single vehicles, pedestrians and bicycles.

Task 9 of NCHRP 3-65, is to develop geometric and traffic control design criteria for roundabouts, including (among other parameters)

> "…….treatments for bicycles and pedestrians (including pedestrians with disabilities and including the impact of accessible pedestrian signals on pedestrian access and vehicle operation); markings and signs" (NCHRP Project 3-65 RFP, website, accessed 8/2/2006)

4.7 Pedestrian Access to Roundabouts

Two Federal Highway Administration (FHWA) studies were intended to address double-lane accessibility issues for visually impaired pedestrians (Vaughan, Davis and Sauerburger, May 2006).

The first study was conducted on a closed course with rumble strip devices to evaluate the feasibility of these pavement treatments alerting blind pedestrians when vehicles have yielded to them. In this study, test drivers either yielded, failed to yield and departed according to a script. The second study was to examine drivers' yielding behavior at a two-lane roundabout and to test the rumble strip devices in an actual operational environment.

Three rows of sound strips, transverse to the pavement, were used in the study. One row was at the upstream edge of the crosswalk, the second was 20 feet upstream of the first row and the third was 24 feet upstream from the first row. The result was described as follows:

> “Seven individuals with severe visual impairment participated in the studies. In the first study, the audible strips increased the probability of detecting stopped vehicles and decreased pedestrian overall crossing time to make a detection by one second; however, they did not decrease the number of the false detections. The false detections without strips was 10 percent vs. 13 percent with the strips. These levels would not be acceptable for an acceptable system” (Vaughan, Davis and Sauerburger, May 2006).

In the second study, the rumble strip type sound strips treatments were not effective in the operating environment. The authors speculate that this may have been because the majority of vehicles stopped in the circle before crossing over the rumble strips. (Vaughan, Davis and Sauerburger, May 2006)

In addition to the sound strips the researchers placed yield to pedestrian signs (MUTCD, R1-5 and R1-6) between the two travel lanes at the roundabout exit. The purpose in using the signs was to attempt to get drivers to stop at the crosswalk instead of some distance away where a blind pedestrian would not hear an idling engine. The sign increased drivers' yielding from 11 percent in the control condition (no sign) to 16 percent.

Although statistically significant, the researchers maintain that the increase in stopping probably has no practical significance. Because visually impaired pedestrians are slower leaving the curb, they are not likely to benefit from a small increase in brief stops. Further, it appeared drivers who stopped only because of the sign were less patient. (Vaughan, Davis and Sauerburger, May 2006)

The authors also noted that the amount of increase in yielding from the signs was about the same as found by two previous studies. These two studies showed that motorist response to these signs varies from site to site. (City of Madison, 1999 and Huang, Nassi and Fairfax, 2000) Thus the authors of the FHWA studies cautioned about over generalizing results from their one location.

The researchers concluded that the treatments explored in these studies:

> "……do not appear to be promising for double-lane roundabouts, but should be explored further to see if they might work at single lane crossings" (Vaughan, Davis and Sauerburger, May 2006).

In their discussion of the study results the researchers pointed out that the participants were not trained to use the sound cues provided, nor were they informed of the treatment ahead of time. There were two reasons given for this approach: 1. Cost of training effort required and 2. they felt that the desirable treatment is one that is self explanatory and the study goal was to determine if the treatment would work without training. The authors speculate that: "it is conceivable that with training the detection performance of the sound strips would have been better.” (Vaughan, Davis and Sauerburger, May 2006)

There were some challenges in conducting the second real-world operational study. It had been assumed drivers would stop reasonably close to the crosswalk. However, in practice, where they stopped was generally unpredictable. Some stopped before exiting the roundabout (detrimental to roundabout vehicular operation). The YIELD HERE sign did not appear to be effective in increasing driver stopping location consistency.

Discussion in FHWA Study 2, included some interesting comments based on observation of driver stopping behavior. They pointed out that even though fewer then 15 percent stopped this did not mean that more than 85 percent did not see or respond to the pedestrians present. They observed indications that most drivers were aware of pedestrians. Many drivers slowed and it appeared they were attempting to get a “non verbal response” from the pedestrians, i.e., they likely would have stopped had the pedestrian moved forward to cross in response to their slowing. That is, the researchers hypothesized that many drivers perhaps would have stopped if the pedestrian had moved toward their path or taken more aggressive action to “take control of the crosswalk”. The researchers also made the interesting observations below.

> “Apparently, the drivers did not perceive that people carrying long white canes or using guide dogs might not have access to this type of nonverbal exchange. Other drivers appeared to be unwilling to stop. Some honked as they accelerated past the crosswalk. Other drivers visibly altered their path to move farther away from the pedestrians. This last behavior was

> not unique to drivers who did not stop. A few drivers who stopped in the near lane proceeded to move on by merging into the far lane. In the treatment condition, this lane change required sharp maneuvers to avoid striking the yield sign" (Vaughan, Davis and Sauerburger, May 2006).

The researchers presented a description of unexpected actions of some drivers that made conduct of the study challenging. (Vaughan, Davis and Sauerburger, May 2006) An unexpected finding was the proportion of trials in which pedestrians or motorists intervened to assist the visually impaired pedestrians. Although this level of altruism is encouraging, it would be better if the assistance were more effective. Some of the assistance greatly increased the risk to both the pedestrians and the motorists. For instance, some of the drivers who stopped to shout out that it was okay to cross did not monitor other traffic and did not warn the pedestrians that cars were continuing to go through the exit. When a transit bus attempted to blockade the exit, two vehicles accelerated around the bus and drove briskly through the crosswalk even though the bus obstructed these drivers' sight line to the pedestrians. Some pedestrians who stood in the crosswalk and signaled vehicles to yield watched the visually impaired pedestrians cross and turned their back to oncoming vehicles. Thus, the researchers cannot recommend reliance on passersby to resolve accessibility challenges to the visually impaired. (Vaughan, Davis and Sauerburger, May 2006)

4.8 Conclusions and Recommendations (Vaughan, Davis and Sauerburger, May 2006)

"Study 1 showed that a pavement treatment can increase the proportion of double-lane yields that are detected and decrease the amount of time required to detect the yields. False detections of yields were not reduced by the treatment, and this problem would still need to be addressed."

"Study 2 showed that motorists might stop long before they reach either the crosswalk or the roundabout exit, thus rendering pavement treatments in the exit ineffective. Before sound treatments similar to the one evaluated in these studies can be made to work, the frequency of motorists' yielding would need to increase, the location of the yields would need to be consistently closer to the crossing, motorists who yield would need to show more consistent patience, and the problem of false yield detection would need to be solved."

"A reliable yield detection system that did not rely on where motorists stop might be effective without changes in motorist behavior because wait times for double yields were relatively short."

"It is possible that a pavement treatment similar to that used in these studies would be effective at single-lane roundabouts. Study 1 showed that the second vehicle to yield is difficult to detect when it stops in the far lane, but is quite easy to detect when it stops in the near lane. Single-lane roundabouts do not present these challenges and might allow higher detection rates than were observed in study 1; however, single-lane operations were not observed in these studies, and the hypothesis that pavement treatments would be effective in the single-lane case requires empirical testing."

"The finding that motorists tend to stop well upstream of the crosswalk may suggest that roundabout crosswalks should be moved two or more vehicle lengths from the inscribed circle. Such a design would reduce the likelihood that vehicles yielding to pedestrians would obstruct the circular roadway. It might also increase the likelihood that an effective pavement treatment to cue visually impaired pedestrians can be devised. This hypothesis, too, requires empirical testing. Moving the crosswalks farther from the circular roadway may change driver behavior in several ways. For instance, it might decrease driver willingness to yield. Moving the crosswalks farther from the circular roadway would increase pedestrian travel distance; therefore, the effects of situating the crosswalks at a great distance from the circular roadway would need to be carefully studied to ensure any benefits that might result are not offset by a loss in benefits."

4.9 Crossing Solutions at Roundabouts and Channelized Turn Lanes NCHRP 3-78A (Initially 3-78)

The most relevant and arguably the most important research addressing the issue of roundabout accessibility is NCHRP 3-78A, Crossing Solutions at Roundabouts and Channelized Turn Lanes for Pedestrians with Vision Disabilities. Note: This project was initially designated as 3-78; however, it became 3-78A when the contract was moved from University of North Carolina at Chapel Hill to North Carolina State University. This research effort, currently (April 2007) underway, will build on NCHRP 3-65, "Applying Roundabouts in the United States," and NCHRP 3-72, "Lane Widths, Channelized Right Turns and Right Turn Deceleration Lanes in Urban and Suburban Areas," Channelized right turn lanes present some of the same challenges/problems to blind and low-vision pedestrians as roundabouts; however, only the issues relating to roundabouts will be reviewed here. The objective of NCHRP 3-78A is:

> "The objective of this research is to recommend a range of geometric designs, traffic control devices, and other treatments that will make pedestrian crossings at roundabouts and channelized turn lanes useable by pedestrians with vision impairment. These recommendations should be suitable for inclusion in transportation-industry practice and policies, including the *ASSHTO Policy on Geometric Design of Highways and Streets* and the FHWA *Manual on Uniform Traffic Control Devices*. Exploration of the proper balance among the needs of passenger cars, trucks, pedestrians (including pedestrians with vision impairments), and bicycles is central to achieving the objectives of the research"
> (NCHRP, website, NCHRP 3-78A).

Completion of the following tasks are required for successful completion of NCHRP 3-78A. (http://www4.trb.org/trb/crp.nsf/All+Projects/NCHRP+3-78A)

4.9.1 Phase I Tasks

(*1.*) Review the existing geometric design, traffic control, and other relevant literature (both domestic and international) to (a) Document the current state of practice with respect to pedestrian and vehicular control at roundabouts and channelized turn lanes and the subsequent impact on pedestrian safety and access, (b) Identify changes in the design or operation of roundabouts and channelized turn lanes as well as new technologies that have potential for improving usability and safety for pedestrians with vision impairment, and (c) Determine engineering policies and practices that may need to be revised as a result of the anticipated recommendations from this research effort. Augment the literature review by consulting with transportation professionals, orientation and mobility professionals, pedestrians with vision disabilities, and others with experience on this topic.

(*2.*) Define the information needs and functional requirements for pedestrians with vision disabilities at intersections. Two critical aspects are the ability of a visually impaired person to determine (a) where to cross and (b) when it is safe to cross. Based on those needs and requirements, establish a facility-performance specification. Develop draft criteria to be used to evaluate potential solutions. Describe how to apply the facility-performance specifications and the metrics to be used. (*3.*) Identify and examine changes to geometric design elements, traffic control devices, and other physical treatments that could be implemented to meet the facility-performance specification established in Task 2. The identification of potential solutions should attempt to address the full range of operational and geometric types of roundabouts and channelized turn lanes that are now in existence or anticipated to be built in the United States. (*4.*) Examine the application of a range of advanced technology (e.g., Intelligent Transportation Systems devices and wayfinding products) that could be used to meet the facility-performance specification established in Task 2. The immediate focus for this research effort will be on publicly provided infrastructure ITS solutions as opposed, for example, to hand-held products that might be carried by a pedestrian. (*5.*) Based on the results of Tasks 1 through 4, identify the most promising potential solutions. Refine the Phase II work plan to further evaluate potential solutions. At a minimum, the work plan should include the geometric and operational conditions under which each potential solution selected is expected to be appropriate, the number of field sites required for testing, a list of potential sites, the research methodology, and the evaluation criteria. (*6.*) Submit an interim report presenting the results of Tasks 1 through 5 in an accessible format. The interim report shall include the products of Tasks 1 through 4 as separate chapters and the updated work plan developed in Task 5. Document the results of Tasks 1 through 5 in an accessible format suitable for publication on the NCHRP website.

4.9.2 Phase II Tasks

(*7.*) Execute the work plan approved for Phase II. (*8.*) Develop cost estimates for the solutions that are recommended based on the Task 7 evaluation. The costs include initial implementation costs as well as operation and maintenance costs over the life-cycle of the solutions. These cost estimates apply only to solutions at newly constructed roundabouts and channelized right turn lanes, not to retrofits. (*9.*) Submit a final report that documents the entire research effort, recommends the most promising solutions, and includes the products of Tasks 1 through 4 as separate chapters. Where appropriate, the report should include appendices with recommended language for the *AASHTO Policy on Geometric Design of Highways and Streets*; the *AASHTO Guide for the Planning, Design, and Operation of Pedestrian Facilities*; the *AASHTO Guide for the Development of Bicycle Facilities*; the FHWA *Manual on Uniform Traffic Control Devices;* the *Traffic Control Devices Handbook;* and other documents as appropriate.

This project is currently underway and tasks through 4 of Phase I were completed as of June 2006. No published report is available at this time. (as of April 2007)

4.10 NCHRP 3-78A Literature Review Summary

4.10.1 Previous research.

Based on five years of previous (to May 2006) research by members of the 3-78A team (funded primarily by the National Institutes of Health (NIH)) and subsequent research, the 3-78A Interim Report summarized "What we currently know" about crossing problems by the blind and visually impaired" as follows: (Crossing Solutions at Roundabouts, May 2006)

- "Blind pedestrians have significant problems correctly identifying gaps between vehicles that are of sufficient length to permit a safe crossing (i.e., without having to assume that drivers, upon perceiving a pedestrian in their path will yield to the pedestrian).

- The gap detection problems experienced by blind pedestrians are more acute at roundabout exit lanes than at entry lanes.
- Blind pedestrians do not reliably detect and/or recognize some naturally occurring gaps in traffic.
- Many crossable gaps created by drivers who yield are also not detected by blind pedestrians who may be unable to perceive that the vehicle has yielded. A prototype automated yield detection capability was demonstrated under the NIH grant.
- Blind pedestrians often take "risky" gaps; i.e., gaps that are too short to permit them to reach the far side curb before the "approaching" car arrives at the crosswalk. While such "risky" gaps do not always result in collisions between a pedestrian and the approaching vehicle, they create a situation (a "conflict") that requires that the approaching driver take some action to avoid striking the pedestrian in the crosswalk. The likelihood that the driver under such conditions will yield to the pedestrian is a function of (a) the driver detection of the pedestrian, (b) the speed of the vehicle and the distance to the pedestrian, and (c) the driver's likelihood of being able to, or willing to, yield.
- Blind and visually impaired pedestrians are likely to experience longer delays.
- The work conducted by the NIH/National Eye Institute research team, as well as the anecdotal experience of blind travelers and orientation and mobility (O&M) instructors is that even though drivers are legally required to yield to

pedestrians in the crosswalk, the likelihood of their yielding is too low for a visually impaired pedestrian to use as an expectation of driver performance.

- Data collected by the Western Michigan team under the NIH grant and by TTI under TCRP D-8/NCHRP 3-71 suggests that vehicle speed may be inversely related to the likelihood of drivers yielding to pedestrians, i.e., the lower the speeds, the higher the likelihood of drivers yielding to pedestrians. Even so, the data show that the presence of a pedestrian (even a blind pedestrian with cane) in the crosswalk is not a sufficient condition to cause drivers to reliably yield.
- Blind pedestrians often experience difficulty in locating the crosswalk, and once having located it, may also experience difficulty in properly aligning to cross as well as maintaining that alignment during the crossing. Difficulty in locating the crosswalk has the effect of increasing overall travel time as well as potentially exposing individuals to risks associated with crossing at locations where their presence is not expected by motorists. The effects of crosswalk location errors can be compounded by veering errors during the crossing itself.
- The research reviewed (e.g., NCHRP 3-62 and NIH project) on the use of Accessible Pedestrian Signals (APS) has shown that, aside from the value of APS in identifying the pedestrian phase at a signalized intersection, the provision of a pushbutton locator tone can aid the blind individual in locating the crosswalk. Tactile arrows, when properly installed, may aid in establishing an initial alignment to cross.

- Work conducted under the NIH grant also demonstrated the potential for automated yield detection. Further experimental work is required before automated yield (and automated gap) detection capabilities are ready for full scale operational evaluation. Additional development and evaluation work on these capabilities is planned under a proposed extension to the original NIH/NEI grant. [NCHRP] 3-78A will continue to monitor this work, but will not include automated yield and automated gap detection as treatments to be evaluated under 3-78A.
- Outside the work conducted under the NIH grant at the Nashville, TN (multilane) roundabout and the FHWA study (Inman, Davis, and Sauerburger, 2005), there has been little or no work documenting the crossing performance attributes of blind and visually impaired pedestrians at multilane facilities. The Nashville data show that, for the blind and visually impaired pedestrian, crossing a multilane roundabout, especially the exit lane, is extremely difficult without some form of assistance. Six blind and six sighted pedestrians negotiated the double-lane urban roundabout in Nashville under high and low traffic volumes. Blind participants waited three times longer to cross than sighted participants. About 6% of the blind participants' crossing attempts were judged dangerous enough to require intervention, compared to none for sighted pedestrians. Drivers yielded frequently on the entry lanes but not the exit lanes. Sighted participants accepted drivers' yields, whereas blind participants rarely did so.

- FHWA investigations of the use of 'sound strips' to aid visually impaired pedestrians in detecting the presence of vehicles on multilane approaches indicated that such treatments did not provide adequate information to reliably detect vehicles yielding on multilane crossings. Their use at single lane facilities has been included within the range of treatments proposed for evaluation by 3-78A.

4.11 NCHRP 3-78A Study Background

Modern Roundabouts, even though relatively new to the US, have a proven record of reducing vehicle crashes at intersections, and are particularly valuable for reducing motorists' fatal and injury crashes at intersections. Although not as clear cut, European and some US studies indicate they are also safer for pedestrians. However, for those pedestrians who are blind or have serious visual impairments, the absence of visual clues, and the continuous nature of traffic flow, can significantly increase crossing difficulty, delay and risk (Guth, et al., 2005)

The purpose of NCHRP 3-78A is to identify solutions that can be shown to improve access at roundabouts and channelized turn lanes to blind and visually impaired pedestrians. (Note: only information dealing with modern roundabouts will be presented here.)

The research team conducting NCHRP 3-78A is a joint effort by North Carolina State University, Western Michigan University, Accessible Design for the Blind, Kittelson and Associates, Inc. and Midwest Research Institute. Unless specifically specified, material in this section is taken from a paper written by R.G. Hughes, principal investigator, for the 2006 Annual ITE Conference and notes from his presentation made available to the author of this report. (Hughes, R.G., paper, August 2006)

The purpose of Hughes' paper is to "provide an overview of the types of treatments being considered for implementation and operational evaluation in Phase II of the NCHRP 3-78A research project." (Hughes, R.G., paper, August 2006)

The 3-78A research team defines the functional requirements of an effective system as follows:

> "The functional requirements of an effective 'system' consist of (a) the presence of crossable gaps in traffic and (b) a high likelihood of drivers yielding to pedestrians, either voluntarily or in response to signal indications, especially during high traffic volume conditions where naturally occurring crossable gaps are minimized, and (c) blind pedestrians detecting gaps or yields." (Crossing Solutions at Roundabouts, May 2006)

According to the "functional specification" proposed by the 3-78A team, pedestrian accessibility can be expressed as a function of:

- "the likelihood of encountering crossable gaps,
- the likelihood that a pedestrian can reliably identify crossable gaps,
- the likelihood that drivers will yield to pedestrians, and
- the likelihood that pedestrians can reliably detect vehicles that are yielding"

(Hughes, R.G., paper, August 2006).

The paper presented several examples of "treatment to increase the likelihood of drivers yielding to pedestrians." These are summarized below.

<u>Static</u>. Static treatments include such things as pedestrian signs, pedestrian signs with flashers, etc. Examples are presented below in Figure 4.5.

Figure 4.5: Examples of 'Static' Pedestrian Sign (left); Pedestrian Signs with Continuously Flashing Beacon, Pole-Mounted (Center) and Mounted on Overhead Mast Arm (Right). (Images are from Hughes paper but originally from TTI Report on "Improving Pedestrian Safety at Unsiganlized Crossings (NCHRP 3-72))

The effectiveness of these current, static pedestrian signs and pavement markings is that they are associated in drivers' minds more with absence of pedestrians than pedestrian presence. Flashers, beacons, etc., do not improve the effectiveness if not related to pedestrian presence. Therefore, the 3-78A team proposes to increase the "information value" of the pedestrian sign by adding a "pedestrian activated" flashing beacon. The following are examples of pedestrian activated displays: (Hughes, R.G., paper 2006)

Figure 4.6: Examples of Pedestrian-Actuated Displays; on the left, a flashing beacon mounted on pole with pedestrian warning sign; on the right, in-pavement lighting. Image on right is from TTI NCHRP Report 562/TCRP Report 112, Appendix A. Image on left is from product description, Carmanah, Inc at http://www.roadlights.com/ **(referenced in Hughes paper)**

In addition, an APS component would be utilized to provide a positive audible indication to the pedestrian where pressing the “call button” for the flashing beacon.

Hughes points out that the effectiveness of pedestrian activated signals is somewhat reduced by the fact that their activation is not perfectly correlated with pedestrian presence because not all pedestrians use the call buttons at signalized crossings. An alternative would be an automated pedestrian detection system as shown below: (Hughes, R.G., paper 2006)

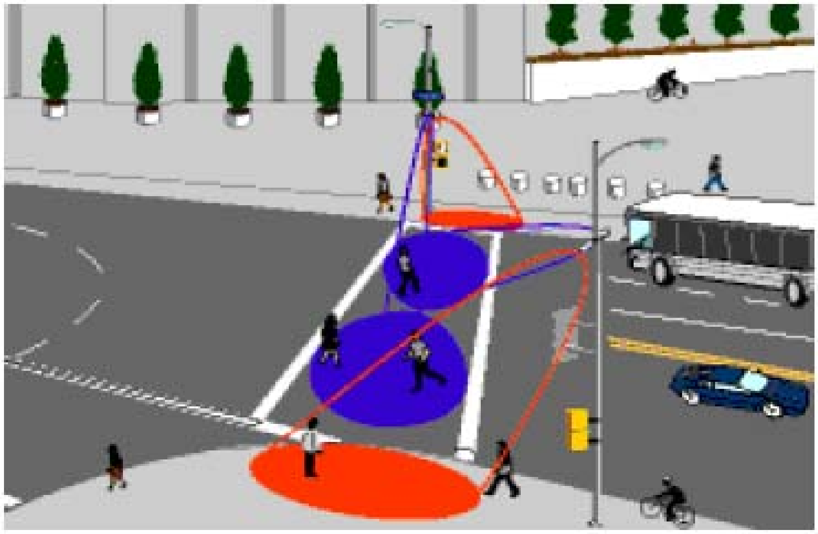


Figure 4.7: Concept of Automated Pedestrian Detection (from PedSmart website) http://www.walkinginfo.org/pedsmart/nookit.htm (referenced in Hughes paper)

One drawback, whether manual or automated, is that the signal would govern one lane at a time, i.e., it would have to be reactivated at the splitter island.

The 3-78A team's current, initial assessment of the utility of providing, "—more visually conspicuous, pedestrian – actuated signing," is as follows:

- "A relatively inexpensive treatment (compared to other alternatives),
- technical risk is low.
- Provides increased information value of the display, but is not ideal due to the "un-announced" nature of crossings by pedestrians who fail to press the button before crossing.
- Should increase the likelihood of drivers yielding when beacon is flashing.
- Provides no help to blind pedestrian in detecting vehicles that have yielded but which cannot be detected by the pedestrian.

- Can be installed at single and multilane roundabouts as well as channelized turn lanes.
- Solar-powered devices can minimize costs associated with having to provide conventional power" (Hughes, R.G., paper 2006).

4.11.1Detecting Yielding Vehicles

In addition to drivers' yielding, another problem is for blind and visually impaired pedestrians to detect when a vehicle has yielded (stopped). Hughes cites the study by Inman, Davis and Sauerburger (2005) (reviewed in detail previously in this report). Inman, et al., placed sound generating strips across the travel lanes to produce an auditory signal to give the pedestrian a cue to no moving vehicles. The Inman study indicated that detecting a vehicle in the far lane proved "problematic." The initial assessment of the 3-78A team of these treatments is that:

- It is relatively inexpensive to install.
- Effectiveness has not been studied under different road conditions (rain, snow, etc.),
- maintainability is unknown at this time.
- Reliable auditory detection of the sound pattern that is produced may be reduced by high ambient noise levels.
- Accurate discrimination of the sound 'pattern' produced may depend upon training an experience (i.e., may diminish over time).
- Does not aid the blind pedestrian's ability to discriminate crossable gaps in traffic.

- Inconsistency in where drivers yield, in terms of distance from the crosswalk, may mean that some yielding vehicles will produce no cue for the pedestrian to use.

  (Hughes, R.G., paper 2006, p. 6)

4.12 Signals at Proximal Crosswalks

The 3-78A team has "coined" two terms, "proximal" and "distal" to indicate whether a crossing is in close proximity to the circular lanes of the roundabout, e.g., one or two car lengths as is the usual case, (sometimes referred to by the 3-78A team as "splitter island crosswalks") or some greater distance away (to be defined by the research), i.e. somewhere between close proximity (proximal) and mid-block.

Basically, at this point in the research (prior to site selection, data collection and analysis) the 3-78A team is not recommending the usual one-or two-car lengths location of the crosswalk (proximal) based on the rationale, "---that signals would generate vehicle queues of varying lengths that would back up into the circulatory lane affecting basic operation and throughput of the roundabout." (Hughes, R.G., paper, August 2006). However, Hughes indicates that while not recommending signals at splitter island or proximal crosswalks, the team is not ruling out the use of signals or pedestrian beacons at distal crosswalk locations. In regard to the discussion above regarding signals, Hughes points out that it applies whether the signals were "conventional" or some version of pedestrian beacon or HAWK signal, renamed pedestrian hybrid signal in FHWA's 2007 NPA. (Note: This signal will be discussed in greater detail in a following section of this report.) Hughes points out that although not all activations of a signal would generate queues sufficient to impact roundabout operation, the team expects that likelihood. (Hughes, R.G., paper, August 2006). The likelihood of facility disruption can be calculated empirically given assumptions of vehicle and pedestrian volumes as well as frequency of signal activation.

4.12.1 Distal Crosswalk Treatments

For some single lane roundabouts with higher volumes and speeds (to be determined) the 3-78A team has recommended an approach (to be researched in Phase II) that would locate the pedestrian crossing at some increased distance, i.e., distal, to the circulatory lanes. Two possible methods are: 1. staggered, with exit distance from the circulatory lanes greater than the entry distance. An example from Gatineau, Quebec is shown below in Figure 4.8, or 2. Straight across at some yet-to-be-determined distance from the circulatory lane(s).

Figure 4.8: Example of 'staggered' median crosswalk installed in Gatineau, Quebec (Canada). (Image provided by personal contact of 3-78A principal investigator.)

The possible advantages of the distal exit lane in a staggered configuration are presented below:

- “Additional vehicle storage is provided for vehicles, which yield to pedestrians.
- More space is provided for the placement of sound strips or other devices intended to alert the pedestrian of approaching/yielding vehicles in the area between the circulatory lane and the distal crosswalk.
- The larger refuge island provides more pedestrian storage.
- [It]Accentuates the 2-stage nature of the crossing task.
- [It] Is conducive to the use of pedestrian-actuated beacons to increase the likelihood of drivers yielding on the exit lane and entry lanes.
- [It] Is conducive to the use of more traditional signals or pedestrian beacons (e.g., a HAWK device) on entry and/or exit lanes” (Hughes, R.G., paper, August 2006, p. 8).

The distance of the pedestrian crosswalk would be moved from the circulatory lane would be a function of:

- “the calculated need to store vehicles in the area between point at which vehicles exit the circulatory lane and the downstream crosswalk, as well as
- the effect on pedestrian behavior of the tradeoff between a perception of increased safety and a possible increase in overall travel time (i.e., the detour time).

  (Hughes, R.G., paper, August 2006, p. 9)

Where a distal crosswalk is used, it would be the only crossing, that is, it would not be in addition to a proximal or splitter island crosswalk. Cues to the crosswalk location could be provided by: (Hughes, R.G., paper, August 2006)

- landscaping,
- sidewalk orientation,
- fencing,
- directional surface tiles,
- locator tones, and/or
- other.

The distal crossing would still be divided into phases crossing one direction of travel at a time. This would require some type of median.

Hughes presents "key advantages" of a distal location:

- "It provides a separation of vehicle and pedestrian conflicts normally experienced as vehicles exit the circulatory lane.
- It provides for the use of all previously mentioned treatment alternatives.
- It is consistent with the ability to incorporate pedestrian-actuated beacons or signals (e.g., a HAWK).
- It supports either standard (straight through) or staggered/off-set crosswalk designs.
- It provides a consistent, perpendicular orientation of the crosswalk to the curb, thereby aiding proper alignment stet visually impaired pedestrians.
- It is capable of 'evolving' over the life cycle of the facility as more traffic control becomes required.

- The distal crosswalk location ‘may’ (but has not yet been demonstrated) to reduce the difficulty of the auditory discriminations that must be made by the blind and/or visually impaired pedestrian in conjunction with gap acceptance (stet, the distal location may, or may not, improve the gap and yield detection performance of the blind pedestrian)” (Hughes, R.G., paper, August 2006, p. 10).

There has been some research on automated gap and yield detection. However, automated capabilities will not be investigated by NCHRP 3-78A. These will be left to future research.

While the primary focus is on access for visually impaired pedestrians at roundabouts and channelized right-turn lanes, data will also be collected on the effect of the treatments to facilitate finding the crosswalk.

The NCHRP 3-78A team has ruled out education and enforcement, as effective solutions to roundabout access. In regard to enforcement, Hughes expresses the following viewpoint:

> “Enforcement is a component of the environment that serves to shape and maintain desired behavior, but for obvious reasons enforcement cannot be held totally responsible for drivers’ failing to yield. Neither the cost of uniformed enforcement presence nor the cost of automated enforcement is trivial and thus cannot be relied upon as primary determinants of whether or not a driver yields to a pedestrian” (Hughes, R.G., paper, August 2006, p. 12).

In regard to education, Hughes makes the following comments:

> "So, if we want better control over the behavior of drivers yielding to pedestrians, we need to design and utilize signs, markings, etc. in a manner more consistent with recognized principles of learned behavior and stimulus control. All things considered, drivers are displaying the very type of yielding behavior that one would expect given the nature of control associated with current principles of signing and marking and the inability of enforcement to detect and consequate inappropriate behavior. If we want better control, we need to give more attention to the variables of which improved behavioral control are a function. In this sense, it is the traffic engineering profession and not the driver who stands to benefit most from 'education'" (Hughes, R.G., paper, August 2006, p. 13).

4.13 Overview of NCHRP 3-78A Status as of August 2006

The following information in this section, unless otherwise noted, is from a Powerpoint presentation by the project principal investigator at the 2006 ITE Annual Meeting (Hughes, R.G., August 2006). *NOTE: Unless otherwise noted, all material in this section in quotation marks is quoted with permission from the Powerpoint presentation.*

This presentation provides an update of NCHRP 3-78A, and provides some insight into the research teams' viewpoints as of August 2006.

The two key behavioral issues being researched are:

- "finding the crosswalk and establishing correct alignment to cross, and
- deciding when it is safe to cross."

The two key engineering/operational issues are:

- “improving pedestrian access without destroying operational benefits of roundabouts, and
- system costs.”

Hughes goes on to summarize the U.S. Access Board position in one statement:

“Signalization may be the treatment of necessity, especially at multilane facilities.”

He goes on to acknowledge that the access board is “sensitive” to the concern of the traffic engineering community that a blanket requirement to install signals will “destroy” the growth of roundabouts and negate the positive safety benefits.

Hughes presented the goal of the NCHRP 3-78A team as follows:

- Preserve the positive benefits of roundabouts and continuous turn lanes without having to resort to signalization as an automatic first course of action.
- Define access such that compliance (improved access) can be defined and implemented along a continuum rather than as an ‘all or none’ approach.
- Begin with off-the-shelf ‘treatments’ and their measured contributions to improved access?

To meet the above goal, the NCHRP 3-78A team came up with the term “Functional Specification.” They define a functional specification as a relationship between what is implied by improved access and observed measures of effectiveness. It is *not* a warrant. To illustrate their concept, Hughes presented the following schematic, shown below in Figure 4.9.

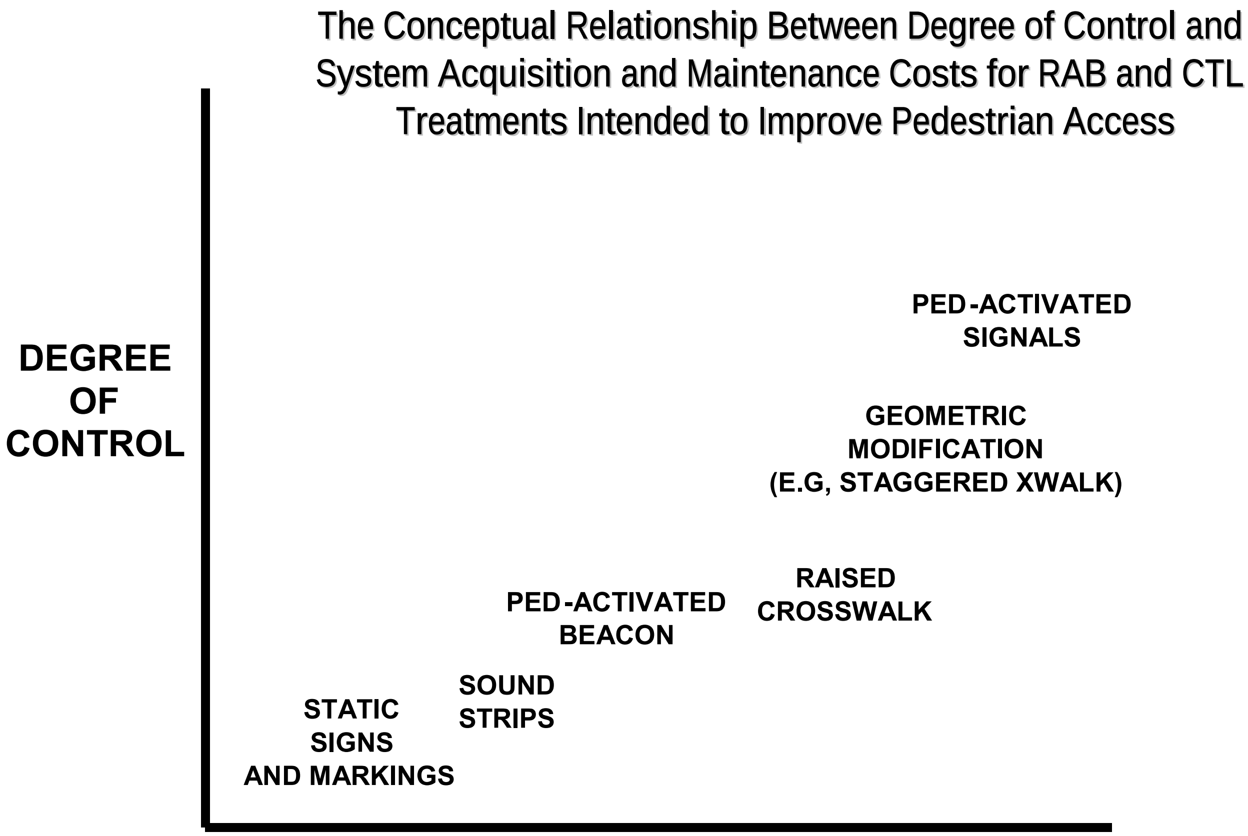


Figure 4.9: Acquisition and Maintenance Costs (from Hughes, R.G., August 2006).

The NCHRP 3-78A team developed the following list for improving access for blind pedestrians at modern roundabouts:

“For the current problem, improved access for the blind pedestrian means……

- decrease in the time it takes the pedestrian to ‘locate the crosswalk’,
- increased availability of crossable gaps (natural or ‘created’),
- increased pedestrian ability in correctly identify ‘crossable gaps’,
- decreased likelihood of a pedestrian taking a ‘risky’ gap,
- increased likelihood of drivers yielding to pedestrians,
- increased pedestrian ability to detect yielding vehicles,

- reduction in the overall delay experience by a blind pedestrian in crossing the facility, and
- accomplish goal without significant disruption to overall vehicle/system delay." (Hughes points this last bullet as the "big challenge")

Initially, the NCHRP 3-78A team developed a long list of promising treatments, including those in the categories of automated gap and yield detection (being researched by others). Overpasses and underpasses; education and training initiatives (considered necessary but not sufficient). They subjectively arrived at a short list, a range of treatments that the research team believes to ---"represent a set of feasible, low risk tools to be applied."

Hughes presented the following as attributes of the short list:

- "increasing the 'information value' of existing static signs through pedestrian-activation (benefit to driver) and APS feedback (benefit to blind),
- features for generating auditory assistance in yield detection,
- modifications to crosswalk location and geometry to potentially reduce task difficulty, and
- innovative uses of 'signals' (in the broad sense) to ensure access and to minimize pedestrian-induced vehicle delay."

As a baseline for evaluating the short list of treatments, the following "standard" modern roundabout will be used:

- "for single lane and multi-roundabouts, a marked crosswalk located at the splitter island (proximal) approximately 1-to-2 car lengths from the circulatory lane providing for a two-stage crossing and conventional static signing."

Hughes presented the following list of treatments to be evaluated in NCHRP 3-78A:

- "pedestrian actuated 'beacon' used in conjunction with existing signing and APS annunciation of activation,
- selective use of a raised pedestrian crosswalk,
- sound strips as auditory 'aid' to yield detection,
- 'proximal' and 'distal' locations for (roundabout) crosswalk,
- a modified, staggered crosswalk configuration,
- the use of conventional and/or HAWK signal at proximal and/or offset crosswalk locations, and
- for the channelized turn lane situation, a single crosswalk location midway between upstream and downstream locations (in conjunction with one or more of the treatments listed above)."

The final product of the NCHRP 3-78A research will be "clear and easily measurable criteria" for use by traffic engineers in evaluating present and future treatments to improve roundabout access by visually impaired pedestrians, e.g., effective treatments should have one or more of the following criteria:

- "increase the availability of crossable gaps,
- increase the likelihood that a visually impaired pedestrian can reliably detect the presence of a crossable gap,
- decrease the likelihood that a visually impaired pedestrian will take a 'risky' gap,
- increase the likelihood of drivers yielding to pedestrians, and

- increase the likelihood that a visually impaired pedestrian can detect yielding vehicles."

As of this writing (April 2007), the above could change as the research progresses. The work plan has not been finalized, and the team is looking for suitable sites and possible state or city help and involvement. The team believes that implementation is a local issue and not a research issue.

Tables 4.4 and 4.5 below are tentative lists of Treatment "Packages" that will be researched in the field.

Table 4.4: Treatment "Package" Recommendations for Single Lane Roundabouts

	Treatment	**Splitter Island Location**	**Offset Design**	**Distal Crosswalk**
Baseline	None			
Package 1	Sounds Strips	Yes	May be difficult to accommodate in retrofit. May be restricted to 'new' construction	Yes, on both entry and exit lanes
Package 2	Ped-actuated flashing yellow beacon	Yes		Yes
Package 3	Ped-actuated flashing yellow beacon plus sound strips	Yes		Yes
Package 4	Raised crosswalk	Yes		Yes
Package 5	HAWK beacon	May not be necessary at most single lane facilities but could be done		Yes

Table 4.5: Treatment "Package" Recommendations for Multilane Roundabouts

	Treatment	Splitter Island Location	Offset Design	Distal Crosswalk
Baseline	None			
Package 1	Sound Strips	N/A	N/A We have no reason to believe that the multiple threat problem gets any better!	N/A We have no reason to believe that the multiple threat problem gets any better!
Package 2	Ped-actuated flashing yellow beacon	Yes	Yes	Yes
Package 3	Ped-actuated beacon plus sound strips	N/A	Yes	Yes
Package 4	Raised crosswalk	Yes	Yes	Yes
Package 5	HAWK beacon	Yes	Yes	Yes

4.14 Next Phase

Phase II of NCHRP 3-78A began in the fall of 2006. The intent is to evaluate a range of possible solutions (as discussed above) having potential to improve access for visually impaired pedestrians. It is anticipated that different treatments will provide different levels of effectiveness to positively impact one or more elements of the "functional specification" presented above in this section.

4.14 Additional Information

Additional information on HAWK, PELICAN and TOCAN pedestrian signals can be found in Appendix B or accessed at http://dot.ci.tucson.az.us/traffic/tspedestrian.cfm. A video of HAWK operation is also available at this website. There has been some discussion if the HAWK signal, which is blank when not activated, was an acceptable device in conformance with the MUTCD. The concern among many traffic engineers is that a blank signal means “stop”, i.e., legally, has the effect of a stop sign. However, recent action by the NCUTCD took care of this concern in 2006.

> “The National Committee on Uniform Traffic Control Devices has reviewed the Tucson, AZ “Hawk” pedestrian traffic control device and has approved language designating such a configuration which rests in a “dark” mode as a pedestrian beacon (and not as a “signal” which shall operate full time with either green, yellow, or red displayed)” (Fred Ranck, email, 8/18/2006). In 2008, FHWA changed the name to pedestrian hybrid signal, as per their NPA 2008.

Thus, a dark pedestrian hybrid signal would not legally require a stop action by drivers. However, as other new devices presented to drivers, education is likely to be necessary before all drivers understand their proper response to a HAWK beacon.

CHAPTER 5 - PEDESTRIAN AND MOTORIST INTERACTION AT TWO KANSAS ROUNDABOUTS

As part of the K-TRAN study of the effects of ADA on roundabouts, vehicle-pedestrian interaction was to be observed in the field. Due to a lack of roundabouts with any significant numbers of pedestrians, only two were considered worthwhile for videotaping – Olathe and Lawrence, both near schools. At Olathe, the roundabout is at the intersection of an arterial and residential street in front of Olathe North H.S.; at Lawrence the roundabout is at the intersection of two collector streets near Langston Hughes Elementary School.

The analysis follows methodology developed by Harkey and Carter (2006) for a pedestrian observational study of digital video collected for NCHRP project 3-65. (Applying Roundabouts in the United States, 2006) In this project, data were collected for 769 pedestrian crossing events that occurred on 10 approaches, distributed among 7 roundabouts. The observational data acquired from DVDs and videotapes included variables such as crossing time and location, yield behaviors and conflicts. (Harkey and Carter, 2006) This study will be reviewed in the following sections. Analysis of the Kansas pedestrian data will follow the Harkey-Carter methodology, with the exception of crossing time.

5.1 Review of the Harkey and Carter Study

The objective of the study by Harkey and Carter (2006) was to perform an observational analysis to ---"characterize how pedestrians interact with motor vehicles at roundabouts, make safety assessments on the basis of these observations and determine if there is an association between observed behaviors and the geometric and/or operational characteristics" (Harkey and Carter, 2006) In the Kansas study, using only two roundabouts meant that data would be insufficient to relate the results to geometric characteristics.

The Harkey and Carter analysis resulted in a series of descriptive statistics defining the actions and behaviors of motorists and pedestrians. Several tables and graphs illustrating key relationships will be reproduced below.

In the Harkey-Carter study, a “site” was defined as an approach to a roundabout, i.e., a four-leg roundabout could account for up to four sites. Average values for the behavior at each site were produced then aggregated to produce overall results. These results were presented in terms of either entry legs or exit legs at the crosswalk location. (Harkey and Carter, 2006) This entry vs. exit behavior was separated, because of greater concerns by some of pedestrian safety at exit crosswalks (Applying Roundabouts in the United States, 2006)

The key to the Harkey-Carter study is the analysis of interaction between pedestrians and vehicles. Therefore, “interaction” was defined as: (Harkey and Carter, 2006)

> “Interaction is defined as the pedestrian either accepting or rejecting a gap when a vehicle was present.”

It was found that the majority of crossings by pedestrians involved no interaction. The pedestrian simply arrived at the crosswalk and crossed unimpeded. Overall percentages ranged from 22 to 29 percent on the entry leg and 30 to 35 percent on the exit leg.

For those pedestrians interacting with vehicles, the following categories were developed:

- *Normal* – crossed the street at a normal pace. None of the other behaviors below were observed, and the vehicle yielded.
- *Hesitates* – hesitated on the curb or splitter island due to an approaching vehicle. Most often, the hesitation occurred while the pedestrian made visual or other contact with the driver. Once this communication was made and the vehicle began slowing, the pedestrian would then proceed with the crossing.
- *Retreats* – began crossing and then retreated to the curb or splitter island due to an approaching vehicle.
- *Runs* – ran across the approach due to an oncoming vehicle. Note that running did not indicate that a conflict was eminent; it was a simple choice that was made by the pedestrian. Conflicts are covered in a later section of this report" (Harkey and Carter, 2006)

Harkey and Carter noted that in their study no "retreats" were observed.

Using the following categories of observed pedestrian behavior, Harkey and Carter plotted pedestrian crossing behaviors as shown below in Figures 5.1 (entry leg) and 5.2 (exit leg).

Note that following comments on the Figures are those of the author of this report and differ in some cases from the text of the Harkey and Carter (2006) paper.

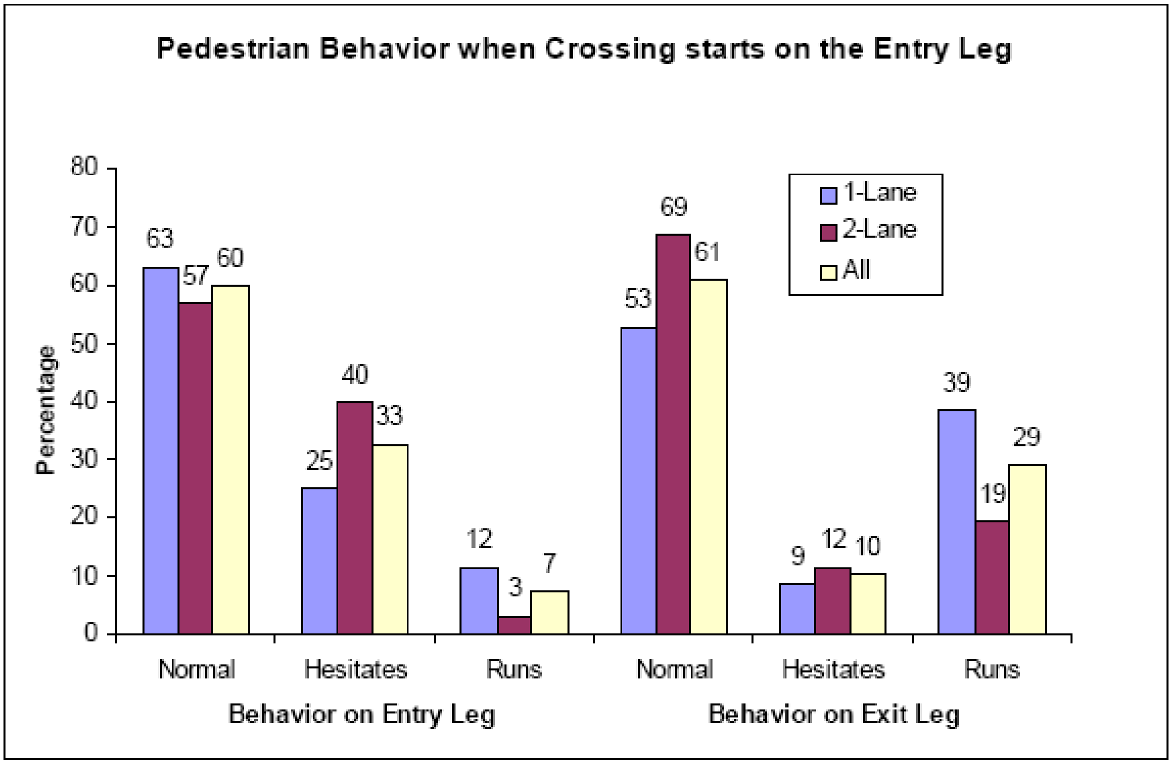


Figure 5.1: Pedestrian crossing behaviors when a vehicle was present and the crossing began on the entry leg. (Harkey and Carter, 2006)

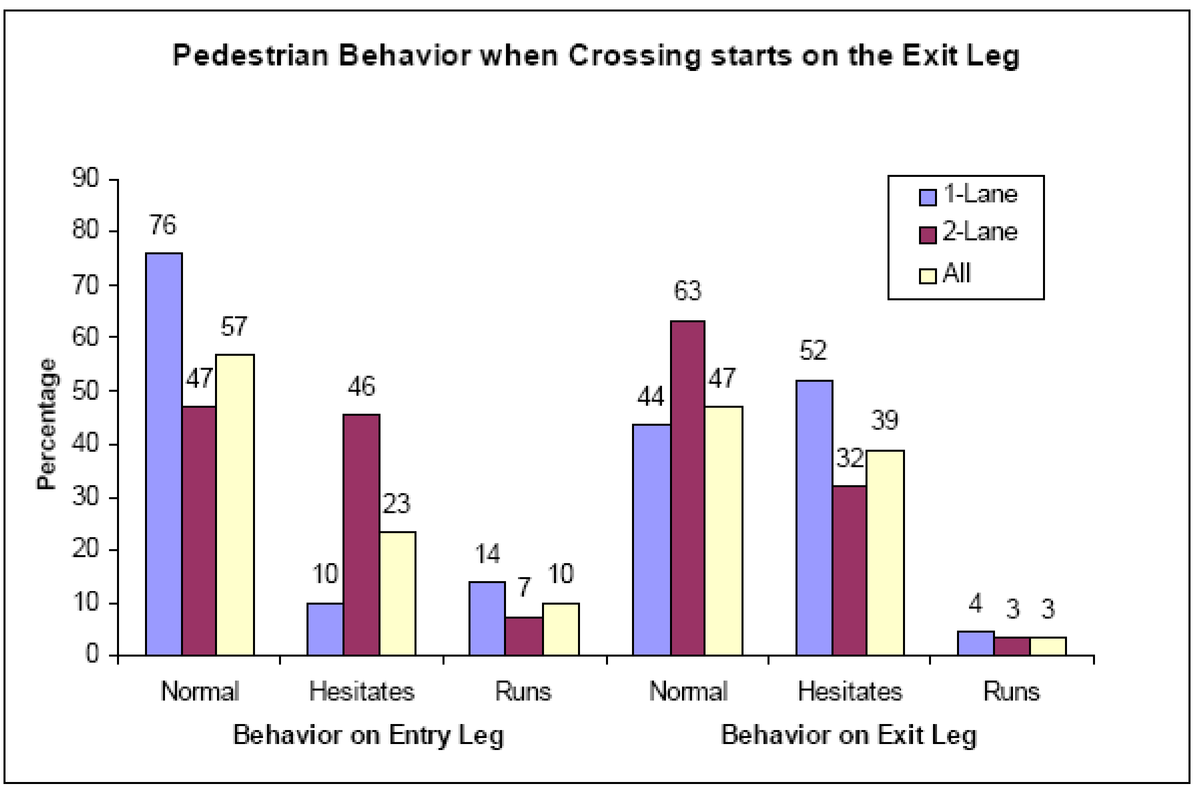


Figure 5.2: Pedestrian crossing behaviors when a vehicle was present and the crossing began on the exit leg. (Harkey and Carter, 2006)

For crossings that began on the entry leg it can be seen that the most-observed behavior on the entry leg was normal. (63 percent on one lane approaches and 57 percent on two-lane approaches with 53 and 69 percent respectively on the exit leg.) At the exit leg (hesitation at the splitter island) was much less – 9 percent for one lane exits and 12 percent for two-lane exits, than at the entry leg – 25 and 40 percent, respectively.

For crossings that began on the exit leg, the overall percentage of normal crossings was slightly lower than the entry lane starts. The most observed behavior for exit leg starts was also normal. For one-lane roundabouts hesitation was 52 percent on the exit (starting) leg and 10 percent on the splitter island. For two-lane roundabouts it was 32 percent on the exit leg and 46 percent on the splitter island. It can be seen that hesitation percentages decrease at the splitter island for all cases except two-lane where it increases from 32 to 46 percent for pedestrians starting from the exit leg.

It can be seen that for both crossing starts on the entry or exit leg, running percentages are higher for all cases when the pedestrian continues crossing from the splitter island. Running percentages were highest from the splitter island (exit leg) for starts on the entry lane.

Another crossing behavior observed was whether the crossing was made within a marked crosswalk or outside its boundaries. It was observed that more than 17 percent of the crossings at one-lane approaches and 12 percent at two-lane approaches occurred outside the crosswalk boundaries. (Harkey and Carter, 2006)

Harkey and Carter (2006) also defined three categories of motorist behavior.

- *Active Yield* – The motorist slowed or stopped for a crossing pedestrian or a pedestrian waiting on the curb or splitter island to cross. The pedestrian was the only reason the motorist stopped or slowed.
- *Passive Yield* – The motorist yielded to the pedestrian but was already stopped for another reason. This situation occurred most often when there was a queue of vehicles waiting to enter the roundabout or when the vehicle was already stopped for a prior pedestrian crossing event.
- *Did Not Yield* – The motorist did not yield to a crossing pedestrian or a pedestrian waiting on the curb or splitter island to cross" (Harkey and Carter, 2006).

The main overall observations regarding motorists' behavior were as follows (Harkey and Carter, 2006)

Overall, approximately 24 percent of the entering motorists did not yield to crossing or waiting pedestrians that started crossing from the entry-leg side of the approach. The overall percentage on non-yielding, exiting motorists increases to 46 percent for crossings initiated on the exit-leg side. In addition, the lack of yielding on two-lane roundabouts is substantially greater than on one-lane approaches in all cases being greatest on the exit leg for both exit leg starts (62%) and entry leg starts (45%) vs. 29 and 15 percent on one lane roundabouts.

Details of motorist yield behavior for pedestrians starting from the entry leg or exit leg can be seen in Figures 5.3 (entry leg) and 5.4 (exit leg) that follow.

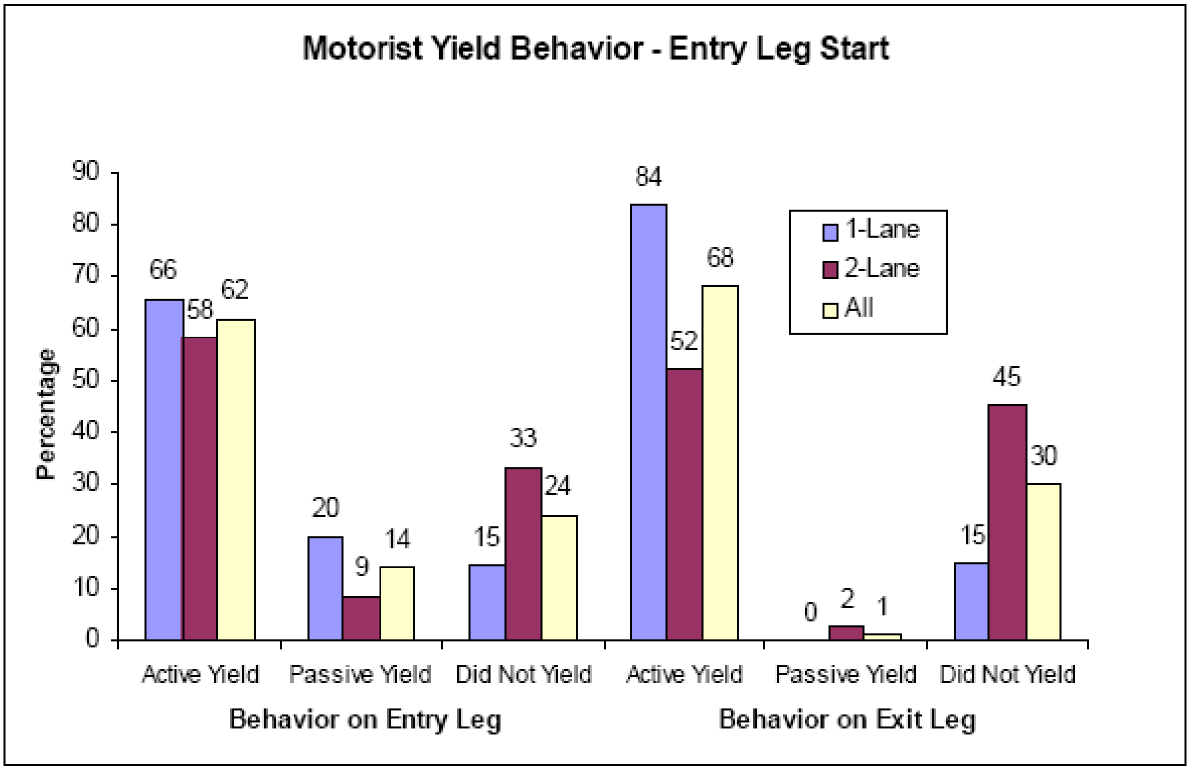


Figure 5.3: Yielding behavior of motorists when the pedestrian crossing begins on the entry leg. (Harkey and Carter, 2006)

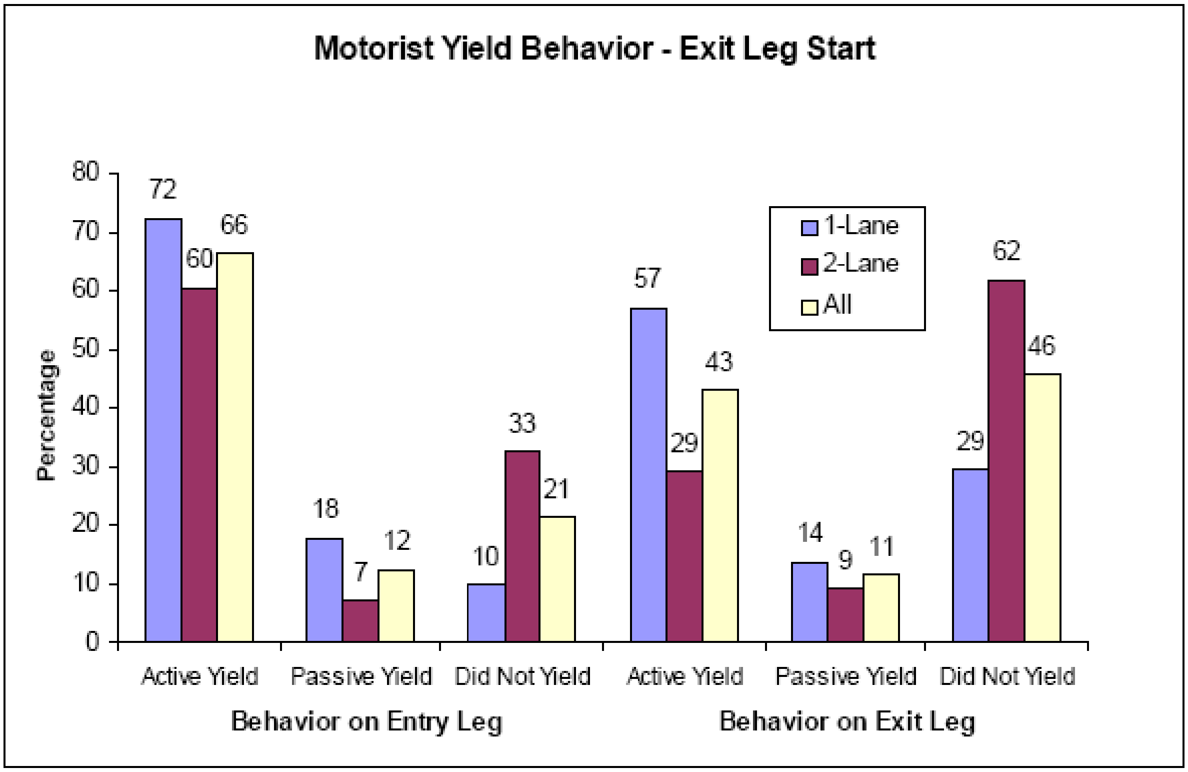


Figure 5.4: Yielding behavior of motorists when the pedestrian crossing begins on the exit leg. (Harkey and Carter, 2006)

Harkey and Carter (2006) also looked at regional differences of motorist yielding. They included Florida, Maryland and Vermont sites as an "east" region, and Washington, Nevada and Utah sites as a "west" region, with each region "balanced" by including two one lane approaches and two, two-lane approaches. They found the following results.

> "Motorist did-not-yield behavior was observed more often at the east-region sites (35 percent) compared to the west-region sites (27 percent). The difference was most pronounced on the exit leg of the approach, where the east and west overall did-not-yield percentages were 48 and 29 percent, respectively" (Harkey and Carter, 2006).

5.2 Comparison to other Intersection Types

Harkey and Carter (2006) made an attempt to compare pedestrian crossing and motorist yielding behavior to other, more traditional types of traffic control. Their basis of comparison was data from an on-going FHWA sponsored project, *Hazard Index for Assessing Pedestrian and Bicycle Safety at Intersections* (July 2005). In this FHWA study, data was collected at 68 signalized and stop-controlled intersections. The Harkey and Carter study used data from 54 of these representing 2881 pedestrian crossing events. Comparisons were based on crossing events where there was a vehicle present.

Comparison of crossing behavior needed to be modified because the FHWA categories combined the Harkey and Carter “Normal and Hesitates” into a “Proceeded Normally” category. Adding the overall Harkey and Carter data for normal and hesitates was similar to the FHWA proceeded normally; 85 percent vs. 88 percent respectively.

The FHWA study also broke down the proceeded normally by traffic control: Stop 100%, Signalized 90% and Uncontrolled 70%.

Comparison of motorist behavior in the FHWA study reported that the percentages of drivers not yielding to pedestrians was: uncontrolled 48%, signalized 15% and stop controlled 4%. The Harkey and Carter overall data showed 32% of drivers not yielding at roundabout (yield control) entrances.

Harkey and Carter (2006) also used the FHWA study data to compare pedestrian wait time and pedestrian crossing pace. In regard to wait time, they presented the following results:

Signalization, 10.7 seconds

Uncontrolled, 3.0 seconds

Roundabout, 2.1 seconds

Stop Controlled, 0.3 seconds

In regard to crossing pace, the results showed that pedestrian crossing pace was similar across all types of traffic control and varied from 4.4 to 5.0 feet per second. Harkey and Carter (2006) concluded that the type of traffic control does not appear to result in any practical differences in pedestrian crossing pace.

5.3 Pedestrian Safety

Harkey and Carter (2006) looked at conflicts as a surrogate for pedestrian safety. They defined a conflict as ---“an interaction between a pedestrian and a motorist in which one of the parties had to suddenly change course and/or speed to avoid a collision. It was observed that during 769 pedestrian crossing events only four conflicts were observed.

Harkey and Carter conducted another analysis based on “opportunities.” They defined opportunities as:

> “an opportunity was defined as any time a pedestrian was either waiting to cross or crossing the approach <u>AND</u> a motor vehicle was in the vicinity of the pedestrian”

It was reasoned that to “avoid a conflict” both parties had to respond properly, i.e., the pedestrian had to reject gaps when the motorist did not yield; and the motorist had to yield when the pedestrian was crossing. With the above definition and reasoning, it was found that the conflict rate was 2.3 conflicts per 1000 opportunities. (Harkey and Carter, 2006)

Using the surrogate “interaction” as developed in their study, Harkey and Carter (2006) concluded that —“the overwhelming majority of the roundabouts in this observational study showed very few problems for crossing pedestrians.” In regard to safety, they state that their surrogate (4 conflicts (0.5 percent) out of 769 crossing events) confirm the findings of the NCHRP-65 study (Applying Roundabouts in the United States 2006) in which data collected from 39 roundabouts found 5 pedestrian crashes (no fatalities) or 0.01 pedestrian crashes per year.

Harkey and Carter (2006) also made the following conclusions (paraphrased):

- Exit legs appear to place crossing pedestrians at greater risk than entry legs (based on [overall average] driver yielding percentages of 38 percent vs. 23 percent).
- Two-lane approaches are more difficult for crossing pedestrians than one-lane approaches. This was based on driver overall average, non-yielding percentages of 17% at one lane crossings and 43% at two-lane crossings. However, it was pointed out that this could be a reflection of overall, average pedestrian hesitation behavior: 33% at two-lane crossings vs. 24% at one-lane crossings.

- Roundabouts result in the type of behaviors expected when compared to other types of intersections and levels of traffic control. Roundabouts, which are under yield control, produced motorist and pedestrian behaviors that were between the behaviors observed at crossings with no traffic control and those observed at crossings with signal or stop-control.

Harkey and Carter (2006) summarize the findings of their study as follows:

"In summary, the findings of this research did not find any substantial safety problems for pedestrians at roundabouts, as indicated by the fact that there were few reported collisions and a very small number of observed conflicts."

5.4 Kansas KTRAN Study

The Kansas, KTRAN Study is an observational study similar to the Harkey and Carter study. Video tapes of pedestrians crossing at two roundabouts – Olathe and Lawrence – were taken and studied. The analysis follows the methodology of Harkey and Carter.

5.5 Kansas Pedestrian Study

It became clear after considerable searching and making personal contacts, that there were no roundabouts in Kansas with large numbers of pedestrians. It was decided to do research on two roundabouts near schools.

Roundabouts near schools generally cause more public concern than in other locations, especially if roundabouts are new to an area or in a community that has no experience with one near a school or on a school route. There is no evidence that roundabouts are not safe and efficient when built near schools. However, negative attitudes, lack of factual information and/or false beliefs that roundabouts will put students at risk, can cause the public, especially parents of school children and elected public officials, to oppose or reject them as a viable option near schools. The author believes there are just over 100 roundabouts near schools in the USA, which makes them relatively rare and has no knowledge of any published study dealing strictly with elementary and high school students and vehicle interaction at roundabouts.

In Olathe, KS was a one-lane roundabout in front of a high school at the intersection of two-lane arterial street and a two-lane collector street. One other location in Lawrence, KS, was a new single lane roundabout built on a school route between a rapidly growing residential neighborhood and a K-6 elementary school. The roundabout forms the intersection of two collector streets. Both streets are two-way, two-lane streets and serve primarily local traffic. Details of the roundabouts can be seen in Figures 5.5 and 5.6 below.

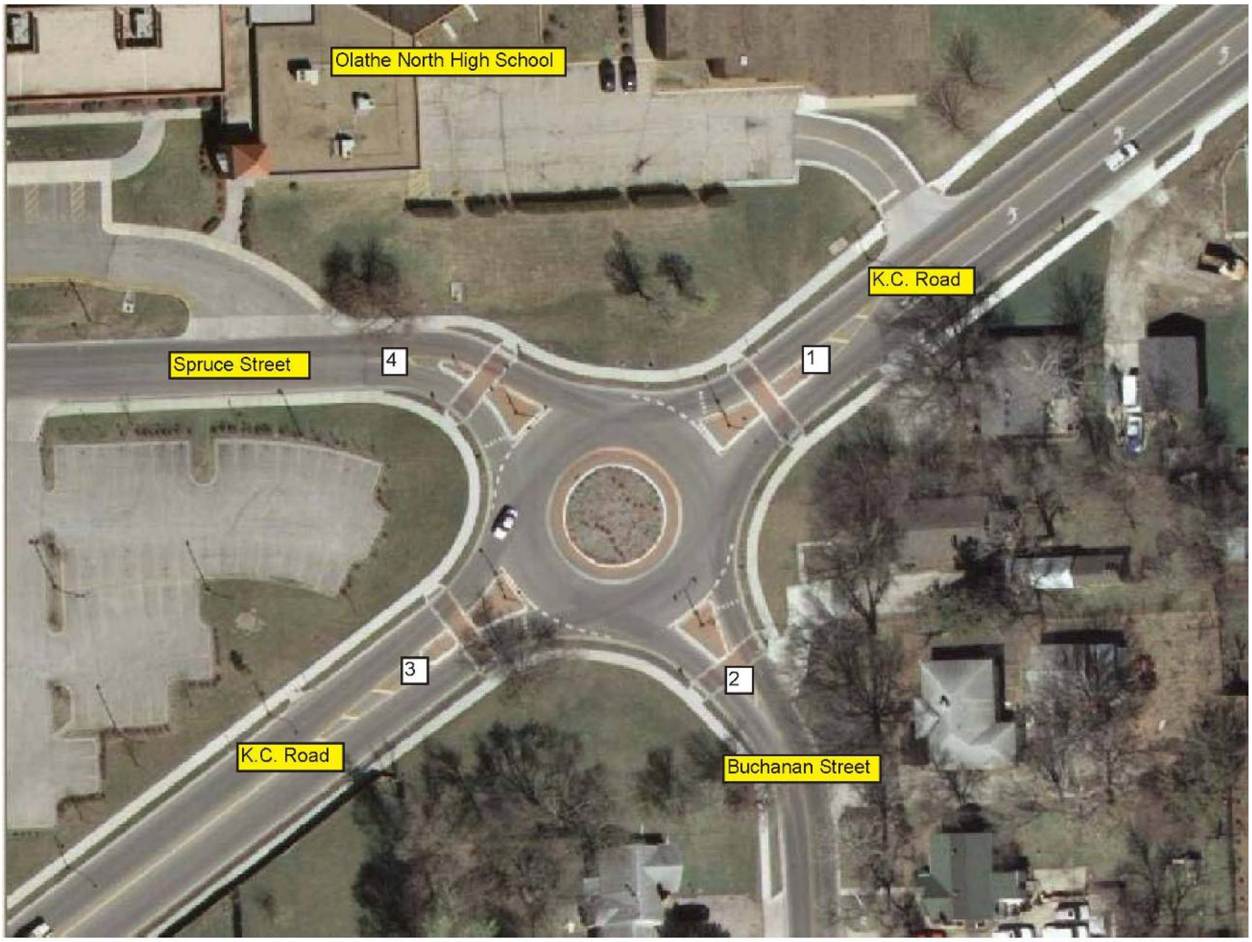


Figure 5.5: K.C. Road and Buchanan/Prarie Rd. Intersection in front of Olathe North High School in Olathe, KS.

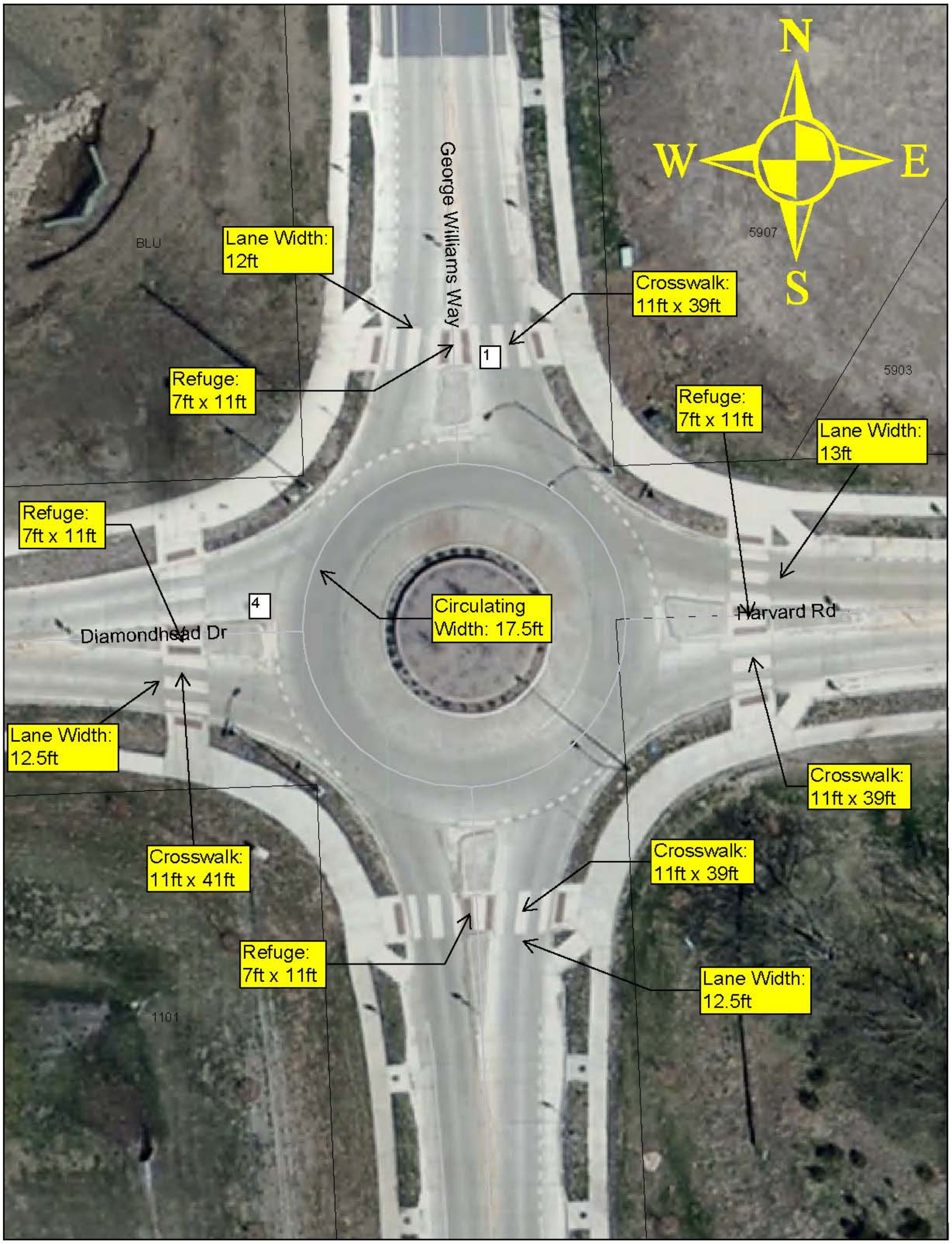


Figure 5.6: George William Way, Harvard/Diamond Head Intersection near K-6 Grade School in Lawrence.

5.6 Methodology

The study was an observational analysis similar to the study conducted by Harkey and Carter (2006) reviewed earlier in this chapter. The objectives were to characterize how school age children interact with motor vehicles (and vice versa) and make a subjective safety assessment on the basis of the observations.

Data on pedestrian crossings and pedestrian vehicle interactions, were obtained on videotape by an omnidirectional, 360° camera on street light poles over the roundabouts. The videotapes were then viewed to produce descriptive statistics following the model developed by Harkey and Carter (reviewed previously and summarized briefly in the next paragraph). The video data was collected during the spring of 2006.

First the study was primarily concerned with "interactions" as defined by Harkey and Carter. A pedestrian crossing with no vehicle present is not an interaction. In their study of general pedestrian-vehicle behavior at seven roundabouts, the majority of crossings involved no interaction. (Harkey and Carter, 2006)

As in the Harkey and Carter study, at those crossings where there was an interaction, pedestrian behaviors were categorized as:

- normal
- hesitates
- retreats, or
- runs.

Motorists behavior was described as:

- active yield
- passive yield, or
- did not yield.

Three other actions/reactions were observed during the study:

1. Conflicts, defined by Harkey and Carter as: “an interaction where one of the parties had to suddenly change course and/or speed to avoid a collision”,
2. Pedestrians’ behavior staying in the marked crosswalks, and
3. Vehicles yielding in the circle.

Since there is currently no consensus among roundabout researchers or practitioners regarding differences in pedestrian-vehicle interaction between entry and exit legs, these were kept separate.

5.7 STUDY SITES AND DATA

5.7.1 Lawrence

No. of Lanes: 1

No. of Approaches: 4

Circulation Lane Width: 17.5 feet

Diameter of Center: 104 feet

Highest Approach Speed: 35 mph

Roundabout Speed: 20 mph

Approach Volumes: 2007 Total 3035 (NB=1100, SB=1270, WB=555, EB=110)

5.7.2 Olathe

No. of Lanes: 1

No. of Approaches: 4

Circulation Lane Width: 23 feet

Diameter of Center: 62 feet

Highest Approach Speed Limit: 35 mph

Roundabout Speed Limit: 20 mph

Approach Volumes: 2005 Total 8601 (NB=1810, SB=1159, EB=2089, WB=3543)

5.8 ANALYSIS OF DATA

The analysis of the data was by roundabout legs and lanes within legs, and whether the pedestrian started on the entrance or the exit lane(s) of the roundabout.

5.8.1 Lawrence Pedestrian Behavior

At the Lawrence roundabout, only the morning data was valid. Due to the route taken by all observed students on the way to school, only two legs of the roundabout were crossed. These were designated 1 and 4 as shown on Figure A.1. The K to 6 students observed were both on foot and on bicycles. From initial observations, the observer concluded there was no difference in the actions of those on bicycles and those on foot. All students on bicycles rode on the sidewalk and crossed within the crosswalk. Their actions in regard to normal, hesitates, were indistinguishable from those on foot. In several cases, students were in small groups with some of the group on bicycles and some on foot, therefore, they were lumped together and in this study all are called “pedestrians”. Roughly 60% were on bicycles.

On leg 4 there were a total of 97 pedestrian crossings of which 26 or 26.8% involved interaction. On leg 1 there were a total of 287 pedestrian crossings of which 167 or 58.2% involved interaction. It should be noted that all of the pedestrians observed crossing leg number 4 went on to also cross leg number 1. The intersection categories are shown in Tables 5.1 and 5.2.

Table 5.1: Lawrence pedestrian interaction category on leg 1, with start on entry lane.

Lane	Normal	Hesitates	Retreats	Runs	Total
Entry	80 (47.9%)	84 (50.3%)	2 (1.2%)	1 (0.6%)	167 (100%)
Exit	137 (82.0%)	17 (10.2%)	0 (0%)	13 (7.8%)	167 (100%)

Table 5.2: Lawrence pedestrian interaction category on leg 4, with start on entry lane.

Lane	Normal	Hesitates	Retreats	Runs	Total
Entry	17 (65.4%)	6 (23.1%)	0 (0%)	3 (11.5%)	100 (%)
Exit	21 (80.8%)	2 (7.7%)	0 (0%)	3 (11.5%)	100 (%)

It should be noted that there were insignificant crossings on the other two legs of the roundabout. With two or three exceptions per day, all of the flow appeared to be elementary age students on their way to the school in the morning. Also, given this school route, morning flow should have reversed in the afternoon, when the school day ended. However, while viewing the videotapes of the afternoon flow, it was obvious the students were assisted across in groups that appeared to be led by crossing guards.

Thus, the afternoon data was not valid for the purposes of the analysis. It was later learned from a conversation with David Woosley, Traffic Engineer, that some teachers at the school were concerned about students crossing the roundabout and on their own went to the roundabout to act as crossing guards.

In regard to staying within the crosswalk, 100 percent compliance was observed during the period of the videotaping.

In regard to interaction category, on the highest pedestrian volume leg (number 1) the “hesitates” category was slightly higher than “normal” (50.3% vs. 47.9%) crossing the entry; but “normal” was much higher than “hesitates” on the exit lane (82.0% vs. 10.2%); indicating that once they started across, there was little hesitation at the splitter island. It should be noted that it was not clear to the observer whether some pedestrians hesitated due to vehicles or for other pedestrians a few paces behind to catch up, i.e., crossing in groups of two to four was common. Those that did not hesitate (normal category) appeared to have complete trust in driver yielding.

In regard to the “retreat” and “runs” category, on the entry lane of leg 1, only 2 (1.2%) retreated, 1 ran (0.6%); and on the exit lane, none retreated and 13 ran. However, there was never a case where the observer felt that a vehicle or driver action was responsible for the retreat or running, i.e. vehicle yielding could be described as exemplary and there were no conflicts observed during the period of the study. (To be discussed further in the next section.)

Similar results were observed on leg 4 which had fewer pedestrians and vehicles. The “normal” category (no hesitation) was considerably higher on both the entry lane and exit lane. (See Table 5.2.)

5.8.2 Lawrence Motorist Behavior

In general, the overall impression of watching the 10 days of videotaped data was that drivers were extremely cautious. It should be noted that on entry two legs, only one or two car lengths back from the crosswalk lines were visible. This means that there could have been more passive yields – those stopped beyond a lead vehicle stopped at the crossing – were likely undercounted.

Table 5.3 below summarizes Lawrence motorist behavior. As in the case of pedestrians, only legs 1 and 4 had any significant pedestrian-vehicle interaction. Also, all pedestrians started on the entry lane of both legs 1 and 4.

Table 5.3: Lawrence motorist behavior.

Leg	Lane	Active	Passive	Did not Yield	Total
1	Entry	73 (83.9%)	14 (16.1%)	0	87 (100%)
	Exit	95 (93.1%)	7 (6.9%)	0	102 (100%)
4	Entry	10 (71.4%)	4 (28.6)	0	14 (100%)
	Exit	14 (100%)	0 (0%)	0	14 (100%)

The most important category in Table 5.3 is that there was never a case of "did not yield." In all cases, this behavior of drivers' yielding included when pedestrians were at the curb or in many cases, *nearing the curb*. Most drivers yielded (stopped) some distance back from the crosswalk. It was observed that most vehicles stopping for pedestrians on the exit lane of leg 1 were stopped partially or totally in the roundabout circulatory lane. The actual numbers were kept for only half of the tapes, but this sample resulted in approximately 85 percent of the vehicles partially or totally stopped in the circle. There were a few vehicles that stopped for pedestrians starting or waiting *at the curb of the entry lane*.

As indicated above, the videotape observer can only describe motorist behavior as exemplary and contrary to several national studies that show poor compliance to yielding for pedestrians. However, the author believes that the cautious behavior exhibited at this roundabout is not unusual for drivers in the vicinity of elementary schools or the presence of young children. It is also possible that the low speed environment of the roundabout adds to or enhances the positive driver behavior. The author concludes that the roundabout at this location in no way increases risk of the crossing students and possibly decreases it. There is no reason to believe this would not be the case in any elementary school environment.

5.8.3 Olathe Pedestrian Behavior

The roundabout in Olathe was in front of Olathe North High School. Videotaping was conducted for five consecutive days. The only significant pedestrian activity observed was in the morning prior to the start of school and in the evening at the end of the school day. Unfortunately, there were very few pedestrians. The author believes the situation here is typical in the USA today, and high school students who walk to and from school are in the minority.

The total numbers of pedestrians and interactions observed on all four legs of the Olathe roundabout are presented in Table 5.4. Also noted were the numbers of pedestrians who crossed various legs without using the marked crosswalks, i.e., out of the crosswalk.

Table 5.4: Total pedestrians and interactions at the Olathe roundabout.

	Leg 1	Leg 2	Leg 3	Leg 4	Total
Pedestrians	25	8	87	30	150
Interactions	12 (48%)	0 (0%)	27 (31.0%)	5 (16.7%)	44 (29.3%)
Out of crosswalk	6 (24%)	2 (25%)	30 (34.5%)	8 (26.7%)	45 (30.0%)

In addition to the low numbers of pedestrians, two differences from the Lawrence elementary school were immediately obvious to the observer: a large percentage (30%) of the pedestrians paid no attention to the marked crosswalks and although there were no conflicts as defined by Harkey and Carter, motorists did not yield or slow to pedestrians at the curb obviously waiting to cross. This behavior is more typical of other studies where driver yielding to pedestrians waiting to cross was generally poor and in some cases even after pedestrians had stepped into the street. In all cases observed, pedestrians waited for reasonable gaps and once they where in the street vehicles slowed or yielded, i.e., there were no "close calls" requiring sudden evasive action (conflict) by either pedestrian or a driver.

Tables 5.5 and 5.6 below contains the observed numbers of pedestrians in each category by legs at the Olathe roundabout. Table 5.5 contains the numbers by categories of pedestrians who started across on the entry side of the leg and Table 5.6 contains the numbers by categories of pedestrians who started on the exit side of the leg.

Table 5.5: Pedestrian behavioral categories on all legs of the Olathe roundabout for pedestrians who started on the entry lane.

Leg	Lane	Normal	Hesitates	Retreats	Runs	Total
1	Entry	3	2	0	0	5
	Exit	5	0	0	0	5
2	Entry	0	0	0	0	0
	Exit	0	0	0	0	0
3	Entry	7	7	0	0	14
	Exit	11	3	0	0	14
4	Entry	2	0	0	0	2
	Exit	2	0	0	0	2
All legs Combined	Entry	12 (57.1%)	9 (42.9%)	0	0	21 (100%)
	Exit	18 (85.7%)	3 (14.3%)	0	0	21 (100%)

Table 5.6: Pedestrian behavioral categories on all legs of the Olathe roundabout for pedestrians who started on the exit lane.

Leg	Lane	Normal	Hesitates	Retreats	Runs	Total
1	Entry	3	4	0	0	7
	Exit	4	3	0	0	7
2	Entry	0	0	0	0	0
	Exit	0	0	0	0	0
3	Entry	10	3	0	0	13
	Exit	6	7	0	0	13
4	Entry	1	2	0	0	3
	Exit	3	0	0	0	3
All legs Combined	Entry	14 (60.9%)	9 (39.1%)	0 (0%)	0 (0%)	23
	Exit	13 (56.5%)	10 (43.5%)	0 (0%)	0 (0%)	23

It can be seen from the tables above that the predominant pedestrian behavior was "normal" for both entry and exit lane starts. For the pedestrians who hesitated, the "hesitates" behavior was higher on the curb side they entered on versus the splitter island, i.e. 42.9% vs. 14.3% for pedestrians starting on the entry lanes and 43.5% vs. 39.1% for pedestrians starting on the exit lanes. The author does not place any great significance on these numbers or differences; however, they seem to indicate that pedestrians have no greater concerns crossing the exit lanes than the entry lanes.

5.8.4 Olathe Motorist Behavior

The numbers and yielding behavior of drivers at the Olathe roundabout can be seen in Table 5.7 below. It can be noted that there were no drivers in the "did not yield" category. As previously stated, there were no observed cases where pedestrians were put at risk; however, the caution and care exhibited at the Lawrence roundabout near an elementary school was not in evidence. For example, all yielding observed was with pedestrians already in the street. There was not a single case of driver yielding to pedestrians at the curb waiting to cross either in or out of the cross walk.

Table 5.7: Yielding behavior of drivers on all legs of the Olathe Roundabout.

Leg	Lane	Active	Passive	Did Not Yield	Yielded in Circle
1	Entry	11	0	0	0
	Exit	6	0	0	3
2	Entry	0	0	0	0
	Exit	0	0	0	0
3	Entry	12	4	0	0
	Exit	10	3	0	5
4	Entry	1	0	0	0
	Exit	4	0	0	0
All legs Combined	Entry	24	4	0	0
	Exit	20	3	0	8

It can also be seen that half of the vehicles that yielded on the exit lane stopped partially or wholly in the circle. This was so even though if the active yielders had proceeded and stopped right at the crosswalk, they would have been out of the circle. It can be concluded that all observed yielding drivers showed caution when pedestrians were in the street but took no noticeable action for those waiting at the curb.

CHAPTER 6 - LOCAL ROUNDABOUT ACCEPTANCE

As of this writing (August 2007) there is still considerable opposition to roundabouts in some communities. This is true in Kansas, as well as in communities throughout the U.S. The author believes negative attitudes persist in communities where there are no roundabouts, where community leaders and/or public don't understand their benefits--particularly safety--and are swayed by negative myths and biases against roundabouts. In the early years, the early to mid-1990's, when little was known about roundabouts, there was considerable misunderstanding and really outrageous statements like: "traffic will back up 20 miles", "there will be several crashes per day", and similar statements the author calls "irrational opposition" or roundabout myths.

It is important that the first one or two roundabouts in an area will solve an obvious problem, e.g., a high number of right angle crashes or excessive delays at a two- or four-way stop controlled intersection; be simple and well designed. A public relations and/or media campaign explaining what roundabouts are, their benefits, and how to drive them, should be conducted.

The Insurance Institute for Highway Safety (IIHS) did a before and after roundabout acceptance study in three communities getting their first roundabout. Before, respondents were about 60 to 30% against; after, that changed to 30 to 60% for; i.e., those who liked it doubled.

6.1 A Suggested Program

The State of Washington is one of the leading states in number of roundabouts and promotes roundabout use in communities throughout the state. One person in their state DOT deals with local government problems and assistance, standing out as one of their top promoters. A summary of advice and four key points he sets forth follows. (Walsh, January 2, 2007 email.)

6.1.1 General

The simplest way to "sell" roundabouts is in the early stages when a state DOT, city or county is meeting with people (e.g., at a public hearing on road or street problems) and mention roundabouts, explain how they work, why they are safer and more efficient than other intersection treatments. He suggests to mayors or public works directors that they need someone like him with knowledge of and passion for roundabouts to be the one to introduce them to the community.

6.1.2 Specific Suggestions

Given the general advice above, it follows that specific suggestions are:

1. The state DOT should identify an individual with knowledge and passion for promoting the benefits of roundabouts. Preferably it should be someone who really wants to do this.
2. Roundabout "selling"/promoting is about good public speaking and communication, i.e., the person doing the presentations should have good public speaking skills. Specific facts should be presented, e.g., a roundabout at "x" location should reduce injury crashes by 4 per year, reduce delay to each vehicle by 24 seconds on average, reduce pollution by 16%--less stopping, waiting, maintenance costs, etc. Successful examples from other cities and key research results should be cited. A power point presentation with lots of photos or video should back up facts presented.

3. Be prepared to be constantly on the offensive, giving out information and anticipating questions. Use your factual knowledge to combat emotional language, irrational opposition or myths.
4. Where possible, tour existing roundabouts with community leaders or any interested groups whenever possible. Even if the main purpose of the tour has nothing to do with roundabouts, per se, lead the group through any in the area when it is easy to do so.

6.1.3 Topeka, KS

The City Traffic Engineer has had a lot of success in getting roundabouts approved. She believes in knowing the facts and getting them out. A summary of her advice on "selling" roundabouts follows: (Voss, April 27, 2007 email.)

1. "Get the facts. Typically an engineering study that would include a roundabout comparison to other alternatives.
2. The study. The study should include, as a minimum, safety, capacity, cost and esthetics.
3. Stress safety. Safety should be first, especially if dealing with an intersection with a crash rate above average. Estimate the expected crash reduction with a roundabout.
4. Capacity. What kind of delay are you exercising now and what kind will you experience in the future?

5. Cost. How much will it cost--how much would other options cost--how much of that is local fund--how much is other funds? What will the maintenance costs be?
6. Esthetics. While esthetics may be of least importance to an engineer, the community is interested in how it will look when it is done. Will it be a "gateway" to an area or a city--what will the plantings be--who will take care of them?--and there may be others like decorative brick.
7. Administrator "buy in". Once you get a study you need to get "buy in" from your Public Works Director, City Engineer, City Traffic Engineer, perhaps KDOT, if highway, or if they are funding. After there is agreement that the roundabout is the correct option for the intersection, you would likely move forward in different directions, depending on your city. In Topeka, you would make the City Manager aware of the project and address any questions he/she may have and take it to the council for a budget.
8. Public involvement. Is different in every city, and even within a city, public involvement may be different, depending on the area of the city or the type of intersection."

The following sections are based on interviews and/or e-mail from traffic engineers in large Kansas cities where roundabouts have been successfully implemented.

6.1.4 General

Overland Park, KS has had success in getting roundabouts approved and into successful operation. They are currently accepted as a viable tool for intersection traffic control. It was not always that way and the process of changing attitudes provides a case study that has some good lessons. (Wacker, private conversation, May 2007.) These are summarized below.

In Overland park it was not only the general public but the politicians who were initially opposed to roundabouts. The city engineering staff had to prove the benefits of roundabouts to the city council and governing body. They had proposed one small roundabout to replace a 4-way stop which was averaging 6 crashes per year. It was 90% designed when the project was canceled by the mayor, after concern by the Chamber of Commerce that a roundabout would slow traffic flow and adversely affect property development and/or businesses in the area. The engineering staff proceeded to convince these key persons that traffic flow would be improved and not adversely affected by the roundabout. The mayor was taken on tours of area roundabouts and thereafter gave the ok for another roundabout. Some city council members who were unfamiliar with roundabouts were also briefed on their operation and benefits. The very important lesson here is that local politicians, leaders and those who influence them need to be made aware of the operation and benefits of roundabouts. Following these developments, a roundabout was proposed at an intersection on a street in front of an elementary school and a middle school. This proposal led to further concerns by school officials and parents. How this was addressed is covered in the next section below.

6.1.5 Near Schools

First, as part of this research, a roundabout near a grade school in Lawrence, KS was videotaped for one week during elementary children's travel to a nearby school.

Details have been presented in a previous section of this report. Overall, the conclusion was that their safety there was very high.

Where a roundabout is proposed near a school or on a school route, particularly in a community with no or few roundabouts, there appears to be a tendency for concern and/or opposition by parents, parent-teacher associations and administrators. According to discussions over the past year on a KSU Roundabout Research listserv, there are over 100 locations with roundabouts near schools. Although no adverse effects have ever been reported, when a new one is proposed in other communities, it is common for concern and/or opposition arises. The author has never been aware of any problems and believes there are none; however, it is an issue that needs to be addressed.

In the Overland Park, KS case, a mock roundabout was set up in the school gyms in both the elementary school and the middle school. A representative of a consultant that does considerable roundabout design and analysis in Kansas, came in and provided information and training to the school children. In addition, several information meetings were held with parents and neighbors. One issue with parents, and an example of how factual information overcomes some concerns, was understanding the use of the crosswalk in the splitter island. When parents were shown a full sized model of the proposed splitter island, and how wide it was, their concerns about the children standing unprotected in the center of the road vanished or diminished. This roundabout acceptance had the advantage that at the same time of this proposed roundabout, several non-controversial ones were operating successfully in the city--another example that extra effort should be made to assure the first one or two in an area fulfill a need to improve some intersections' flow or safety, and be well designed.

6.1.6 Olathe, KS

This city, south of the Kansas City area, has had considerable success in getting public acceptance.

6.1.7 When installing several roundabouts

In 2001 the City of Olathe began installing roundabouts to replace 4-way stops at congested intersections. Also in 2001, the city conducted a survey to see how Olathe residents felt about roundabouts. In 2006, the city contracted with ETC Institute of Olathe to administer another survey. As the city neared the five-year point since implementing roundabouts, the city wanted to evaluate the overall effectiveness and desirability of roundabouts as a traffic management tool. The second survey also allowed a comparison of public attitudes and perceptions regarding roundabouts after five years.

The major findings from the ETC Institute report are as follows: (ETC Institute Final Report, April 2006.)

6.2 Major Findings

6.2.1 Overall Satisfaction with roundabouts is Very High.

Olathe residents were four times more likely to be satisfied (62%) with roundabouts than they were to be dissatisfied (15%); 23% of those surveyed gave a neutral rating or did not have an opinion. Overall satisfaction with roundabouts has increased from 55% in 2001 to 62% in 2006. Three-fourths (75%) of those surveyed who used roundabouts daily were satisfied compared to 51% of those who used them just a few times per month.

6.2.2 Residents Generally Think Roundabouts Have Decreased Travel Time.

Olathe residents were nearly four times more likely to think that travel times on streets with roundabouts have decreased (42%) since roundabouts were completed than they were to think travel times have increased (11%); 24% of those surveyed thought travel times were about the same, and 24% did not have an opinion (total does not sum to 100% due to rounding). The percentage of Olathe residents who thought travel times have decreased on streets with roundabouts has increased from 36% in 2001 to 42% in 2006. The percentage who thought travel times have increased has declined from 19% in 2001 to 11% in 2006.

6.2.3 Olathe Residents Think the City Should Continue Developing Roundabouts

Sixty-one percent (61%) of those surveyed thought the City of Olathe should continue using roundabouts as a traffic control option for intersections; 23% did not think the City should continue using roundabouts, and 16% did not have an opinion.

6.2.4 Residents Prefer Roundabouts Over Other Traffic Control Options

More than half of those surveyed (53%) indicated that they would prefer to see roundabouts at intersections in Olathe; 27% indicated they would prefer traffic signals, 15% indicated they would prefer four-way stops, and 5% did not have an opinion."

An Executive Summary of the Olathe survey is presented in Appendix C. The full report is available online from the City of Olathe.

The City of Olathe is one of the leading cities in Kansas insofar as implementing roundabouts that operate successfully and are widely accepted. However, although in a decreasing minority, roundabouts have their detractors. The current Public Works Director has been heavily involved in the effort to promote roundabout growth in Olathe over the past five years. His following comments on promoting roundabouts are based upon a great deal of experience, and are quoted below: (Linan, April 30, 2007, email.)

General First and foremost, support is critical from upper management within an organization. This begins with the Public Works Director, then goes up to the City Manager and finally the City Council. These will be the ones that have to first respond to any negative comments. However, it's not just their support, but understanding that there are no "Silver bullets" and that roundabouts are another tool that can be employed to address traffic flow AND that they have their drawbacks, as well. The support from these positions is critical. You don't want to face opposition from the public and your own management at the same time. Additionally, I'd educate and garner the support of the fire, medical and police operations (just like any other traffic calming option) so that you don't have an internal group playing the safety card at the end of the process.

6.3 Specific Comments

1. "A successful process begins with solid upfront planning and buy in.
    - Identify your potential "torpedo" holders (those who seem to agree by their silence, but at any time can torpedo the whole thing by objecting).

- Get early and widespread support from the outset (city management, emergency responders, schools, bike clubs…as many as you can).
- Specifically define what success will look like.
- Don’t over promise the impacts of roundabouts.
- Be honest about the downside of roundabouts.
- Educate, educate, and educate some more on how they operate (use the paper, city cable station, interviews, flyers, school visits…whatever it takes).

2. The second part of a successful process is a good design.
   - Don’t try to do more than what roundabouts are intended for.
   - Keep with the latest reasonable design guidelines (FHWA and KDOT seems to encapsulate these).
   - Don’t get cute and try to anticipate where the profession will be when it comes to ADA requirements (follow what’s on the books).
   - Have your peers review the design for accuracy (many states offer this service to municipalities).
3. The next part of a successful process is a well managed construction.
   - Don’t do a temporary construction (be committed to the project. Besides, it could cost just as much).
   - Have a construction inspector out there for every stage and every part of the construction (most contractors haven’t done this before).
   - Don’t allow bad or the wrong habits to develop during construction (have traffic operate as it would when the roundabout is complete).

- Close the intersection down completely if you can for the construction work.
- Celebrate its opening.

4. Finally, the project's success is sustained with consistent enforcement and project follow up.
    - Agree with the police on how to interpret collisions and violations.
    - Agree on a reporting system that can recreate the incident.
    - Give the original buy in groups something to look back on (they need to know that their support was worth it--after study)" (Linan, April 30, 2007).

CHAPTER 7 - SAFETY ANALYSIS OF KANSAS ROUNDABOUTS

7.1 Previous Safety Discussion

In Chapter 3, safety statistics from the literature were discussed. The IIHS results from 24 intersections in the US that had been converted from traffic signals to roundabouts showed a 39 percent decrease in all crashes, a 76 percent decrease in injury crashes and predicted a 90 percent decrease in fatal crashes (Persaud, Retting and Garder, 2001). This study and these results have been accepted as reliable and are probably the most quoted. They are most often quoted as rounded to 40, 80, or 90 respectively.

The recently published NCHRP Report 572, “Roundabouts in the United States,” (NCHRP 572) studied worldwide crash prediction models and found that none fit available US data. The researchers concluded that new intersection level models that were calibrated to US data were needed.

NCHRP 572 presents details of development of intersection-level prediction models and approach level prediction models. The intersection-level models are recommended for evaluating the safety performance of existing roundabouts and predicting safety (crash) changes if a roundabout is built at a specific location. The report suggests that approach level models need more development and recommend using intersection-level models. Only intersection-level models will be reviewed in this report.

One caveat is emphasized in NCHRP 572 follows: (NCHRP 572, p. 102)

"At both the intersection and approach levels, the potential user should confirm that the models adequately represent the jurisdiction or can be recalibrated using data from the jurisdiction." [emphasis added]

7.2 General Discussion

In Kansas (and most other states), there are several reasons why accurate, statistically reliable crash reductions after roundabouts are installed, are difficult to obtain. First, there are very few Kansas roundabouts with enough crash history for reliable, statistical analysis. Secondly, many Kansas roundabouts are in new developments where there was no previous intersection. Thirdly, the Kansas Accident Report does not separate right angle crashes from lesser angles (probably true in most if not all states). Fourth, data to use the state-of-the-art Empirical Bayes (EB) method is not available. The EB method requires locally developed or calibrated models, known as Safety Performance Functions (SPF), and none are available.

The primary reason that straight before and after analysis using numbers of crashes can be misleading is due to the statistical concept of "regression to the mean". Basically, this means that crashes are random events, and in any given year (assuming no major changes in conditions or the nature of traffic), the expected number of crashes at an intersection will tend to be close to the mean. For example, a long term mean at some intersection is four crashes, but during some given year it jumps to ten. The laws of probability and statistics indicate that in the following year it will most likely "regress" to around four – the mean. This is because crashes are rare, random events.

Many times in practice when there is a large jump, (like to ten in the example), there is "pressure" to do something. No matter what is done (possibly including building a roundabout) the number of crashes in the following year, or years, is most likely to be closer to four, which it likely would have been if nothing had been done. Also, should traffic conditions (or any condition) change, it is difficult to correctly adjust the number of crashes.

In addition to the "regression to the mean" problem, it is naïve to assure that nothing has changed from the before period to the after period except the number of crashes. As noted by Hauer (2002, pg 75):

> "In general, the noted change in safety [e.g. change in crash numbers] reflects not only the effort of [any treatment] but also the effect of factors such as traffic, weather, vehicle fleet, driver behaviors, and so on. It is not known what part of the change can be attributed to the treatment [for example building a roundabout]."

To correct for regression to the mean and the multitude of other possible changes, the state-of-the-art method for before-after studies is the Empirical Bayes (EB) procedure. The EB procedure basically predicts the expected number of future crashes *given that no improvement was made*. That is, the expected crash frequency with the status quo in place is the EB estimate. To calculate an EB estimate, a Safety Performance Function (SPF) is needed. A SPF is an equation developed from local data or a "borrowed" SPF assumed adequate for local conditions or calibrated for local crashes. The result of the SPF is then combined with observed crashes to obtain a site-specific, weighted value that is the "EB estimate." (See equations and examples below). In the case of a before-after crash analysis for roundabouts, the observed after crashes are compared to the EB expected number of crashes that would have occurred had the roundabout not been built.

The EB method combines both SPF model predictions and local crash history into a site specific, single estimate of expected crashes, i.e. the EB estimate. This process considers the observed crash frequency of a site *while recognizing that the observed crash frequency by itself is a poor predictor of future crash consequences because of the random nature of crashes and other factors that cannot be controlled.* (emphasis added)

A simple before-after analysis (sometimes called a “naïve” before-after analysis) may be acceptable if the roundabouts were not built because of a large jump in crashes the year previous to the decision to build a roundabout, and it is known for sure that all possible conditions have not changed – probably unlikely. Also, where averages for several years are available, (the author believes five years minimum although this is debatable) and traffic has been stable (e.g., ADT, traffic mix and physical characteristics have not changed substantially), a simple or naïve before-after analysis *may* be meaningful, i.e. give a reasonable indication of the safety (crash reduction) aspect of a roundabout. However, such an analysis may be difficult to defend from a statistical standpoint.

It should be kept in mind that in areas where the first roundabout is installed, or there are few roundabout crashes may initially increase while drivers get used to them. However, roundabout crashes, in a well-designed roundabout, should be mostly minor, i.e. in the “fender bender” category. Thus, the true safety value of a roundabout should be a decrease in injury crashes or risk of injury crash. The author believes the “possible injury" category should not be included. This is also a recommendation of NCHRP Report 572 (pg. 26). The author further believes that roundabouts should reduce the most serious injury; therefore levels of injury seriousness should be studied, and included whenever accident statistics are summarized and/or reported. Roundabouts should also reduce the *risk* of more serious or fatal high angle crashes, e.g. 75 to 90 degrees ("T-bone"). However, the level of injury seriousness and angle of crash are not readily available from Kansas accident records (probably true in other states' records) without obtaining and studying copies of the police reports. Also, procedures or equations to determine expected crashes at intersections with various traffic controls, i.e. SPF's, are not available in Kansas. However, there are data, to confirm that modern roundabouts generally decrease all crashes and in almost all cases, significantly decrease injury crashes. Table 7.9 below (reproduced from NCHRP Report 572, Table 28) is the current state-of-the-art, national evidence. The lone, obvious deviation from this is when four-way stop control is converted. However, converting four-way stops significantly decrease delay, stopping, queuing and corresponding vehicular emissions. In regard to conversion of two-way stop and signalized intersections, the reduction of injury crashes is a nationally proven fact. In Kansas, conversion of two-way stop control to roundabouts are clearly decreasing crashes; however, in the case of signal conversion, data are insufficient for statistically reliable results.

Of course, there can be exceptions. Just as there can be design flaws in traditional intersections and sections of road and street, design (or construction) flaws can occur in roundabouts. Just as typical high-accident locations (HALs) or "black spot" analysis as it is sometimes called, flags traditional intersections as "problem intersections” that need a engineering study and correction, any roundabout with significantly higher crashes than established national norms (IIHS and NCHRP data) should be “flagged” for possible, correctable problems. As emphasized in NCHRP 572, *“For roundabouts performing below par from a safety perspective, diagnostic procedures can then be used to isolate any problems and to develop corrective measures.”* [emphasis added] Conversions to roundabouts with significantly higher crashes than reported national averages should be a candidate for a detailed traffic engineering study to determine the cause(s) and make necessary alterations.

7.3 Empirical Bayes Before-After Procedure

In this section the EB analysis and example for correct application are quoted from NCHRP Report 572, pages 31 to 33.

> “The Empirical Bayes before-after procedure (Hauer, E., 2002) was employed to properly account for regression-to-the-mean while normalizing, where possible, for differences in traffic volume between the before and after periods.
>
> The change in safety at a converted intersection for a given crash type is given by:
>
> Change in safety = B – A
>
> Where:
>
> B = the expected number of crashes that would have occurred in the after period without the conversion
>
> A = the number of reported crashes in the after period

B was estimated using the Empirical Bayes procedure in which a Safety Performance Function (SPF) for the intersection type before roundabout conversion is used to first estimate the annual number of crashes (P) that would be expected at intersections with traffic volumes and other characteristics similar to the one being evaluated. [The following tables 5.7, 7.1, 7.2, and 7.3 are reproduced tables from NCHRP 572.] The SPF crash estimate is then combined with the count of crashes (*x*) in the *n* years before conversion to obtain a site-specific estimate of the expected *annual* number of crashes (*m*) at the intersection before conversion. This estimate of *m* uses weights estimated from the mean and variance of the regression estimate as follows:

$m = w_1 x + w_2 P$

where:

m = expected site-specific annual number of crashes before conversion.

$$w_1 = \frac{P}{\frac{1}{k} + nP}$$

x = count of crashes in the *n* years before conversion.

$$w_2 = \frac{\frac{1}{k}}{\frac{1}{k} + nP}$$

P = prediction of annual number of crashes using SPF for intersection with similar characteristics

k = dispersion parameter for a given model, estimated from the SPF calibration process with the use of a maximum likelihood procedure.

[See Tables 7.2, 7.3, or 7.4 for SPF and k values derived from NCHRP 572 data]

Factors then are applied to account for the length of the after period and differences in traffic volumes between the before and after periods. The result is an estimate of *B*. The procedure also produces an estimate of the variance of *B*. The significance of the difference

(B – A) is established from the estimate of the variance of *B* and assuming, based on a Poisson distribution of counts, that:

Var (A) = A

In the estimation of changes in crashes, the estimate of *B* is summed over all intersections in the converted group of interest (to obtain B_{sum}) and compared with the count of crashes during the after period in that group (A_{sum}). The variance of *B* is also summed over all conversions. The variance of the after period counts, *A*, assuming that these are Poisson distributed, is equal to the sum of the counts."

Table 7.1: Results for before-after analysis by logical group.(From NCHRP Report 572, Table 27)

Control Before	Sites	Setting	Lanes	Crashes recorded in after period		EB estimate of crashes expected without roundabouts		Index of Effectiveness θ (standard error) & Point Estimate of the Percentage Reduction in Crashes	
				All	Injury	All	Injury	All	Injury
All Sites	55	All	All	726	72	1122	296.1	0.646 (0.034) 35.4%	0.242 (0.032) 75.8%
Signalized	9	All	All	215	16	410.0	70.0	0.522 (0.049) 47.8%	0.223 (0.060) 77.7%
	4	Suburba n	2	98	2	292.2	Too Few	0.333 (0.044) 66.7%	Too Few to estimate
	5	Urban	All	117	14	117.8	34.6	0.986 (0.120) 1.4%	0.399 (0.116) 60.1%
All-Way Stop	10	All	All	93	17	89.2	12.6	1.033 (0.146) -.3.3%	1.282 (0.406) -28.2%
Two-Way Stop	36	All	All	418	39	747.6	213.2	0.558 (0.038) 44.2%	0.182 (0.032) 81.8%
	9	Rural	1	71	16	247.7	124.7	0.285 (0.040) 71.5%	0.127 (0.034) 87.3%
	17	Urban	All	102	6	142.7	31.6	0.710 (0.090) 29.0%	0.188 (0.079) 81.2%
	12		1	58	5	93.7	22.5	0.612 (0.101) 39.8%	0.217 (0.100) 80.3%
	5		2	44	1	48.9	Too few	0.884 (0.174) 11.6%	Too few to estimate
	10	Suburba n	All	245	17	357.2	57.0	0.682 (0.067) 31.8%	0.290 (0.083) 71.0%
	4		1	17	5	77.1	21.8	0.218 (0.057) 78.2%	0.224 (0.104) 77.6%
	6		2	228	12	280.1	35.2	0.807 (0.091) 19.3%	0.320 (0.116) 68.0%
	27	Urban/ Suburba n	All	347	23	499.9	88.6	0.692 (0.055) 30.8%	0.256 (0.060) 74.4%
	16		1	75	10	162.8	44.3	0.437 (0.060) 56.3%	0.223 (0.074) 77.7%
	11		2	272	13	329.0	44.3	0.821 (0.082) 17.9%	0.282 (0.093) 71.8%

Table 7.2: Base safety performance functions used in the empirical Bayes before-after analysis. (From NCHRP Report 572, Table 27, page X)

Setting	Previous Control	Number of Legs	Source of SPF Data	Model
Urban	Signal	4	Howard and Montgomery Counties, MD	Acc/yr = exp(-9.00)$(AADT)^{1.029}$, k=0.20 InjAcc/yr = exp(-10.43)$(AADT)^{1.029}$, k=0.20
Urban	Two-way stop	4	Howard and Montgomery Counties, MD	Acc/yr = exp(-1.62)$(AADT)^{0.220}$, k=0.45 InjAcc/yr = exp(-3.04)$(AADT)^{0.220}$, k=0.45
Urban	All-way stop	4	Minnesota – rural sites used due to lack of urban data	Acc/yr = exp(-12.972)$(AADT)^{1.465}$, k =0.50 InjAcc/yr = exp(-15.032)$(AADT)^{1.493}$, k=1.67
Urban	Signal	3	California	Acc/yr = exp(-5.24)$(AADT)^{0.580}$, k=0.18 InjAcc/yr = exp(-6.51)$(AADT)^{0.580}$, k=0.18
Urban	Two-way stop	3	Howard and Montgomery Counties, MD	Acc/yr = exp(-2.22)$(AADT)^{0.254}$, k=0.36 InjAcc/yr = exp(-3.69)$(AADT)^{0.580}$, k=0.36
Urban	All-way stop	3	Minnesota – rural sites used due to lack of urban data	Acc/yr = exp(-12.972)$(AADT)^{1.465}$, k=0.50 InjAcc/yr = (-15.032)$(AADT)^{1.493}$, k=1.67
Rural	Two-way stop	4	Minnesota	Acc/yr = exp(-8.6267)$(AADT)^{0.952}$, k=0.77 InjAcc/yr = (-8.733)$(AADT)^{0.795}$, k=1.25
Rural	All-way stop	4	Minnesota	Acc/yr = exp(-12.972)$(AADT)^{1.465}$, k=0.50 InjAcc/yr = (-15.032)$(AADT)^{1.493}$, k=1.67

Legend: SPF = safety performance function; Acc/yr = total crashes per year; InjAcc/yr = fatal and injury crashes per year; AADT = average daily traffic entering the intersection; k = dispersion factor

Table 7.3: Intersection – Level Safety Prediction Model For Total Crashes (From NCHRP 572, Table 19, Page 28)

Number of Circulating Lanes	Safety Performance Functions [Validity Ranges]		
	3 Legs	**4 Legs**	**5 Legs**
1	0.0011$(AADT)^{0.7490}$ [4,000 to 31,000 AADT]	0.0023$(AADT)^{0.7490}$ [4,000 to 37,000 AADT]	0.0049$(AADT)^{0.7490}$ [4,000 to 18,000 AADT]
2	0.0018$(AADT)^{0.7490}$ [3,000 to 20,000 AADT]	0.0038$(AADT)^{0.7490}$ [2,000 to 35,000 AADT]	0.0073$(AADT)^{0.7490}$ [2,000 to 52,000 AADT]
3 or 4	Not In Dataset	0.0126$(AADT)^{0.7490}$ [25,000 to 59,000 AADT]	Not In Dataset

Dispersion factor, k=0.8986

Table 7.4: Intersection – Level Safety Prediction Model For Injury Crashes (From NCHRP 572 Table 20, Page 28)

Number of Circulating Lanes	Safety Performance Functions [Validity Ranges]		
	3 legs	**4 legs**	**5 legs**
1 or 2	0.0008$(AADT)^{0.5923}$ [3,000 to 31,000 AADT]	0.0013$(AADT)^{0.5923}$ [2,000 to 37,000 AADT]	0.0029$(AADT)^{0.5923}$ [2,000 to 52,000 AADT]
3 or 4	Not In Dataset	0.0119$(AADT)^{0.5923}$ [25,000 to 59,000 AADT]	Not In Dataset

Dispersion factor, k=0.9459

The estimate of safety effect, the Index of Effectiveness (θ), is estimated as:

$$\theta = \frac{A_{sum} / B_{sum}}{1 + Var(B_{sum}) / B_{sum}^{2}}$$

The percentage change in crashes is equal to 100(1-θ); thus, a value of θ = 0.70 indicates a 30% reduction in crashes.

The variance of θ is given by:

$$Var(\theta) = \theta^{2} \frac{\frac{Var(A_{sum})}{A_{sum}^{2}} + \frac{Var(B_{sum})}{B_{sum}^{2}}}{\left(1 + \frac{Var(B_{sum})}{B_{sum}^{2}}\right)^{2}}$$

NCHRP 572 Table 27 [reproduced as Table 7.2 in this report] lists the base SPFs used as described previously. These data were taken from a variety of reliable sources because data were not collected for this purpose in this [NCHRP] project. These base SPFs were recalibrated for used in the specific jurisdictions using data for the sample of roundabout conversions for the period immediately before conversion. Only the data in the one year immediately prior to the roundabout construction were used for this purpose to guard against the possibility that a randomly high crash count in earlier years may have prompted the decision to install the roundabout and therefore provide functions that would overestimate safety performance. Examination of annual crash trends in the before periods indicated that this decision was justified.

The composite results are shown in [NCHRP 572] Table 28 [reproduced as Table 7.1 in this report], both in terms of percentage reduction in crashes and the index of effectiveness, θ. Injury crashes are defines as those involving definite injury or fatality. In other words, PDOs and possible injury are excluded. Results are shown separately for various logical groups for which sample sizes were large enough to facilitate a disaggregate analysis. The aggregate results for all sties are reasonably consistent with those from the IIHS and New York State DOT studies. The following conclusions [from NCHRP 572] can be drawn:

- **Control type before.** There are large and highly significant safety benefits of converting signalized and two-way-stop-controlled intersections to roundabouts. The benefits are larger for injury crashes than for all crash types combined. For the conversions from all-way-stop-controlled intersections, there was no apparent safety effect.
- **Number of lanes.** Disaggregation by number of lanes was possible for urban and suburban roundabouts that were controlled by two-way stops before conversion. The safety benefit was larger for single-lane roundabouts than for two-lane designs, for both urban and suburban settings. All rural roundabouts were single lane.
- **Setting.** The safety benefits for rural installations, which were all single lane, were larger than for urban and suburban single-lane roundabouts.
- **Additional insights**. Further disaggregate analysis provided the following insights:
  - The safety benefits appear to decrease with increasing AADT, irrespective of control type before conversion, number of lanes, and setting.
  - For various combinations of settings, control type before conversion, and number of lanes for which there were sufficiently large samples, there was no apparent relationship to inscribed or central island diameter.

7.5 Overview of EB Calculations and an Example

(Paraphrased from NCHRP 572, pp 102, 103)

7.5.1 Step 1

Assemble data as follows:

- Number of legs.
- Number of circulating legs.
- Years of observed data (up to 10 yrs)
- Total observed crashes.
- Total injury crashes (excluding “possible injury”)
- Total entering ADT

7.5.2 Step 2

Assume the appropriate model from NCHRP 572 is representative of the jurisdiction (Note: KDOT has no such local predictive models available) and select the appropriate intersection level model from NCHRP Tables 19 or 20 (Tables 7.3 or 7.4 in this report). Use the selected model to estimate the annual number of crashes that would be expected at a roundabout with similar traffic volumes and other characteristics.

The model would be best recalibrated with a sample of local roundabouts. As a minimum data from at least 10 roundabouts in a specific category with at least 60 crashes. (Note: KDOT data is insufficient for any reliable recalibration.)

7.5.3 Step 3

Combine SPF estimate, P, from appropriate equation from [NCHRP] Table 19 or 20, (Table 7.3 or 7.4 in this report) with the observed crashes "x" for "n" years to obtain an estimate of the expected annual number of crashes, "m".

$$m = w_1 x + w_2 P$$

where:

$$w_1 = \frac{P}{\frac{1}{k} + np} \qquad w_2 = \frac{\frac{1}{k}}{\frac{1}{k} + np}$$

Where k is the dispersion factor the given model, from NCHRP Table 19 or 20 (16 or 17 in this report) or developed locally from the SPF calibration process with the use of a maximum likelihood procedure.

7.6 Example 1 from NCHRP 572

The following example illustrates the process (NCHRP 572, page 103):

Consider that the calculations for total crashes are of interest for a given roundabout.

7.6.1 Step 1

The assembled data are as follows:

- Number of legs = 4
- Number of circulating lanes = 1
- Years of observed data = n = 3
- Total crashes observed = x = 12
- Total entering AADT = 17,000

7.6.2 Step 2

The appropriate SPF and dispersion factor k from [NCHRP] Table 19 (Table 7.3 in this report), given four legs and one circulating lane, are as follows:

$$\text{Total crashes/yr} = 0.0023(\text{AADT})^{0.7490},\ k = 0.8986$$

Assume for illustration purposes that this model is representative of intersections in the jurisdiction and that no recalibration is necessary. The estimate of *P* is then

$$P = 0.0023(17{,}000)^{0.7490} = 3.39 \text{ crashes/yr}$$

7.6.3 Step 3

Calculate the weights and the EB estimate of expected annual crash frequency.

$$w_1 = \frac{P}{\frac{1}{k} + nP} = \frac{3.39}{\frac{1}{0.8986} + 3 \times 3.39} = 0.30$$

$$w_2 = \frac{\frac{1}{k}}{\frac{1}{k} + nP} = \frac{\frac{1}{0.8986}}{\frac{1}{0.8986} + 3 \times 3.39} = 0.10$$

$$m = w_1 x + w_2 P = 0.30 \text{x} 12 + 0.10 \text{x} 3.39 = 3.94 \text{ crashes/yr}$$

Therefore, the prediction model estimate of 3.39 (P) has been refined to an EB estimate of 3.94 after incorporating of the observed annual crash frequency of 12 crashes in 3 years.

7.7 Example 2 from NCHRP 572

In Example 2 it is assumed that before conversion to the roundabout in Example 1, the site was a four-leg, two-way stop controlled intersection in an urban environment. Further assume that *before* the roundabout was planned, it was desired to know the expected crash reduction if a roundabout were built.

7.7.1 The Preferred Approach

7.7.1.1 Step 1

Assemble site data

- Intersection legs = 4
- Control = 2-way stop
- Years of observed crash data = 3
- Total crashes observed = 17
- Injury crashes observed = 10
- Average entering ADT during years of observed data = 16,000
- Anticipated ADT at time of conversion = 17,000

7.7.1.2 Step 2

Find appropriate SPF model for urban, 4-leg, 2-way stop controlled intersection from [NCHRP] Table 27 (Table 7.2 in this report) to use in the EB procedure to predict the expected annual crashes if the conversion to the roundabout does not take place.

First, the models are used to predict the annual number of crashes by severity:

$$\text{Total crashes / yr} = \exp(-1.62)\,(AADT)^{0.220},\ k = 0.45$$

$$= \exp(-1.62)\,(16000)^{0.220}$$

$$= 1.66$$

$$\text{Injury crashes / yr} = \exp(-3.04)\,(AADT)^{0.220},\ k = 0.45$$

$$= \exp(-3.04)\,(16000)^{0.220}$$

$$= 0.40$$

Next, the weights and EB estimate are calculated for total crashes:

$$w_1 = \frac{P}{\frac{1}{k} + nP} = \frac{1.66}{\frac{1}{0.45} + 3 \times 1.66} = 0.23$$

$$w_2 = \frac{\frac{1}{k}}{\frac{1}{k} + nP} = \frac{\frac{1}{0.45}}{\frac{1}{0.45} + 3 \times 1.66} = 0.31$$

$m = w_1x + w_2P = 0.12 \times 10 + 0.65 \times 1.66 = 2.28$ injury crashes /yr

Because volumes are expected to increase in the after period, albeit only slightly, an adjustment is made to *m* to account for this change. This factor is calculated as:

$(\text{AADT after})^{0.220} / (\text{AADT before})^{0.220} = (17000)^{0.220} / (16000)^{0.220}$
$= 1.01$

[The exponent on the AADTs relates the function that relates the increase in roundabout crashes to increase in AADT]

The adjusted *m* is now equal to:

4.42 x 1.01 = 4.46 for total crashes / yr

2.28 x 1.01 = 2.30 for injury crashes / yr

Thus, the expected numbers of annual crashes that would occur if the 2-way stop were not converted is:

Total = 4.46 crashes / year

Injury = 2.30 crashes / year

If PDO crashes are of interest:

PDO crashes = 4.46 – 2.30 = 2.16 PDO / year

7.7.1.3 Step 3

The intersection level model used in Example 1 to predict the annual number of expected crashes should the intersection be concerted is assumed to be deemed adequate for local conditions for this site. Calculations would be as follows:

The intersection-level model (see example 1) is used to predict the annual number of crashes should the intersection be converted. In this case, the model was deemed adequate and was not recalibrated specifically for the jurisdiction.

$$\text{Total crashes / yr} = 0.0023\,(\text{AADT})^{0.7490}$$

$$= 0.0023\,(17000)^{0.7490}$$

$$= 3.39$$

$$\text{Injury crashes / yr} = 0.0013\,(\text{AADT})^{0.5923}$$

$$= 0.0013\,(17000)^{0.5923}$$

$$= 0.42$$

7.7.1.4 Step 4

Calculate the expected change if the roundabout in Example 1 were built.

Expected change in total crashes:

4.46 – 3.39 = 1.07 crashes / year decrease

$$\frac{1.07}{4.46} = 24\% \text{ decrease}$$

Expected change in injury crashes:

2.30 – 0.49 = 1.88 crashes / year decrease

$$\frac{1.88}{2.30} = 82\% \text{ decrease}$$

Keep in mind in the above example, the changes are the *expected* values to use in deciding the benefit of converting to a roundabout.

7.8 Preliminary Kansas Roundabout Crash Results

These results are called preliminary because in most cases, roundabouts are too new to Kansas to have had a sufficient after crash history to be meaningful. It is not uncommon for the first few roundabouts in an area to initially have more than expected crashes due to drivers getting familiar with them. Also, Safety Performance Functions (SPFs) are not available, nor is data available to this study to calibrate “borrowed” SPFs such as those available in NCHRP Report 572 [Tables 7.1, 7.2, and 7.3 in this report].

For purposes of illustration, the author of this report will *assume* the NCHRP 572 SPFs are appropriate without local calibration and perform EB before-after calculations. The following Tables are the Kansas data available for this study.

Table 7.5: Two-Way Stop Conversion Accident Summary

	Location	ACCIDENTS					
			Yrs.	Total	Fatal	Injury[1]	PDO
1.	23rd and Severence Hutchinson	B	3	39	0	7	29
		A	3	19	0	1	18
2.	110th and Lamar Overland Park	B	3	2	0	0	2
		A	3	8	0	0	8
3.	KS 68, Old KS Road Hedge Ln., Paola	B	3	7	0	1	5
		A	3	4	0	0	4
4.	Nims St., Stackman Dr. Wiley St., Wichita	B	2	1	0	1	0
		A	2	2	0	1	1
5.	Ridgeview and Loula St. Olathe	B	2	6	0	1 [2]	5
		A	2	7	0	0	7
6.	Gary and Candlewood Manhattan	B	3	10	0	2	6
		A	3	2	0	0	2
7.	6th and Wannamaker Topeka	B	2	1	0	0	1
		A	2	2	0	0	2
8.	Nims and Stackman Dr. Wichita	B	2	1	0	1	0
		A	2	2	0	0	1
	TOTALS	B	16	65	0	13	48
		A	16	42	0	2	43

1. All non-incapacitating unless noted. Probable injury removed.
2. Incapacitating

Table 7.6: Four-Way Stop Conversion Accident Summary

	Location	ACCIDENTS					
			Yrs.	Total	Fatal	Injury	PDO
1.	US 75 and 46th Topeka	B	3	15	0	2	13
		A	3	18	0	5	13
2.	6th and Wannamaker Topeka	B	2	1	0	0	1
		A	2	2	0	0	2
3.	Douglas and Sycamore Wichita	B	3	2	0	0	2
		A	3	4	1 [1]	0	3
4.	Santa Fe and Conser Overland Park	B	2	2	0	0	2
		A	2	4	0	0	4
	TOTALS	B	10	20	0	2	18
		A	10	28	1 [1]	5	22

1. Data is not available to determine the reason for the fatal. Final crashes at roundabouts are usually the result of high speed or driver intoxication.
2. Signal that no longer satisfied signal warrants.

Table 7.7: Signal Conversion Accident Summary

	Location	ACCIDENTS					
			Yrs.	Total	Fatal	Injury[2]	PDO
1.	19th and Barker Lawrence	B	2	10	0	0	5
		A	2	5	0	0	5
2.	Monterey Way, Harvard Lawrence[1]	B	3	2	0	1	1
		A	3	4	0	0	4
3.	Sheridan and Clairborne Olathe	B	3	5	0	1	4
		A	3	7	0	1	6
4.	KC Road, Buchannan. St. Prairie St., Olathe	B	2	2	0	0	1
		A	2	1	0	0	1
5.	KC Road, Church St., Nelson St., Olathe	B	2	4	0	0	4
		A	2	4	0	0	4
6.	Sheridan, Ridgeview, Dennis, Olathe	B	3	5	0	0	5
		A	3	11	0	0	11
7.	Sheridan, Ridgeview, Rogers, Olathe	B	3	14	0	**1**	13
		A	3	48	0	1	51
	TOTALS	B	18	42	0	3	32
		A	18	44	0	2	82
	Totals without #7 [3]	B	15	28	0	2	19
		A	15	32	0	1	31

1. 3-way before control; all others 4-way
2. Non-incapacitating unless bold; probable injury removed.
3. This roundabout appears to be an outlier, i.e., far higher crashes than national average and should be flagged for an engineering study.

Table 7.8: Interchange Area Accident Conversion

	Location	ACCIDENTS					
			Yrs.	Total	Fatal	Injury	PDO
1.	I-135 and 1st Newton	B	3	15	0	3	12
		A	3	7	0	1	6
2.	I-135 and Broadway Newton	B	3	12	0	3	9
		A	3	5	0	1	4
	TOTALS	B	3	27	0	6	21
		A	3	12	0	2	10

1. Non-incapacitating, probable injury removed.

First, some comments will be made on the “naïve” analysis – just looking at before and after numbers with no adjustments or attempt to apply the state-of-the-art EB technique. The results can be seen in Tables 7.9 above and 7.10 below.

Table 7.9: Simple, Uncorrected, Before – After Compared To NCHRP 572, Table 28

Control Before	Percent Crash Reduction			
	NCHRP 572		KDOT	
	All	Injury	All	Injury
Various – All Sites	35.4 %	75.8%	-9.07% [1]	54.2%
Signalized – Urban	1.4%	60.1%	-36.8% [1,2]	-150% [1,2]
Two-way stop Urban – all	29.0%	21.2%	35.4%	88.9%
All-way Stop (all-sites)	-3.3% [1]	-28.2% [1]	-31.3% [1,3]	84.6% [3]

1. A minus indicates an increase
2. Data are too limited for meaningful results
3. Value would be -14.3, for all and +50% for injury without #7 from table 7.5 which appears to be an “outlier”, which should flag the roundabout for an engineering study.

It can be seen that combining all Kansas results indicates a 9.7% increase in all crashes. The author of this report believes this is due primarily because most are new and only two or three years if data are available. It is not unusual for a new roundabout to initially have a crash increase. Four-way conversions can be quite variable and if these were removed from the above Table, the total for all remaining sites would be a 2.3% decrease in total crashes at all remaining sites and a 52.4% decrease in injury crashes. Also, there are two roundabouts included that have significantly higher increases then they should have when compared to national data. These roundabouts could have design or operational problems. There is sufficient national data to prove that a well designed roundabout should decrease crashes. When data indicate crash increases after roundabout conversion, or crashes are significantly higher than the norm – for example reductions shown in NCHRP report 572, Table 28 (Table 7.9 in this report), the roundabout should be "flagged" for a detailed engineering study to determine if there is a correctable problem.

In spite of the limited data and lack of SPF equations for adjustments and proper EB analysis, conversion of two-way stop control shows significant crash and injury reductions and *it should be noted that there is still a significant decrease in overall injury crashes.* For example, injury crashes are decreased 54.2% for all sites, 4.6% for urban two-way stops and 33.3% for all-way stop. Note the 54.2% for all sites close to the national average of 75.8%; the 84.6% for urban two-way roundabouts is *above* the national average of 81.2% and even the 54.2% for all-way stop intersection conversion is considerably above the national average, which indicates a 28.2% increase.

Even though these Kansas numbers are in the category of "naïve analysis" and may not be statistically defensible, they show very positive trends and support a strong body of local and national studies that provide evidence that roundabouts increase safety by significantly decreasing injury crashes. This is true even though two sites have an abnormally high increase in total crashes, almost all PDO.

7.9 Additional Comments on Roundabout Angle Crashes

Well designed roundabouts should reduce both the numbers and severity of angle crashes and the risk of same. There should be no high angle (around 80° to 90°) crashes – generally the most serious intersection crash. Crash reports available to this study only report the number of "angle" crashes without indicating the angle. The results of all sites with reported angle crashes are shown in Table 7.10 below. It can be seen that in the case of all signal sites and all two-way sites, total angle crashes are reduced 6.7 to 59% and all sites 16.7% (47.0% excluding one "outlier"). In addition, it is a logical assumption that the average crash speed and severity is likely to be less at a roundabout, further decreasing the risk of injury crashes.

Table 7.10: Summary of Sites with Recorded "Angle" Crashes

Condition	Before Number	After Number	Decrease	Percent Decrease
All Sites	90	75	15	16.7%
All Sites excluding Sheridan, Ridgeview, and Rogers (4-way)	83	44	39	47.0%
All Signal Sites [1]	15	14	1	6.7%
All 2-way Stop Sites	61	26	35	57.4%
All 4-way Stop Sites	14	35	-19 (increase)	-135.7% (increase)
All 4-way stop excluding Sheridan, Ridgeview, and Rogers [2]	7	4	3	42.9%

[1] Very limited data.
[2] Sheridan, Ridgeview and Rogers appears to possibly have (or had) design or operational problems.

The Sheridan, Ridgeview, and Rogers site has an *increase* in angle crashes from 7 to 31. This is an anomaly. Although these appear to be mostly PDO's (increase in PDO from 13 to 51) this should have been a "red flag" for a detailed engineering study of the roundabout design and operation. As stated previously, the actual angle is unknown, and roundabouts generally have low angle, low speed crashes that result in lower risk of injury. In addition, the accident summary report shows three "side-swipe *opposing*." This indicates one of the involved vehicles was apparently driving the wrong way on the roundabout. On a well designed and properly signed roundabout, this occurrence should be very rare. It should definitely have been a "flag" to investigate entry conditions. It is believed that the causes of most crashes at this roundabout are driver error. This was the first multilane roundabout in the area and drivers needed to learn how to drive it properly. The city added lane use arrows on the approaches and circulatory roadway. There is no way to determine from accident reports if or when improvements may have been made.

CHAPTER 8 - CONCLUSIONS AND RECOMMENDATIONS

The author concludes the following from this study.

8.1 Effect of ADA Legislation

The primary thrust of the study was to determine or gain insight into the effect of ADA legislation on roundabout growth in Kansas. Therefore, the first and main conclusion is that, based on literature review, study of numerous documents, interviews, personal contact with various Access Board members and researchers, within four to six years some type of acceptable pedestrian traffic signal or beacon will be mandated by enforceable Federal standards at all two or more lane roundabouts on pedestrian accessible routes. This is analogous to requirements for building access, handicapped parking, curb cuts and similar standards from the ABA and ADA which are now enforceable standards.

Will this slow multilane roundabout growth? One can only speculate; however, the author concludes that although it will initially, the proven safety benefits of roundabouts alone, will eventually overcome resistance to conversion due to the "pedestrian signal" requirement. This conclusion is based partly on the belief that the research project NCHRP 3-78A will come up with relatively low-cost solutions. The Access Board guideline requirement does not require a full-blown signal system. The pedestrian hybrid signal, previously, and still commonly called a HAWK beacon, appears to be a viable lower cost option. Based on preliminary results from NCHRP 3-78A, the HAWK beacon is effective and has little negative impact on roundabout operation. The author believes the situation is analogous to the situations in the 1990s when accessible buildings and facilities became the "law of the land". Architects accepted them as the way it has to be, and went on designing accessible buildings and facilities that met all standards. Although speculative, the author believes that eventually, it will be the same with multilane roundabouts.

In addition, the author believes that if adequate cost records are kept and appropriate dollar amounts for injury and deaths avoided, a proper life cycle analysis will show a high benefit cost ratio for roundabouts with pedestrian signals. Studies of this nature are encouraged.

8.2 Pedestrian and Bicycle Safety

The recent study, NCHRP 3-65 and its final report NCHRP 572, could find little data on pedestrian safety. They observed that the “overwhelming majority” of the roundabouts observed in the study showed very few problems for crossing pedestrians and bicyclists. Their findings did not find any substantial safety problems for non-motorists at roundabouts. There were few reported crashes and a very small number of observed conflicts. The NCHRP 572 did state that (p.110): “multilane roundabouts may require additional measure to improve upon the behaviors of motorists, pedestrians and bicyclists.”

The author of this report concludes that Kansas roundabouts are not a problem for non-motorists at this time. However, blind pedestrians will likely need assistance at multilane roundabouts (covered below).

8.3 Accessibility and Accessible Roundabouts

There is considerable research to conclude that blind pedestrians have problems safely crossing multilane roundabouts. The author concludes that the PROWAG final version will require some sort of pedestrian signal or beacon and be adopted as enforceable standards in the near future. NCHRP Project 3-78A is currently ongoing and, albeit preliminary, have had good results with the pedestrian hybrid signal, formally referred to as the HAWK pedestrian beacon.

8.4 Kansas Pedestrian Studies

Based on 10 days of videotaped school children crossing the roundabout in Lawrence near an elementary school, K-6, it is concluded that drivers were extremely cautious. Drivers stopped not only for the school children while crossing but while they were at the curb, and in some cases while they were approaching and still some distance from the curb. The author believes this behavior is not unusual for drivers in the vicinity of elementary schools; however, it is possible that the low speed environment of the roundabout enhances positive driver behavior. Therefore, the final conclusion is that the roundabout at this location in no way increases risk of the elementary age pedestrians and possibly decreases it.

Five days of videotaped observation at a site in Olathe on an arterial near a high school, showed slightly different results. First the number of high-school age students walking was very low and only a few were observed, prior to the start and end of the school day, i.e. in 5 days only 150 students were observed. It was noted that several pedestrians (30%) did not cross at the crosswalks and some walked in the circular roadway. Although drivers stopped for pedestrians in the crosswalk or street, they did not for pedestrians waiting at the curb. Based on national studies, this behavior is the norm for all crosswalks and should not be attributed to the roundabout. In all cases observed, pedestrians waited for reasonable gaps and once they were in the street vehicles slowed or yielded, i.e., there were no close calls or conflicts. The author concludes that the roundabout at this location in no way increases the risk of the pedestrians and possibly decreases it due to creating a low speed environment on the arterial. This could be an important factor considering the “less-than-desirable” pedestrian crossing behavior at this location.

8.5 Local Roundabout Acceptance

The author believes that is it important that the first one or two roundabouts in an area solve an obvious problem, e.g. a high number of serious crashes or excessive delay. From several interviews, the author concludes that the best way to “sell” a roundabout is in the early stages when a state DOT, city or county is meeting with the public at some public meeting on road or street problems. At this time, mention roundabouts, explain how they work and why they are safer and more efficient than other intersection types. Organizations need someone with knowledge of and “passion’ for roundabouts to be the one to introduce them to a community. Several good suggestions are included in the report. The author believes that the best information uncovered for a state DOT is as follows:

1. The state DOT should identify an individual with knowledge and passion for promoting the benefits of roundabouts. Preferably it should be someone who really wants to do this.
2. Roundabout “selling”/promoting is about good public speaking and communication, i.e., the person doing the presentations should have good public speaking skills. Specific facts should be presented, e.g., a roundabout at “x” location should reduce injury crashes by 4 per year, reduce delay to each vehicle by 24 seconds on average, reduce pollution by 16%--less stopping, waiting, maintenance costs, etc. Successful examples from other cities and key research results should be cited. A power point presentation with lots of photos or video should back up facts presented.

3. Be prepared to be constantly on the offensive, giving out information and anticipating questions. Use your factual knowledge to combat emotional language, irrational opposition or myths.
4. Where possible, tour existing roundabouts with community leaders or any interested groups whenever possible. Even if the main purpose of the tour has nothing to do with roundabouts, per se, lead the group through any in the area when it is easy to do so.

8.6 Safety of Kansas Roundabouts

First, it is concluded that data available for this study were too few for statistically reliable or statistically defensible results, i.e., too few years and too few roundabouts in some categories, particularly in the category of urban signalized conversions. It is not uncommon when roundabouts are new to an area for total crashes to initially increase. Further biasing the data were two roundabouts with significantly higher crash numbers than they should have compared to reliable national data, indicating a possible design or operational problem. It could also be a case of drivers being unfamiliar with a new type of intersection traffic control. The author believes that any roundabout with significantly more crashes after conversion than proven national averages, should be a “flag” to study the design and/or operation.

Also, to conduct a statistically defensible state-of-the-art, Emperical Bayes (EB) before-after analysis, Safety Performance Functions (SPFs) for local conditions are necessary. None are available. In spite of these deficiencies in the available data and equations for a proper EB, before-after analysis, a naïve before after study indicates that although there has been a 9.7% increase in all crashes there has been a significant decrease in injury crashes e.g. 52.4% for all sites, 84.6% for urban, two-way stops and

33.3% decrease in four-way stop after conversion to roundabouts. Even though these numbers are in the "naïve analysis" category, they show very positive trends comparable to a strong body of evidence from national studies; therefore, it is concluded that overall the Kansas roundabouts in this study significantly reduce serious crashes, particularly injury crashes.

8.7 Recommendations

Even though it will be a few years before providing pedestrian signals (or beacons) at all crosswalks on two or more lane roundabouts on pedestrian accessible routes, consideration should be given now to providing them or making provisions to economically add them later.

The pedestrian hybrid signal (previously referred to as a HAWK beacon) should be installed and their effect studied at some two or more lane roundabouts that have pedestrian access.

KDOT should develop Safety Performance Functions (SPF's) for intersection types that are typically converted to roundabouts so that state-of-the-art Empirical Bayes (EB) before-after analysis can be conducted.

For at least the next few years, roundabout crash data should be organized and monitored at least annually. A roundabout with higher than average crash statistics should be flagged for an engineering study.

Roundabout crash reports should be studied to determine the actual angle of crash and injury severity. These two values should be added to the summary report.

Area wide surveys should be conducted to gauge motorist satisfaction with roundabouts, similar to the survey conducted in Olathe.

Data on all costs and benefits associated with intersection conversion to roundabouts should be obtained and put into a comprehensive data base such that reliable life cycle costs of roundabouts vs. various types of traditional intersection can be developed.

A proactive program to educate the public, local administrators and politicians to the benefits of roundabouts should be developed.

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APPENDIX A - PEDESTRIAN ACCESS TO MODERN ROUNDABOUTS: DESIGN AND OPERATIONAL ISSUES FOR PEDESTRIANS WHO ARE BLIND

(Appendix A contains a bulletin taken from the Access Board website and can be found at the following location: http://www.access-board.gov/research/roundabouts/bulletin.htm)

Chief Okemos Roundabout (Okemos, Michigan).***Photo courtesy of Dave Sonnenberg, Director of Traffic and Safety, Ingham County, Michigan Road Commission***

BACKGROUND

Roundabouts are replacing traditional intersections in many parts of the U.S. This trend has led to concerns about the accessibility of these free-flowing intersections to pedestrians who are blind and visually impaired. Most pedestrians who cross streets at roundabouts use their vision to identify a 'crossable' gap between vehicles. While crossing, they visually monitor the movements of approaching traffic and take evasive action when necessary. Blind pedestrians rely primarily on auditory information to make judgments about when it is appropriate to begin crossing a street. Little research has been conducted about the usefulness of such non-visual information for crossing streets at roundabouts. Recent research sponsored by the Access Board, the National Eye

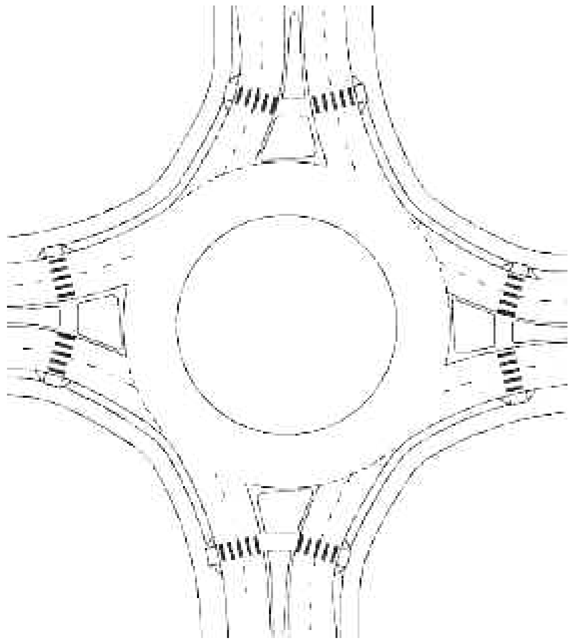
Institute, and the American Council of the Blind suggests that some roundabouts can present significant accessibility challenges and risks to the blind user (for a link to an abstract of this research, see the Resources section at the end of this document). This bulletin:

- summarizes orientation and mobility techniques used by pedestrians who are blind in traveling independently across streets;
- highlights key differences between roundabouts and traditional intersections with respect to these techniques;
- suggests approaches that may improve the accessibility of roundabouts to blind pedestrians; and
- encourages transportation engineers and planners to implement and test design features to improve roundabout accessibility.

MODERN ROUNDABOUTS

There are an estimated 40,000 modern roundabouts worldwide, and more than 200 have been constructed in the United States. Most of these have been built within the last 5 years. Many jurisdictions are now considering roundabouts to improve vehicle safety, increase roadway capacity and efficiency, reduce vehicular delay and concomitant emissions, provide traffic-calming effects, and mark community gateways.

A typical modern roundabout (Figures A.1 and A.2) is an unsignalized intersection with a circular central island and a circulatory roadway around the island. Vehicles entering the roundabout yield to vehicles already on the circulatory roadway. A dashed yield line for vehicles is painted at the outside edge of the circulating roadway at each entering street. The dashed line defines the boundary of the circulatory roadway (not to be confused with a conventional ‘stop bar,’ since there is not requirement to stop prior to entering the roundabout).



Typical urban double-lane roundabout from *Roundabouts: An Informational Guide (FHWA)*

Roundabouts have raised or painted splitter islands at each approach that separate the entry and exit lanes of a street. These splitter islands are designed to deflect traffic and thus reduce vehicle speed. Splitter islands also provide a pedestrian refuge between the inbound and outbound traffic lanes.

Roundabout design in the U.S. has not yet been standardized, although several types have been defined in industry publications. Engineers use a variety of design techniques, mostly geometric, to slow vehicles as they approach or exit a roundabout. Differing design practices in Europe and in Australia continue to influence U.S. engineers as they refine design approaches for application in urban, suburban, and rural areas.

Studies conducted in western Europe, where roundabouts are common, and in the U.S. have generally found that roundabouts result in less severe vehicular crashes than more traditional intersections. This reduction in the rate of serious vehicular crashes is the most compelling reason cited by transportation engineers for the installation of roundabouts. Roundabouts increase vehicular safety for two main reasons: 1) they reduce or eliminate the risk arising at signalized intersections when motorists misjudge gaps in oncoming traffic and turn across the path of an approaching vehicle; and 2) they eliminate the often-serious crashes that occur when vehicles are hit broadside by vehicles on the opposing street that have run a red light or stop/yield sign.

The research findings on pedestrian safety at roundabouts are less clear. There have been relatively few studies, mostly conducted in Europe, concerning pedestrians and roundabouts. Pedestrian-vehicle crashes, the most commonly used dependent measure in pedestrian safety studies, tend to occur infrequently both before and after an intersection is converted to a roundabout. As a result, it is difficult to draw firm conclusions from the literature regarding pedestrian safety and roundabouts. One issue that is often not considered in pedestrian research is the degree to which pedestrian volume changes when intersections with signal or stop-sign control are converted to roundabouts. There is a need for research on this topic as well as a broad range of other pedestrian-related concerns at roundabouts. Little is known about the effect of roundabouts on older pedestrians, children, and pedestrians with disabilities. Anecdotal evidence indicates that many Australian engineers (who have extensive experience with roundabouts) consider these intersections to be unsuitable if large numbers of pedestrians are present.

The differences between modern roundabouts and traditional intersections controlled by traffic signals and stop signs have important implications for blind pedestrians. While some of these implications are not yet well understood, they must be considered by any transportation engineer or planner whose goal is to create an accessible pedestrian environment.

Improvements for wayfinding

- ***well-defined walkway edges***
- ***separated walkways, with landscaping at street edge to preclude prohibited crossings to center island***
- ***tactile markings across sidewalk to identify crossing locations***
- ***bollards or architectural features to indicate crossing locations***
- ***detectable warnings (separate at splitter islands) at street edge***
- ***perpendicular crossings ; where angled, use curbing for alignment cues***
- ***high-contrast markings***
- ***pedestrian lighting***

CROSSING AT TRADITIONAL INTERSECTIONS

The techniques and cues used by blind pedestrians crossing at traditional intersections are diverse and vary by location and individual. Many blind pedestrians have received instruction in using these techniques from orientation and mobility (O&M) professionals. In the most common technique for crossing at fixed-time signalized intersections, pedestrians who are blind use traffic sounds to align themselves properly for crossing and then begin to cross when there is a surge of through traffic next to and parallel to them. This occurs at the onset of the walk interval, when the traffic signal changes in the pedestrian's favor. Cues that can be used for identifying that a street is just ahead, and for determining when to cross, include traffic sounds, the orientation and slope of curb ramps, textural differences between the street and sidewalk, detectable warnings underfoot, locator tones at pedestrian pushbuttons, and audible or vibrotactile information from accessible pedestrian signals (APS).

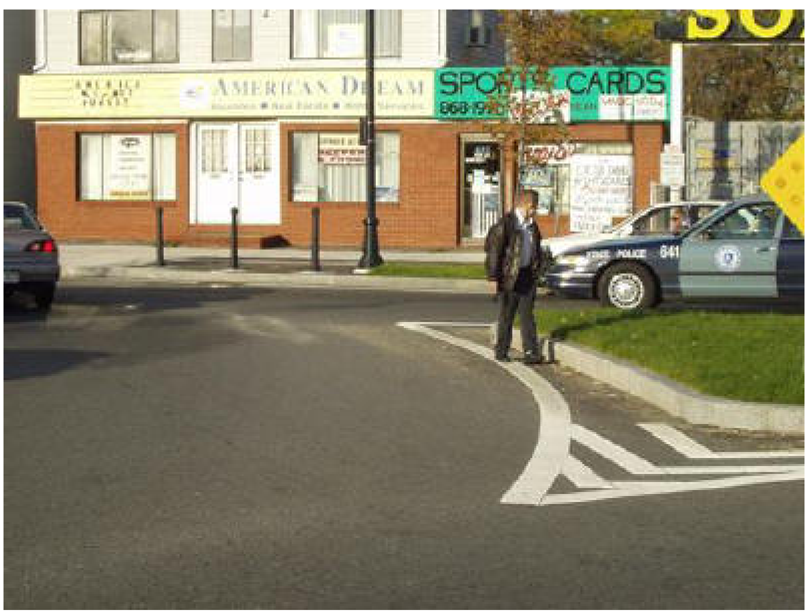
Key street-crossing tasks for the blind pedestrian include:

- detecting the intersection;
- locating the crosswalk and aligning the body in the direction of the crosswalk;
- analyzing the traffic pattern;
- detecting an appropriate time to initiate the crossing (at signalized intersections, determining the onset of the walk interval);
- remaining in the crosswalk during the crossing;
- monitoring traffic during the crossing; and
- detecting the destination sidewalk or median island.

When traffic sound cues are absent (e.g., when there are no cars on the street parallel to the pedestrian's line of travel, and thus no auditory cue that the signal has changed) or unpredictable (e.g., when the intersection is of a major and minor street, and traffic signals are actuated by vehicles), information may be insufficient for determining the onset of the walk interval. In such situations, APS systems may be necessary. New guidance on the use of APS appears in the 2000 edition of the *Manual of Uniform Traffic Control Devices* (MUTCD).

CROSSING AT ROUNDABOUTS

Orientation and mobility techniques used by blind individuals at traditional intersections rely heavily on traffic sounds. When traffic signals and stop signs regulate traffic movements at intersections, the resulting breaks in traffic flow provide identifiable and predictable periods – gaps – during which pedestrians can cross. Such predictable breaks do not usually occur at roundabouts, and so pedestrians must make judgments about the speed and travel paths of approaching vehicles (and the duration of gaps between vehicles). It appears that sighted adults are generally able to safely make such judgments, although some pedestrians (e.g., those with cognitive impairments, children -- see Figure A.3) may have difficulty doing so. Research suggests that the selection of appropriate gaps at roundabouts is problematic for blind pedestrians at some roundabouts.



Pedestrian with cognitive disability crossing in roadway

Traffic sounds at roundabouts can provide ambiguous cues. Circulating vehicles can mask the sounds of entering and exiting traffic, making it difficult to identify an appropriate time to cross. At exit legs, auditory information may not be adequate to reliably convey whether circulating vehicles will exit or continue around the roadway.

Driver fails to yield to pedestrian using long cane

At entry legs, it may not be clear from auditory information whether a driver intends to yield to a waiting pedestrian. While research has shown that driver-yielding rates increase at low speeds, many drivers do not yield to blind pedestrians at crosswalks (see Figure A.4) and yielding behavior may be difficult to detect.

Planter used to indicate crosswalk location

The curvilinear layout of roundabouts poses several challenges to blind pedestrians. One challenge is obtaining information about the location and direction of the crosswalk. Sidewalks at roundabouts often curve in large arcs and, unlike traditional intersections, rarely lead directly to crosswalks. Instead, crosswalks are typically to the pedestrian's side (see Figure A.5) and must be located using different strategies and sources of information than those used at traditional intersections.

Crosswalk not aligned with approach

Another challenge is aligning the body with the crosswalk prior to crossing (see Figure A.6). At traditional intersections, a common nonvisual technique for accomplishing this is to use traffic sounds to line up to face parallel to the traffic to one's side (i.e., one's 'parallel street' traffic). This technique is probably not useful at roundabouts.

At some roundabouts, however, some of the nonvisual street-crossing methods used at traditional intersections may be appropriate. For example, it would appear to be appropriate to cross during the periods of 'all quiet' that occur at roundabouts where the traffic volume is very light (e.g., 1 lane roundabouts in residential areas) or where there are long periods during which there is no traffic (e.g., due to traffic signals at nearby intersections). However, as vehicles become quieter, this technique may be unsuitable at both traditional and roundabout intersections.

Roundabouts: An Informational Guide, published in 2000 by the Federal Highway Administration (FHWA), acknowledges the need for improvements in roundabout access for blind pedestrians.

> *"It is expected that a visually impaired pedestrian with good travel skills must be able to arrive at an unfamiliar intersection and cross it with pre-*

existing skills and without special, intersection-specific training. Roundabouts pose problems at several points in the street crossing experience, from the perspective of information access.

"Unless these issues are addressed by design, the intersection is 'inaccessible' and may not be permissible under the ADA…[M]ore research is required to develop the information jurisdictions needed to determine where roundabouts may be appropriate and what design features may be appropriate for the disabled, such as audible signalized crossings."

Title II of the Americans with Disabilities Act (ADA) requires that new and altered facilities constructed by, on behalf of, or for the use of state and local government entities be designed to be readily accessible to and usable by people with disabilities (28 CFR 35.151).

Improvements for speed control/yielding

- ***single lane crossings at entrance and exit***
- ***raised crossings , especially at exit***
- ***'YIELD-TO-PED' markings/driver signs/beacons ; if pedbutton, need voice message to clarify not a RYG signal***
- ***pedestrian lighting***
- ***yield cameras***

IMPROVEMENTS WORTH INVESTIGATING

Across the U.S., roundabouts are being designed and installed at a rapid pace. It is becoming increasingly clear that current roundabout design practices do not yield the same access to crossing information for blind and low vision pedestrians as for sighted pedestrians. An accessible roundabout will provide nonvisual information about crosswalk and splitter island location, crossing direction, and safe crossing opportunities.

An understanding of the auditory, tactile, and other cues used by blind individuals as they negotiate intersections will aid engineers and planners in designing and building accessible roundabouts. Orientation and mobility (O&M) specialists can aid transportation professionals in understanding the demands of non-visual travel and the strategies that blind people use to successfully meet these demands. Much research and development work is needed to improve the usability of modern roundabouts by persons with blindness and visual impairments. It is essential that transportation engineers and planners involve themselves in this R&D by working to devise, implement and test design features with potential for improving accessibility. Promising avenues for further investigation fall into four broad task categories:

1. LOCATING THE CROSSWALK AND ESTABLISHING ALIGNMENT

Landscaping, planters, pedestrian channelization, bollard-and-chain separation, railings, and other architectural features can delineate paths that lead to the crosswalk and prevent or discourage crossing at locations other than the crosswalk (see Figure A.4 above).

A distinctive edge, particularly paving-to-grass or a raised curb can provide orientation to the crossing direction.

High-contrast markings and pedestrian routes that are well-lit at night will be useful to pedestrians who use residual vision to travel, the larger proportion of pedestrians who have vision impairments. Lighting will also enhance pedestrian visibility to drivers.

A standardized tactile paving is used in many foreign countries to mark the crossing location for pedestrians traveling along the sidewalk. For clarity of message, it should be a linear pattern that is distinguishable from the truncated dome pattern required in detectable warnings at the street edge (see Figure A.7).

Australian use of bar tiles across sidewalk to indicate crossing location

When alignment using traffic sounds is not possible, other sources of alignment information must be available. Curb ramps with returned edges aligned with crosswalk direction offer useful cues for establishing a line of travel. It is probably also the case that when curb ramp slope is sufficiently steep to be detected underfoot, additional information for alignment can be provided by aligning the slope of the ramp with the crosswalk. However, the usefulness of slope information for alignment is an unresolved research question, and it raises issues where non-standard crosswalk location (e.g., diagonal or apex ramps) may give misleading information that can result in crossings outside the legal or marked crosswalk.

2. DETECTING WHEN IT IS APPROPRIATE TO CROSS

Designing roundabouts that provide pedestrians with nonvisual information about the appropriate time to initiate a street crossing appears to be the greatest challenge facing transportation engineers at roundabouts. Key issues include:

- First, to cross streets safely at roundabouts, there must be gaps in traffic that are long enough to permit pedestrians to cross to the splitter island (or from the splitter to the destination curb). As the traffic volume increases, the number of 'crossable' gaps decreases.
- Second, pedestrians must distinguish 'crossable' gaps from those that are too short to cross. They must make crossing decisions quickly, before approaching vehicles are too close. Longer gaps are needed to cross multi-lane roads than roads with only one lane in each direction.
- Third, instead of accepting a gap in moving traffic, pedestrians will sometimes cross in front of vehicles that have stopped for them (effectively creating a gap). When (if) vehicles stop, pedestrians who are blind must use their hearing to detect the presence of the stopped vehicle, and they must then decide whether it is safe to walk in front of the vehicle.

As noted earlier, the speed of vehicles influences the likelihood that drivers will stop for pedestrians. Traffic calming measures (e.g., pedestrian signage, flashing beacons, raised crosswalks, narrow lanes, neckdowns) should be considered to maintain low speeds at the crosswalk.

It is more difficult – and dangerous – to cross in front of stopped vehicles if the pedestrian is crossing more than one lane. Vehicles in the lane nearest the pedestrian stop but vehicles in other lanes (moving in the same direction) may not. To facilitate crossing in front of stopped vehicles, consideration should be given to locating crosswalks before the point where two-lane roads are flared to accommodate multiple-lane entries and exits.

Research is currently underway to determine the likelihood that vehicles will yield to pedestrians traveling with dog guides and long canes. Preliminary results about driver yielding behavior collected at 3 crosswalks suggest that most drivers do not yield to blind pedestrians waiting at a crosswalk. This is particularly a problem at exit lanes.

When vehicles do stop, they are sometimes not detected. This is typically the case when vehicles stop several car lengths away from the pedestrian, when the vehicle is relatively quiet (e.g., hybrid gas/electric vehicles), and/or when the sounds of other vehicles mask the sounds of the yielding vehicle. However, the strategy of crossing in front of a stopped vehicle should work where some vehicles stop and are detectable.

Some designers have incorporated stop bars and LED in-roadway warning lights (MUTCD, Chapter 4L) to encourage vehicles to yield to pedestrians at crosswalks. The use of 'YIELD TO PEDESTRIAN' signage at yield lines may also be effective. Recommendations from a roundabouts summit sponsored by ITE and FHWA in December 2002 included raised crossings, particularly on exit legs to discourage driver acceleration. Testing of the effectiveness of 'rumble strips' or similar sound-generating pavings before entry and exit has also been proposed. Research is needed to determine if pedestrians can gain useful information on approaching and yielding vehicles from such cues.

Jurisdictions are also experimenting with ‘smart’ intersections that can sense and signal pedestrian presence. In situations where there are few 'crossable' gaps and where vehicles do not stop for pedestrians waiting to cross (or, because of multiple lanes, it is unsafe to cross in front of a stopped vehicle), specially-designed pedestrian signals -- models include 'HAWK' and 'TOUCAN' schemes that blink in amber unless activated. Pre-emption signals utilized for emergency vehicles and trains may also have some application to provide street-crossing opportunities for pedestrians who are blind. Research is needed to determine how to optimize such signalization for both pedestrians and drivers. Continuing advocacy for signalization can be expected until effective alternatives are developed. Roundabouts with multiple lane entrances and exits, where signalization is more necessary to provide crossable (and detectable) gaps for pedestrians, would experience greater delays from signalization.

3. REMAINING IN THE CROSSWALK

Several design approaches may be used to provide directional information in the crossing. Jurisdictions have experimented with ultra-high contrast markings and crosswalk lighting (useful for pedestrians who have low vision); raised crosswalks to provide a boundary, and providing a raised guidestrip at the centerline of the crosswalk. By using the constant-contact cane technique, a blind pedestrian can identify and use tactile surface cues that provide information about the direction of the crosswalk.

4. DETECTING THE DESTINATION SIDEWALK OR SPLITTER ISLAND

Detectable warnings at splitter islands and destination curb ramps signal one’s arrival at a pedestrian refuge. Splitter islands should be demarcated with detectable warnings at each street/sidewalk edge, separated by a width of untextured sidewalk surface. Because detectable warnings mark the beginning and/or end of a safe pedestrian area, they should be applied in pairs, separated by standard sidewalk surfacing. Research indicates that 24 inches of detectable warning surface is needed for underfoot detection while walking.

The use of similar design features across roundabouts will enhance their accessibility to persons who are blind. Consistency in the location of crosswalks, in the design of splitter islands, in the use of bollards and pedestrian channelizing devices, separators, and edging, and in the use of landscaping features can provide effective non-visual cues for negotiating roundabouts.

When a roundabout is introduced to a community through newspaper and TV stories, be sure to emphasize that pedestrians are expected to cross there. Show photos and film of drivers yielding to pedestrians.

Improvements for gap creation

- ***pedestrian-actuated crossing signals (HAWK, puffin, or similar)***
- ***upstream /downleg signals***
- ***signal metering (as at freeway ramps)***
- ***pre-emption***

RESEARCH IN PROGRESS

Empirical research about the accessibility of modern roundabouts is in its infancy. In 1999, a program of research on roundabout accessibility was initiated by

Western Michigan University and Vanderbilt University. Conducted at three modern roundabouts in metropolitan Baltimore, Maryland, the study provides information about the ability to use vision and hearing to distinguish 'crossable' gaps in traffic from gaps that are too short to afford safe crossing. 'Crossable gaps' were defined as those that would have allowed pedestrians sufficient time to cross from a curb to a splitter island before the arrival of the next vehicle at the crosswalk. The results of the study suggest that there are significant differences in the ability of blind and sighted pedestrians to determine whether it is safe to initiate a crossing at some roundabouts, presumably because of differences in the way information is obtained to make decisions about crossings.

The Western Michigan/Vanderbilt team also conducted a comparable study at three roundabouts in the greater Tampa, Florida area with similar results. A principal finding of this research was that the ability to judge whether gaps are crossable or not is strongly affected by vehicle volume. For example, the judgments of blind and sighted pedestrians were similar at a single-lane roundabout at mid-day, but blind pedestrians were significantly disadvantaged at rush hour.

The team is currently studying the behavior of blind and sighted pedestrians as they cross at roundabouts and the behavior of drivers as they approach blind pedestrians waiting at uncontrolled crosswalks (both at roundabouts and mid-block crosswalks). Preliminary analysis suggests that few drivers yield, although this varies widely from crosswalk to crosswalk. While such research has begun to address several of the key issues cited earlier in this bulletin, it is clear that much more work remains to be done.

Improvements for gap identification/notification

- ***ITS technologies with APS or other audible output***
- ***sound surfaces on entrance/exit legs***

Note: avoid masking vehicle sounds with water features in central island or nearby

FEDERAL RESEARCH INITIATIVES

The dearth of research addressing the negotiation of roundabouts by blind pedestrians has prompted Federal funding of several projects on this topic. The first, funded by the National Eye Institute of the National Institutes of Health, was awarded in 2000 to a consortium led by Western Michigan University. This project emphasizes the identification of variables affecting blind pedestrians' safety while crossing streets at roundabouts and treatments to enhance this safety. The second project, funded by the National Institute on Disability and Rehabilitation Research, was awarded in 2001 to a consortium led by the Sendero Group, LLC. This project emphasizes the identification of wayfinding information needed by blind pedestrians at roundabouts (e.g., crosswalk location, intersection geometry) and ways to convey this information to the pedestrian. A third project, focused specifically on the usability of roundabouts and slip lanes by pedestrians who have vision impairments, will be awarded in 2004 by the National Cooperative Highway Research Program (a prior NCHRP study still underway will identify "geometric, traffic, and other characteristics that are expected to affect the safety and operation of all roundabout users, including bicycles, pedestrians, and pedestrians with disabilities" and to "refine geometric and traffic control design criteria used for roundabouts, including….treatments for bicycles and pedestrians (including pedestrians with disabilities and including the impact of accessible pedestrian signals on pedestrian access and vehicle operations)…"). The Turner-Fairbanks Research Center of the Federal Highway Administration/DOT has a human factors study newly underway that will test several potential improvements to roundabout usability by pedestrians who have vision impairments.

Collectively, these and other projects should significantly enhance engineers' and planners' access to information about how to build roundabouts that can be negotiated safely and efficiently by blind pedestrians.

PUBLIC RIGHTS-OF-WAY ACCESS ADVISORY COMMITTEE RECOMMENDATIONS

The U.S. Access Board is an independent Federal agency that develops accessibility guidelines for buildings, facilities, transportation vehicles, and communications technologies and electronic devices covered by the ADA and other laws. In 1999, the Board established a Public Rights-of-Way Access Advisory Committee (PROWAAC) to make recommendations on accessibility guidelines for public rights-of-way. The 33 members of PROWAAC represented Federal agencies, traffic engineering organizations, public works agencies, transportation departments, traffic consultants, standard-setting organizations, disability organizations, and others. On January 10, 2001, the PROWAAC submitted its report[1] to the Board recommending a new national set of guidelines for accessible sidewalks, street crossings, and related pedestrian facilities. The report includes several recommendations regarding access to roundabouts. In particular, the report recommends:

[1] Found by going to http://www.access-board.gov/prowac/commrept/index.htm.

- barriers (landscaping, railings, bollards with chains) where pedestrian crossings are prohibited;
- cues (locator tones, detectable warnings, other) to identify crossing locations; and
- pedestrian-activated traffic signals at crossings.

The Access Board will consider Committee recommendations in developing a Notice of Proposed Rulemaking (NPRM) on guidelines for public rights-of-way for publication in the Federal Register. The NPRM will seek public input and comment on the proposed guidelines before a rule is finalized. Further information on the status[2] of this rulemaking is provided on this website.

[2] Found by going to http://www.access-board.gov/prowac/status.htm.

APPENDIX B - PEDESTRIAN TRAFFIC SIGNAL OPERATION

B.1 PELICAN Traffic Signal

The Tucson PELICAN crossings, Pedestrian Light Control Activated, were initiated by the city of Tucsan, Arizona using the European mid block pedestrian crossing technique of the same name. The technique incorporates a standard RED-YELLOW-GREEN signal indication method that rests in GREEN for vehicular traffic until a pedestrian wishes to cross. The signal then changes to YELLOW and then RED and a WALK light is shown to the pedestrian.

The pedestrian crosses the street in two stages, first to a median island and then along the median to a second signalized crossing point a short distance away. The pedestrian then activates a second crossing button and another crossing signal changes to RED for the traffic giving the pedestrian a WALK signal. The two crossings only delay the pedestrian minimally and allow the signal operation to fit into the arterial synchronization thus reducing the potential for stops, delays, accidents and air quality environmental issues. Tucsons experiences at the PELICAN crossings indicate that driver's compliance seems as good as other traditional traffic signals. However some driver violations have been reported and noted. The device is quite effective overall in providing a safe crossing for pedestrians at mid block crossings when the technique can be accommodated into the roadway cross section.

B.2 TOCAN Traffic Signal

The signal system was designed similar to the European technique to provide a safe crossing for "two" groups-pedestrian and bicyclists, thus the name "TOCAN"or TwO (groups) CAN cross the roadway.

The process of designing the TOCAN was as important as the end product. The design team consisted of community members, citizen bicycle advisory members, and associated neighborhood groups. A traditional signal system would be inappropriate at most locations when just a bicycle crossing is needed. In many cases the bike route is along a residential street where the crossing of the arterial is at an irregular spacing. Thus, the installation of a traditional full signal would not allow for good signal synchronization creating excess stops, accidents, delays and air quality concerns. The second concern is that a traditional full signal would encourage additional traffic to cut through or along the residential street thus negatively impacting the "livability'of the street. The committee worked together to find a balance of these competing transportation objectives and reached a consensus for the design and implementation of the pedestrian-bicycle signal.

B.3 HAWK Pedestrian Flasher

The signaling system is a combination of a beacon flasher and traffic control signaling technique for marked crossings. The Tucson High-intensity Activated crossWalK or HAWK crossing is an extension of the traditional school bus flashing warning signal when children are crossing the road and the European level or emergency crossing signal. The new edition of the Federal Highway Administration's Manual on Uniform Traffic Control Devices, 2001, recognizes the use of a flashing beacon signal in the context of use for emergency beacons. The beacon signal consists of a standard traffic signal head with a RED-YELLOW-RED lens.

The unit is normally off until activated by a pedestrian. When a pedestrian wishes to cross the street, they press a button and the signal begins with a FLASHING YELLOW indication to warn the approaching drivers, just like a school bus signal. The FLASHING YELLOW is then followed by a SOLID YELLOW indication, advising the drivers to prepare to stop. The signal is then changed to a SOLID RED indication at which time the pedestrian is shown a WALK indication. The beacon signal then converts to an ALTERNATING FLASHING RED, allowing the drivers to proceed when safe, after stopping at the crosswalk.

A video showing the operation of the HAWK Pedestrian Flasher can be found by going to http://www.dot.ci.tucson.az.us/traffic3/video/HAWK.wmv.

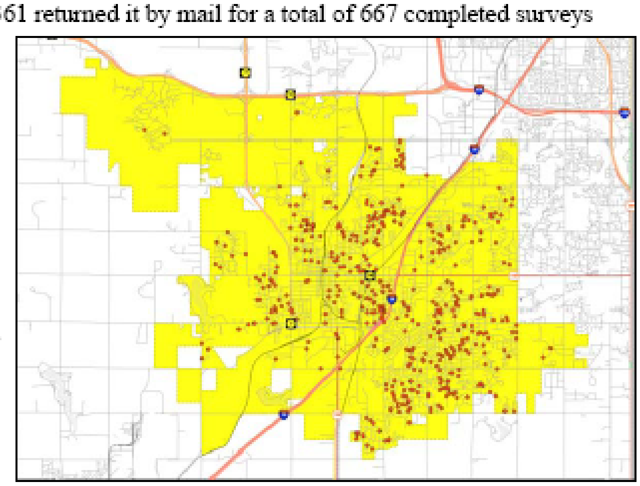
APPENDIX C - CITY OF OLATHE 2006 ROUNDABOUT SURVEY EXECUTIVE SUMMARY

City of Olathe
2006 Roundabout Survey
Executive Summary

Purpose and Methodology

ETC Institute administered a survey for the City of Olathe during March 2006. The purpose of the survey was to gather input from residents regarding their perceptions of roundabouts, which have been implemented as a traffic control measure at several intersections in the City. This was the second time the City of Olathe has conducted a survey on roundabout issues. This first survey was conducted in 2001.

Methodology. The survey was mailed to a random sample of 1,500 households in the City of Olathe on March 14, 2006. Approximately seven days after the surveys were mailed, residents who received the survey were contacted by phone. Those who indicated that they had <u>not</u> returned the survey were given the option of completing it by phone. Of the households that received a survey, 306 completed the survey by phone and 361 returned it by mail for a total of 667 completed surveys (44% response rate). The results for the random sample of 667 households have a 95% level of confidence with a precision of at least +/- 3.8%. There were no statistically significant differences in the results of the survey based on the method of administration (phone vs. mail). In order to better understand the perceptions of residents in specific areas of the City, ETC Institute geocoded the home address of respondents to the survey. The map to the right shows the physical distribution of survey respondents based on the location of their home.



This report contains:

- a summary of the methodology for administering the survey and major findings
- charts showing the overall results for most questions on the survey
- GIS maps that show the results of selected questions on maps of the City
- crosstabulations that show the results based on the length of residency and the frequency that residents use roundabouts
- a copy of the survey instrument.

Major Findings

Overall Satisfaction with Roundabouts is Very High.
Olathe residents were four times more likely to be satisfied (62%) with roundabouts than they were to be dissatisfied (15%); 23% of those surveyed gave a neutral rating or did not have an opinion. Overall satisfaction with roundabouts has increased from 55% in 2001 to 62% in 2006. Three-fourths (75%) of those surveyed who used roundabouts daily were satisfied compared to 51% of those who used them just a few times per month.

Residents Generally Think Roundabouts Have Decreased Travel Time
Olathe residents were nearly four times more likely to think that travel times on streets with roundabouts have decreased (42%) since roundabouts were completed than they were to think travel times have increased (11%); 24% of those surveyed thought travel times were about the same, and 24% did not have an opinion (total does not sum to 100% due to rounding). The percentage of Olathe residents who thought travel times have decreased on streets with roundabouts has increased from 36% in 2001 to 42% in 2006. The percentage who thought travel times have increased has declined from 19% in 2001 to 11% in 2006.

Olathe Residents Think the City Should Continue Developing Roundabouts
Sixty-one percent (61%) of those surveyed thought the City of Olathe should continue using roundabouts as a traffic control option for intersections; 23% did not think the City should continue using roundabouts, and 16% did not have an opinion.

Residents Prefer Roundabouts Over Other Traffic Control Options
More than half of those surveyed (53%) indicated that they would prefer to see roundabouts at intersections in Olathe; 27% indicated they would prefer traffic signals, 15% indicated they would prefer four-way stops, and 5% did not have an opinion.

Other Findings

- 99% of those surveyed indicated that they have used roundabouts in Olathe; 24% indicated they use roundabouts daily.

- 25% of those surveyed thought roundabouts had made intersections safer, 27% thought roundabout had made intersections less safe, 32% did not think roundabouts had any affect on travel safety, and 16% did not have an opinion.

- 31% of those surveyed thought signage though roundabouts was “easy” to understand; 49% rated the signage through roundabouts as “ok”; 18% thought the signage was “difficult” to understand, and 2% did not have an opinion.

K - TRAN

KANSAS TRANSPORTATION RESEARCH
AND
NEW - DEVELOPMENTS PROGRAM

A COOPERATIVE TRANSPORTATION RESEARCH PROGRAM BETWEEN:

KANSAS DEPARTMENT OF TRANSPORTATION

THE UNIVERSITY OF KANSAS

KANSAS STATE UNIVERSITY