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ROUNDABOUT STUDIES IN KANSAS

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ABSTRACT: The Kansas Department of Transportation (KDOT) became interested in roundabouts in 1998 and started designing and building roundabouts on state highways in Kansas (KS). They sponsored three research projects to get before and after data at several Kansas roundabout locations. These studies are still on going at Kansas State University (KSU). Concurrently, the traffic engineer in the City of Manhattan, (City) when confronted with a high crash rate at the intersection of two residential collector streets with two-way stop control, chose a roundabout over other options. The City co-sponsored a project with Mack Blackwell Transportation Center (MBTC) to compare the traffic operations of the roundabout with other options. The Insurance Institute for Highway Safety (IIHS) funded an additional project to get before and after data and analyze operation of roundabouts in Hartford County, MD, Hutchinson, KS and Reno, NV. The paper will review the data collection and analysis techniques and present results of several comparisons of roundabouts to other types of traffic control that show that the roundabout is superior to almost every other type of traffic control based on the (MOEs) used. The authors will present the results of their analysis that lead them to conclude that roundabouts are the safest and most effective type of intersection traffic control available today. The paper will also present a brief review of some, irrational public opposition.

1. THE MANHATTAN ROUNDABOUT STUDY

The material in this section is exerpted from a report the authors wrote for Mack Blackwell National Rural Transportation Center: “Modeling Traffic Flows and Conflicts at Roundabouts”.(Russell, et al, 2000) The full report is available on the Mack Blackwell web site.

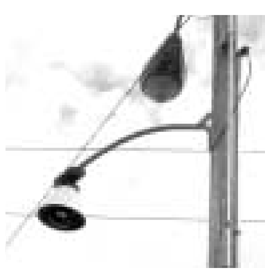

Figure 1. Omnidirectional Video Camera Mounted to Street Light Pole

2. STUDY OBJECTIVE

This study was undertaken to determine how a roundabout functioned compared to traditional intersection traffic control. This section describes the process used to determine which intersections were included in this study, how data was collected and how they were analyzed.

2.1 Video Data Collection

The city of Manhattan, Kansas obtained and installed a specially designed video camera and recording equipment for data collection (see Figure 1). The camera was designed to provide a full 360^{o} view when mounted above the intersection. At the roundabout, the camera was installed on an existing street light pole in the southeast corner of the intersection. The camera was attached to the end of a street light arm that was then attached to the wood street light pole. The camera was mounted perpendicular to the ground, which allowed the video image to be relatively distortion free to the horizon in all directions. Mounting height for the camera was approximately 6 meters (20 feet) above the street surface. According to the manufacturer specifications, this mounting height provides a focal plane of approximately 40.5 meters by 54.0 meters (133 feet by 177 feet). (List and Waldenmaier, 1997) The camera allows the focal plane to be made larger or smaller based on the height above the intersection. At all intersections the camera feed went into a VCR/ TV unit housed in a traffic signal controller cabinet attached to the base of the pole. The signal cabinet provided a secure weather tight location for the recording equipment. The video image was recorded on standard VHS videotapes. In all, over 200 hours of videotape was collected from the modern roundabout and two similar intersections to which it was compared. Once the videotapes were collected, they were evaluated through observation. The main objective of the manual data collection was to obtain traffic flow data which was recorded in 15-minute increments.

3. ANALYSIS I: FIELD - DATA ANALYSIS

The study team and advisory committee members reviewed possible comparable intersections. Based on personal knowledge of the intersections and study focus, two comparable intersections were chosen, both operated under two-way, stop control.

This phase of the project began with a statistical evaluation of raw traffic data to assure that the three intersections were being observed under ‘similar’ traffic conditions. Then the data which had been obtained from the video tapes was used as input into the computer evaluation program SIDRA. SIDRA is an Australian simulation program that can evaluate the operation of a roundabout as well as signalized and unsignalized intersections. It is an excellent computer program to compare modern roundabouts to other types of intersection traffic control. This software was used to evaluate all three intersections operating under their existing traffic control (roundabout, two-way STOP). SIDRA provided output values for the six measures of effectiveness (MOEs) used (described in Table 1). The output from SIDRA was then statistically evaluated using standard statistical methods to determine which, if any, of the three intersections could be considered to be operating better then the others.

Table 1. Intersection Measures of Effectiveness (MOEs) (Russell, et al)

Measure of Effectiveness:	Description:
95% Queue	Length of the queue for all approaches at the 95% confidence level
Average Delay	Average vehicle delay for all entering vehicles
Maximum Approach Delay	Average vehicle delay for the approach with the highest average vehicle delay
Proportion Stopped	Proportion of entering vehicles that are required to stop due to vehicles already in the intersection
Maximum Proportion Stopped	Proportion of entering vehicles that are required to stop due to vehicles already in the intersection on the approach with the highest proportion stopped value
Degree of Saturation	Amount of capacity that is consumed by the current traffic loading (commonly referred to as the v/c ratio)

4. MANHATTAN STUDY SUMMARY

Conclusions were drawn for each MOE with regard to the operation of the intersections and intersection control types. Details of the extensive statistical test summaries run on each MOE for each intersection and statistical tests run on the comparisons are presented in the study final report (Russell, et al, 2000) but only a summary will be presented here.

4.1 Analysis I: Field – Data Analysis

Analysis I examined the operation of the roundabout intersection relative to two comparable intersections with two-way STOP traffic control, using actual field data.

4.2 Analysis II: SIDRA Analysis:

The computer program SIDRA allows theoretical comparisons at intersections, with any type of traffic control including modern roundabouts. Thus SIDRA was used to compare the modern roundabout at Candlewood Drive and Gary Avenue with other options; namely, two-way stop (2S), (existing before roundabout), 4-way stop (4S) and four-way stop with added approach lane for left turns (4L). These three, 2S, 4S and 4L were compared to the modern roundabout (RA).

5. OVERALL - MANHATTAN STUDY CONCLUSIONS

5.1 From Analysis I:

1. The Manhattan roundabout was found to experience a higher level of average vehicle delay but a lower maximum approach vehicle delay than the two comparable two-way STOP controlled intersections.
2. The Manhattan roundabout operated better than the two comparable two-way STOP controlled intersections with regard to degree of saturation (v/c ratio).
3. The Manhattan roundabout was found to have a statistically lower maximum approach proportion stopped.
4. The Manhattan roundabout operated as well as a two-way STOP with regard to average delay and better than the two-way STOP for the other four MOEs.
5. Overall, considering all MOEs the research team judged the Manhattan roundabout to be an equal or better form of intersection traffic control when compared to comparable two-way STOP intersections.

5.2 From Analysis II

1. The roundabout operated better than both four-way STOP alternatives (4S and 4L) for all six MOEs used. A summary is shown in Table 2.

Table 2. Summary of MOE Statistical Results - Analysis II

Measure of Effectiveness:	**Statistical Result:**[a]	**Traffic Control Advantage:**
95% Queue	RA < 4L = 2S < 4S	Roundabout
Average Delay	RA = 2S < 4S < 4L	Roundabout/two-way stop
Maximum Approach Delay	RA < S2 < 4S < 4L	Roundabout
Proportion Stopped	RA < 2S < 4L < 4S	Roundabout
Maximum Approach Stopped	RA < 2S < 4L < 4S	Roundabout
Degree of Saturation	RA < 2S < 4S < 4L	Roundabout

[a] RA = roundabout; 2S = two-way stop; 4S = four-way stop and 4L = four-way stop with added turn lane

5.3 SAFETY, MANHATTAN

The crash experience of the Manhattan roundabout mirrors that found in available U.S. and international studies. There was an average of three per year (with 1.3 injuries per year) prior to installation. In the three years since installation, there has been two minor traffic crashes. This reduction is statistically significant. Therefore, this roundabout significantly reduced the number of crashes.

6. BRIEF HISTORY OF ROUNDABOUTS IN THE WORLD

The following brief history of roundabouts is paraphrased from Brown (1995) except as otherwise noted. Circular places were used as the convergent points of roads since the middle ages, especially during the renaissance. This scheme became popular in many cities on large and small scales. A notable example was in Paris where traffic was designed to circulate around a central monument- the Arc de Triomphe - which today experiences terrible traffic congestion.

The concept of “gyratory” operation of intersecting traffic dates from at least 1903. It was in 1903 when Eugéne Hènard suggested gyratory operation for traffic control at intersecting streets (Hènard, 1903). The concept of Hènard’s “giratoire-boulevard” was inaugurated in Paris until 1907 at Place de l’ Étoile, now Place Ch. d’Gaulle (Brown, 1995). The earliest practical use of a gyratory intersection in the USA is reported to be Columbus Circle installed by William Phelps Eno in New York City in 1905. (Todd, 1988)

The first gyratory intersection in Great Britain was constructed in 1909 (Brown, 1995). In 1913-14 Hellier suggested that where several main streets meet, there should be a circular plot and adoption of a gyratory road system (Hellier, 1913/14). In 1925-26 gyratory systems were introduced in London at several locations.

The trend to use roundabouts was formally recognized in Great Britain in 1929 when a joint effort between the Ministry of Transport and the Town Planning Institute issued MOT Circular No. 302. This appeared to be the earliest use of the term “roundabout”. (Brown, 1995)

In the early 1900's gyratory systems were used in the USA but there was great difficulty in regulating traffic. Local ordinances were unenforceable and there were no uniform rules of the road in the country (Brown, 1995). The roundabout fell out of favor for major intersections in the USA and by the mid 1950's was no longer a viable option. (FHWA, 1999) Subsequently, many of the old rotaries and circles were removed and replaced with signals. It is important to note that these circular intersections - sometimes call gyratories, rotaries or traffic circles - were not modern roundabouts and generally did not have any of the characteristics that make the modern roundabout a safe and efficient means of controlling intersection traffic. Many of these older traffic circles were inefficient, confusing and/or had high crash rates. Many of them in the eastern USA (and elsewhere in the world) were replaced with other traffic control.

Early designs gave priority to entering vehicles facilitating high-speed entry, high-crash experience and congestion. (FHWA, 1999) Worldwide experiences were negative, as Great Britain (and others) experienced circles that locked up as traffic volumes increased. (FHWA, 1999) Although many of these old traffic circles were removed in Europe and the USA, (New Jersey, for example), many remain today, e.g. Washington D.C. Subsequent research in Great Britain led to the idea of “yield at entry” (give-way rule). Great Britain adopted it as a mandatory rule in November 1966. In a short time it ended the “locking problem”, improved capacity, reduced crashes, and created a complete change in philosophy of roundabout design and operation (Brown, 1995).

Research continued in Great Britain and it was determined that where sufficient reduction of traffic speed is obtained due to deflecting traffic at entry, crash rates were low. It followed that in Great Britain in 1975 a revised design recommended that a curved vehicle path or "deflection" be achieved by providing angled deflection islands (usually raised) at entry and a suitably sized and positioned central island to prevent vehicles from taking too straight a path through the intersection (Brown, 1995). Design Standard DTp 16/84 was issued in Great Britain in 1984 that introduced “entry path curvature” (deflection) requirements and the concept of a newer, smaller roundabout as being a “normal” roundabout. (DTp Design Standard 1984) Thus, the concept of the “*Modern* Roundabout,” as the author prefers to call them, came into being in 1984 with three principal features: yield to traffic in the circle, deflection at entry, and low design speed (controlled by the amount of deflection).

Similar design changes followed in European countries and throughout the world. In France, the first roundabouts with priority to traffic in the circle were tried experimentally in the 1970's (Thai Van, et al, 2000). It showed good advantages for safety, fluidity and simplicity, and the rule of priority for traffic on the roundabout was introduced into the highway code in September 1983 (Thai Van, et al, 2000). Since then, roundabouts have grown rapidly throughout France (Thai Van, et al, 2000): 12,000 by the end of 1994, 15% increase from 1993 to 1994, and greater than 17,000 in 2000. It is important to note that these changes in design philosophy and design guidelines took place in the mid-1980s and any circular intersection designed and built before this is not a modern roundabout.

In the USA it was after 1990 before the first modern roundabout was built and operating. Thus any circular intersection in the USA designed and built before 1990 is not a modern roundabout, although opponents (particularly when the first modern roundabout is proposed in an area) keep confusing them with the older traffic circles that can be confusing, inefficient and/or dangerous.

Another traffic engineering concept that was catching hold rapidly in the USA in the 1990s is "traffic calming", a wide range of techniques, usually physical features, with names like chicanes, speed humps, diagonal diverters, bulb outs, etc., to slow vehicles from speeding through residential or commercial neighborhoods. Small traffic circles are a common traffic calming device. A small traffic circle is a raised, circular area built in the center of an existing intersection for the specific purpose of causing traffic to slow to a low speed (or for through vehicles to avoid the street entirely). In a sense, they tend to be “road blocks” and their main purpose is to discourage high speeds and through traffic and not for traffic control. Most are quite small - built within the confines of residential or commercial intersections - and have no entry island to start the deflection of vehicles. It is important to note that they also are *not* modern roundabouts.

6.1 Public Acceptance in Manhattan, Kansas

The city of Manhattan has two modern roundabouts. The first, Candlewood and Gary (analysis discussed above) was more or less “snuck” in with little or no publicity. Neighborhood residents were demanding better traffic control, and the city traffic engineer designed and installed a modern roundabout following the Florida manual, one of the few existing at that time.

Around the same time in Manhattan, about seven small, neighborhood traffic calming circles were constructed in two other neighborhoods. These were installed to slow people down (traffic calming) and/or obstruct or discourage free-flowing, through traffic. Their design has little or no resemblance to a modern roundabout as there was no intention for them to serve any purpose but neighborhood speed control. They were very unpopular and the subject of extensive negative publicity. The author feels that this has biased many Manhattan citizens against modern roundabouts. The average citizen does not seem to understand the difference.

A second modern roundabout was designed and built on a bypass highway on the edge of the city in an area that was becoming heavily residential. It also served as a main route to the football stadium used by thousands of football fans on home game days. Prior to construction there were all sorts of opposition and predictions of “disaster”. These can be summarized as follows (The Manhattan Mercury, various dates):

- football traffic would back up 20 miles (32 km);
- recreation vehicles would not be able to get through the roundabout;
- out of town drivers won’t know how to drive through it;
- there would be numerous crashes;
- football fans would be upset and not support the team; and
- new students would not be able to drive through it safely.

After this modern roundabout (Grand Mere/Kimball) was opened, traffic flowed through it very smoothly. Cars, large trucks, buses and recreation vehicles (RVs) were all observed passing through the roundabout with no problems. On football game days traffic flowed steadily and there never was a queue of more than three or four cars. Subjectively, it could be stated that this roundabout operated quite well. Much of the vocal opposition (to roundabouts) was basically silenced, perhaps disappointed that this roundabout was not the “disaster” they had predicted. However, when a third modern roundabout was proposed (Kimball/North Manhattan) the city council voted it down on a 3 to 2 vote. The 3 to 2 decision was in spite of the fact that the modern roundabout option was recommended by the city engineering staff, a consulting firm and an outside national expert on modern roundabouts, and was the least cost. In the authors opinion, this was due to lack of "political will" due to some vocal opposition by a few community leaders biased against modern roundabouts due to ignorance and/or misunderstanding of the safety and operational benefits of a modern roundabout. For example, one commissioner, during debate referred to the large, old confusing circles such as Dupont Circle in our nations capitol (Washington, D.C.) even though it would be absurd to equate these circles to modern roundabouts. One commissioner used an analogy of the proposed, modern roundabout being like spinach - even bringing a can of spinach as a prop - good for you but unpopular. Another commissioner cited 40 (*forty*) phone calls (out of a population of about 50,000) as "overwhelming" public opposition by his constituents. The above is to emphasize that there is a great deal of opposition to modern roundabouts, albeit, in the author's opinion, irrational.

A small, vocal segment of the general population and KSU administrators continue to argue against roundabouts. The authors believed that the majority of the opposition is due to the lack of understanding of the operation and benefits of a *modern roundabout* due to one or two things: 1) mistakenly equating them to the neighborhood traffic circles; or 2) mistakenly equating them (from experience or hearsay) to operational characteristics of the big old, traffic circles/rotaries built long before the design principles of the modern roundabout were developed in the post 1983 period (1991 in the USA).

Although a few persons who understood and appreciated the safety and operational benefits of roundabouts were beginning to speak out, the opposition remained very vocal. Comments expressed in letters to newspapers showed little or no understanding of modern roundabouts. Excerpts follow:

- "The "roundabout for wimps" on Scenic Drive [Grand Mere/Kimball] doesn't compare with the high-speed free-for-all that would occur on Kimball Avenue [the proposed third roundabout]" (The Manhattan Mercury, A6, Feb. 1, 2001).
- "...As for whether we should have a roundabout at Kimball and Manhattan Avenue [the proposed third roundabout], I suppose if everybody would go in for training, it would be OK. It [training] could be required for new residents. But how do we handle visitors, elderly and drunks?" (The Manhattan Mercury, A6, Feb. 1, 2001).
- "...A roundabout at Kimball and North Manhattan [the proposed third roundabout]? I don't think so. For one car it might work. But it won't work for hundreds of cars" (The Manhattan Mercury, A6, Jan. 22, 2001).
- "...Wefald [Jon Wefald, KSU president] said roundabouts typically are built on flat land and take up acres" (The Manhattan Mercury, Article, Page 1, Jan. 24, 2001).

The authors believe that the facts overwhelmingly supported the installation of a roundabout as the best choice of traffic control for the intersection in terms of safety and efficient traffic flow, as well as low cost. In other words, the clear first choice based on engineering studies would also have been the least cost.

7. PUBLIC ACCEPTANCE OF ROUNDABOUTS IN THE USA

In much of the USA, public acceptance of roundabouts is one of the biggest challenges facing a public jurisdiction planning to install its first roundabout (FHWA, 1999). Without a successful education program or first-hand experience and observation, the public can incorrectly associate all "roundabouts" with the older, inefficient, confusing traffic circles or rotaries they have experienced or heard negative remarks about or with neighborhood traffic circles, generally disliked in many areas. Also there is a natural resistance to change in both driving behavior and driving environment.

This section of the remainder of this paper will primarily discuss examples of community opposition in the USA. Citizen comments are taken from actual "letters to the editor" and editorials from local newspapers. As will be seen in the sections below, many of the views of the opposition are irrational; even silly.

7.1 Acceptance in Other Kansas Cities

To illustrate that negative feelings and misunderstandings are rampant in other parts of Kansas, other examples are presented below. In Olathe, a large city south of Kansas City, two, two-lane roundabouts were installed. Below are some excerpts from the Olathe newspaper.

> "Roundabouts have been used in Europe for years. One most famous roundabout is around Arc de Triumph (SIC) in Paris. Anyone who has experienced driving around it knows this: When there is a break in traffic, don't waste time getting into the traffic flow and don't worry about what's behind you; look straight ahead, drive as fast as you can, try to stay in the farthest right lane and get out of the circle as fast as possible" (Olathe Daily News, October 23, 2000).

The writer obviously has no understanding between a *modern* roundabout and a big, old traffic circle or rotary. (Note: Although France has close to 20,000 modern roundabouts, Paris has none - zero. All those circular intersections in the city are *not* modern roundabouts.) The writer goes on to *prove* that he/she has little or no knowledge of modern roundabouts (Olathe Daily News, October 23, 2000):

> "Roundabouts being constructed in the United States are nothing more than mini-versions of the Arc de Triumph (SIC), but with the same kind of driving challenges."

7.2 Hutchinson, Kansas

The authors will present a few more excerpts from The Hutchinson News to illustrate how ridiculous (or even "silly") people can be in regard to roundabouts. Hutchinson is a medium sized city in central Kansas that proposed and finally built a roundabout at an intersection near the Kansas state fair grounds. The intersection carries heavy traffic and had a serious crash problem - 19 right angle crashes in a period from February 21, 1996 to November 28, 1997. During state fair week, tens of thousands of visitors caused severe congestion and back-ups at the intersection. Engineering studies concluded that a roundabout was the best alternative. A group of citizens became "irrate" and started an anti-roundabout campaign. They called themselves "CAR" (Citizens Against Roundabouts) and produced billboards, lawn signs and petitions against roundabouts. The organizers of the CAR group were quoted as saying: "...almost everyone felt it [the roundabout proposal] was the most asinine idea the city has come up with, bar none" (The Hutchinson News, December 22, 1999). Examples from the local paper illustrate the depth of the opposition:

- "If you do build a roundabout it will be the 'Mother of all Bad Intersections' We could sell tickets to see it" (The Hutchinson News, letters to the editor, October 6, 1999).
- "They [referring to traffic circles in another state] are easy to find; just look for a traffic jam and the ground piled up with broken glass and car parts" (The Hutchinson News, letters to the editor, October 10, 1999).
- "If doctors attached a name to it [peoples concern], they'd call it 'Roundabout Anxiety'" (The Hutchinson News, Editorial, November 9, 1999)
- "…the circles turn mild-mannered people into enraged drivers as they jockey to get into and out of the swift moving traffic" (The Hutchinson News, Editorial, November 1999).

7.2.1 Safety, Hutchinson

It should be noted here that there were 19 right angle collisions that occurred in a 19 month period before the modern roundabout was constructed. In a similar period after, *only two minor crashes have been reported*.

7.3 Other USA States

There is opposition in other states as well. Following is an example from a citizen's editorial in a Colorado paper (Coloradoan, undated clipping).

> "Our roundabout is being installed to relieve the traffic congestion at the intersection of Colorado Highway 14 and Lemay Avenue. There already is strong evidence that it will effectively achieve that goal because many residents have indicated they will quit using that intersection because they 'won't drive through that damn thing.' Although residents are concerned about the projected high costs of constructing the roundabout there are a few things the city could do to generate revenues to offset these costs. For example, the city could sponsor an event called 'Roundabout Days.' On that special weekend, bleachers would be set up on all four corners of the roundabout and local residents and visitors could applaud and vote for their favorite near-miss or fender-bender for various categories of motor vehicles. Special awards could also be given to the 'most confused driver' in each age group. The roundabout could also stimulate some new employment opportunities. Booths housing skilled drivers could be located close to each of the four entry points, and timid drivers could hire these 'experts' to navigate their cars through the roundabout."

8.0 Insurance Institute for Highway Safety Public Acceptance Study

The IIHS is conducted a study in communities where a modern roundabout has been installed, to compare before and after public opinion. The preliminary results of the IIHS study show that once citizens experience a *modern* roundabout, their attitudes change toward acceptance. The "strongly favor" category doubled from 16% to 32% and the "somewhat favor" category doubled from 15% to 31% while the "strongly oppose" category went from 41% to 15%. These are encouraging trends. (IIHS, July 28, 2001)

9.0 ROUNDABOUT BENEFITS: SUMMARY

9.1 Safety

The Manhattan and Hutchinson roundabouts significantly reduced both the numbers and severity of crashes. This reduction is consistent with other worldwide studies. For example, the FHWA guide (FHWA 1999) reported reductions in both total (all) and severity of (injury) crashes of Australia (61% all, 87% injury) in Germany (36% all); France (78% injury); Netherlands (47% all) UK (39% injury), USA (37% all, 51% injury).

The Insurance Institute for Highway Safety (IIHS) conducted the most comprehensive study of crashes at 24 intersections before and after construction of roundabouts (IIHS, May 13, 2000). The study found a 39% overall decrease in crashes a 76% decrease in injury – producing crashes and as much as 90% in fatal or incapacitating injuries.

The state of Maryland is the leading USA state for modern roundabouts on state highways. Eight of these have existed long enough to draw before and after crash conclusions (Maryland, Office of Traffic Safety, October 2001). In spite of traffic growth, since conversion to roundabouts, the annual crashes dropped from an average of 5.0 crashes per year (before) to 1.8 crashes per year (after), a 64% reduction. Crash severity dropped from an average of 3.0 injury crashes (before) to 0.5 crashes per year (after), an 83% reduction. (Details of the Maryland Report can be found at http://www.ksu.edu/roundabouts)

9.2 Operational Efficiency

Preliminary results from ongoing studies at KSU on several modern roundabouts are showing that modern roundabouts have greater overall operational efficiency than all other forms of traffic control. For example, a modern roundabout in Lawrence, KS showed statistically significant reductions in 5 of the 6 SIDRA MOE's (discussed previously) used; 95% queue length (-14.1%); Max Approach Delay (Sec) (-34.4%); Proportion Stopped (-33.3%); Max Proportion Stopped (-46.7%) and Degree of Saturation (-13.3%) (KSU, 2002). A study done for IIHS on modern roundabouts in Kansas, Maryland and Nevada, compared before and after stopping and delays. Installing the roundabout reduced the amount of traffic having to stop at the intersections resulting in about a 20% reduction in delay (IIHS, July 28, 2001).

10. CONCLUSIONS

Recent USA studies prove that the modern roundabout is safer and more efficient than all other forms of traffic control at most intersection locations. In some parts of the USA, once they have been installed, drivers have good experiences with them and become converts to their many benefits. However, in the USA at present, misunderstanding, misinformation, bias and prejudice still exist against the use of *modern* roundabouts in many areas. In many places, Midwestern USA in particular, opposition based on misinformation, misunderstanding and bias have limited the growth that has been experienced in other countries and some states in the USA, Maryland, Oregon and Washington (State) for example. The authors have presented evidence of this fact.

The authors conclude that there needs to be more education programs and research results aimed at the public. Acceptance is coming slowly, but it will come. The authors believe that in a few years, the numbers of modern roundabouts will grow exponentially, and as more drivers experience the benefits, it will become widely accepted.

10.1 Caveats

It must be stressed that the significant reductions in crashes and crash severity result from a well designed modern roundabout, with sufficient deflection to ensure low-speeds – no more than 30 to 40 km/hr. Also, the roadway environment or approach geometry (e.g. roadway curvature) should be such that drivers do not approach at high speeds. A study (Flannery, 2000) of crashes at modern roundabouts concluded that the main cause were approach geometry that allowed high-speed entry and lack of adequate deflection in the roundabout. Unfortunately, due to lack of clear cut guidelines and inexperienced designers, some new roundabouts in the USA are being built with little or no deflection.

11.0 Acknowledgements

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