ROUNDABOUTS: AN EFFICIENT FORM OF TRAFFIC FLOW?

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In the waning days of completing this thesis, I truly wanted to be done with this endeavor. As I toiled away in the Fort Wayne Public Library, I had to find a way to motivate myself. So I wrote a note to myself on the white board. The note said, “You still have work to do that you wish you were done with. Though you are not done, you are more than capable of finishing. For this reason, you need to stop complaining and just finish. Finishing is the simplest way for you to grant your wish of being done.”
Chapter 1: Introduction

Introduction and Problem Statement

With the start of automobile mass production in 1913 by Henry Ford, American families were able to purchase mass produced vehicles. The automobile is iconic of the American dream and still serves as such today; the automobile offers personal convenience and independent mobility. Most individuals choose to forego public transit, if the option exists, for the automobile. This power has given individuals the mobility and freedom to come and go as they please. Today, for every licensed driver, there is more than one automobile (Arnott, Rave, & Schöb, 2005). However, as time moves forward, some roads, particularly in urban areas, reach their operational capacity, resulting in traffic congestion and gridlock.

There are three methods for managing traffic flow at intersections. They include (1) signalized or stop light intersections, (2) un-signalized or signed intersections, and (3) roundabouts. These systems, in conjunction is roadway rules and regulations, tell drivers and non-motorized users when and when not to proceed. Intersections are the control modules of traffic flow, but traffic has reached a point where the capacity has overwhelmed these control modules. A good example of this are three intersections that will be evaluated within this thesis. These three intersections are the most congested intersections within the City of Fort Wayne.

As Fort Wayne expands and sprawls out, the roads that feed this expansion becomes more congested and gridlocked. This expansion and sprawl occurs through
population growth and annexation of surrounding communities. People wake up for their morning ritual, what is known as the morning commute – people head to work and/or drop their children off at school or daycare. But this is easier said than done. This is important because getting caught in traffic congestion because you left at 7:35am versus 7:30am may have a dramatic effect on how long a commute takes; the commute that usually takes 15 minutes may now take 50 minutes (WANE News, 2011). Mitigating and finding viable solutions to this problem will help to improve traffic flow. However, spending money on roadway expansion is an excessive solution just so people can save a couple of minutes of time on their commute. Instead, people should learn how to adjust to current traffic conditions. The current solution for traffic congestion is roadway expansion. But soon after expansion, traffic congestion ensues to fill the extra space on the roadway.

This is important to planners because their decisions may mitigate the occurrence of traffic congestion. For this reason, when a planner comes up with ideas, along with addressing safety, health, and protecting the environment, it needs to accommodate the needs of all potential users, including drivers, cyclists, and pedestrians, while not overwhelming the operational capacity of a roadway and/or intersection. Planners must cope with decisions and alternatives while mitigating risk and harm to users.
Background of the Study

Fort Wayne is the second biggest city in the state of Indiana. It has a population of 254,555 as of the 2012 US census. It covers an area of 110.62 square miles (US Department of Commerce, n.d.).

![Figure 1: The Three Intersections That Bisect SR930](image)

Fort Wayne, like any other major city, has problems with traffic congestion. Back in Jan 2011, *Wane News* reported on the three most congested intersections in Fort Wayne. They are all located within less than a mile stretch of freeway on State Road 930 West Coliseum Boulevard. The three intersections that bisect SR930 W Coliseum
Blvd are Lima Road, Coldwater Road, and North Clinton Street (WANE News, 2011). They are illustrated in Figure 1.

At the intersection of W Coliseum Blvd & Lima Rd, there are no sidewalks except for the segment heading south along Lima Rd from W Coliseum Blvd. Next, at the intersection of W Coliseum Blvd & Coldwater Rd, there are sidewalks along Coldwater Rd heading north and south from Coliseum Blvd. Finally, at the intersection of W Coliseum Blvd & N Clinton St, there are no sidewalk in any direction. For pedestrians, crossing these intersections are intimidating. There is no signal phase for pedestrians at any of these intersections. Even at the intersection of W Coliseum Blvd & Coldwater Rd, where there is a sidewalk north and south of W Coliseum Blvd along Coldwater Rd, pedestrians must use their best judgment to find a time when they may safely cross the street along with traffic.

This corridor contains many commercial and retail establishments. This includes restaurants, car dealerships, outlet stores, and Fort Wayne’s biggest indoor mall, Glenbrook Square.
A bit over a mile south of W Coliseum Blvd, all three of these streets diverge from one street. Before diverging, they all start as one road, N Clinton St. The road of N Clinton St then divides into Lima Rd and Coldwater Rd, continuing as separate north/south corridors. However, Coldwater Rd divides one more time a half mile north of the initial divergence point. Coldwater Rd then divides into Coldwater Rd and N Clinton St, continuing as separate north/south corridors. This is illustrated in Figure 2.

In the opposite direction of N Clinton St, it divides again into separate one-way streets heading toward downtown Fort Wayne. N Clinton St divides into N Clinton St,
which serves southbound traffic, and Spy Run Ave/Lafayette St (when it is south of the St. Mary’s River), which serves northbound traffic.

In the southern part of Fort Wayne, Lafayette Street and South Clinton Street merge to become Lafayette St, continuing as a major north/south corridor out the southern end of the city.

Opposite Clinton St and Lafayette St is Washington Boulevard, which serves westbound traffic, and Jefferson Boulevard, which serves eastbound traffic. On opposite ends of Fort Wayne, the streets of Washington and Jefferson Blvd merge. In the west it becomes West Jefferson Boulevard and in the east it becomes East Washington Boulevard.

Lafayette St serves northbound traffic and S Clinton St serves southbound traffic. Both intersect E Washington Blvd, which serves westbound traffic and E Jefferson Blvd, which serves eastbound traffic, in downtown Fort Wayne, IN.

SR930 Coliseum Blvd starts in the west part of Fort Wayne, serving east/west traffic. As SR930 Coliseum Blvd moved through Fort Wayne, it curves south, serving north/south traffic. Since the three intersections of Lima Rd, Coldwater Rd, and N Clinton St, are the busiest intersections in the city, they have the most crashes that occur for any intersections in the City of Fort Wayne (WANE News, 2011). However, crash data obtained from the Metropolitan Planning Organization (MPO), Northeastern Indiana Regional Coordinating Council (NIRCC), showed that other than the intersection of Coldwater Rd and Coliseum Blvd, these intersections are not that dangerous. Between 2010 and 2012, Coldwater Rd and Coliseum Blvd were highlighted as an
intersection with a high crash density. The other two intersections of Lima Rd and N Clinton St are not highlighted as major crash density intersections within the report.

Even though two of the three intersections are not highlighted on the crash density report, these three intersections still have the highest number of crashes because of the sheer number of cars that travel through these intersections. Intersections only get highlighted in the crash density report when the Rate per Million Vehicles (RMV) versus crash ratio are 1.00 and above.

The usual approach to traffic congestion is roadway expansion, adding lanes to the current roadway. However, the usual solution to traffic congestion, adding lanes, eventually leads back to the initial problem. The expanded roadway is still congested, just larger. A solution that leads to the same problem is the very definition of insanity. For this reason, this study evaluates another potential solution to traffic congestion.
What is a Roundabout?

A roundabout is a rotary intersection in which traffic travels counter-clockwise around a central island (Transportation Research Board of the National Academies, 2010). Entering traffic must yield to circulating traffic. Circulating traffic continues in the roundabout until each vehicle reaches the desired exit. This is illustrated in Figure 3.
One of the major purposes of a roundabout is to reduce the number of conflicts that exist in a traditions four-way stop intersection (Transportation Research Board of the National Academies, 2010). The geometric designs of roundabouts causes drivers to slow down before proceeding through the intersection. As a result, the potential for incidents and fatal crashes are significantly reduced. In return, this makes the roundabout intersection safer for users. This is illustrated in Figure 4.

**Objective of the Study**

The research reflected in this paper was designed to determine whether roundabouts may help to alleviate congestion and accommodate traffic capacity on the three busiest intersections in Fort Wayne along SR930 W Coliseum Blvd.
At peak, Coliseum Blvd serves over 50,000 drivers per day, Lima Rd serve over 40,000 drivers per day, Coldwater serves over 35,000 drivers per day, N Clinton serves as many as 30,000 per day. This data was obtained from the City of Fort Wayne Engineers. This is illustrated in Figure 5. However, the crash data reports shows ADT reach as high as 70,000.

There are several variables that are usually observed for roundabout studies. Data items usually looked at for a signal warrants study are (Florida Department of Transportation, 1996):

- Traffic Flow
• Peak hour turning movement counts
• Existing geometrics
• Pedestrian and bicycle volumes, if applicable
• Distance to other intersections
• Crash experience (collisions)
• Institutional locations: schools etc.
• Posted speed limits
• Fatalities
• Area population

Significance of the Study

A roundabout's first prerogative is to reduce traffic speed and fatal incidents along with helping to reduce traffic congestion. This research is important because it will help determine whether or not roundabouts are worth considering for these three intersections.
Chapter 2: Literature Review

Economic Impact

Time is money. Every moment someone is stuck in traffic is time that he or she can be using to make money – or to do something else that is a more productive use of their time. However, traffic is inevitability. For people to make money, they need to put in the time. Unfortunately, some of the time will be lost for multiply reasons, one of which is traffic congestion. But it is worth mentioning that this is hard to translate into a tangible number that can be measured.

“While current congestion research attributes substantial economic drags to travel time or scheduling delays, it does not offer any information on whether these delays constitute foregone productivity.” (Sweet, 2011)

People put time into making money, but it is not the only reason they trade their time. Some time goes into leisure as well. People travel to events and to visit family. Many such events have nothing to do with making money. Despite the fact that travel might involve a choice between congestion and time, people will make the necessary time to get where they need to be. Traffic congestion can have a multiplying effect on commute time. This can make a 15 minute commute a 50 minute commute during rush hour. Leaving a couple minutes earlier can help commuters avoid this expansion in commute time.
Intersection Conversions

Because people are involved, traffic incidents will occur. Therefore, it is in our best interest as a society to reduce the occurrence and severity of incidents. Unfortunately, people sometimes fail to heed traffic intersection procedure. As a result, incidents happen – most commonly, right angle crashes, which tend to be the most severe (Faghri, et al., 2008). One way to do this is by converting all-way stop-controlled (AWSC) intersections into modern roundabouts. Since roundabouts move traffic in one direction, they reduce the occurrence of right angle crashes.

“The Insurance Institute for Highway Safety (IIHS) conducted before and after studies of 24 stop- and signal-controlled intersections after their conversion into roundabouts and reported a total of 39% reduction in all types of crashes, with injury-producing crashes reduced by 76% and fatal or incapacitating crashes reduced by 90%.” (Faghri, et al., 2008)

In a report from the Insurance Institute for Highway Safety, Senior Transportation Engineer Kenneth A. Retting wrote to the Federal Highway Administration (FHWA):

“We also reported that when several intersections with traffic signals were converted to modern roundabouts, police-reported crashes were reduced by approximately 39 percent, and injury crashes were reduced by 76 percent.” (Retting, 2000)

Also, there are numerous international studies that highlight the safety benefits of converting signalized intersections into roundabouts.

“Schoon and van Minnen studied 181 Dutch intersections converted from conventional controls (traffic signals or stop signs) to modern roundabouts and
reported that crashes and injuries were reduced by 47 and 71 percent, respectively; with the more severe injury crashes (resulting in hospital admissions) being reduced by 81 percent.” (Garder, Lord, Persaud, & Retting, 2001)

As the number of cars on the road increase, so will the number of traffic incidents. So we must do our best to make choices that reduce injuries and the loss of life.

**Intersection Module Type**

There are three types of intersections. They include (1) signalized or stop light intersections, (2) un-signalized or signed intersections, and (3) roundabouts. Each type of traffic intersection works best in particular circumstances. Roundabouts have the ability to ease congestions, but when it comes to high volume traffic, signalized traffic intersections may be more efficient (Kakooza, Luboobo, & Mugisha, 2005).

Most congestion occurs at intersections caused by actions like pedestrians crossing and drivers turning. To increase capacity of roadways, there are several solutions depending on the size of the intersection and the intersection footprint. If a signalized intersection is at capacity the amount of lanes are increased. If an un-signalized intersection reaches its capacity, it might be changed into a signalized intersection. However, it is worth noting, that sometimes, capacity is not the issue, user conflict is. Traffic can back up the roadway because the drivers turning onto the adjacent roadway are held up by crossing pedestrians.
But after a while, capacity will always exceed space available to increase capacity. The physical constrains of the surrounding area simple may not allow for roadway expansion. This due to buildings and properties in close proximity to the roadway. At that point alternative transportation options like public transportation should be considered.

**Public Opinion**

Public opinion on roundabouts are mixed. People unfamiliar with roundabouts typically do not think they are a good idea. Once roundabouts are installed, public opinion changes to majority support of roundabouts. This was demonstrated in a case study near Bellingham, Washington. These surveys were conducted over the telephone.

>“The proportion of drivers who favored the roundabouts increased from 34% before construction to 51% six months after and 70% more than one year after.”

(Hu, Jermakian, Mandavilli, & McCartt, 2013)

A survey was taken in several U.S. communities to get drivers opinion on newly installed roundabouts. The communities were Hutchinson, KS; Harford County, MD; and Reno, NV — that constructed modern roundabouts in the summer of 2000, were the subject of this research. These surveys were also conducted over the telephone.

>“The proportion of drivers opposed to the roundabouts declined from 55 to 28 percent, and the proportion strongly opposed declined from 41 to 15 percent. The proportion favoring roundabouts increased from 31 to 63 percent.” (Luttrell, Retting, & Russell, 2002)
Another study was conducted where six communities were surveyed. The six communities were Harford County, Maryland; Hutchinson, Kansas; Reno, Nevada; Bellingham, Washington; Greenwich, New York; and Nashua, New Hampshire. The communities were chosen because they had limited experience with roundabouts.

“The proportion of drivers in favor of roundabouts ranged from 22% to 44% before construction compared with 48% to 67% soon after roundabouts were built and 57% to 87% after roundabouts were in place for at least 1 year. The majority of drivers of all ages favored roundabouts after they were in place for 1 year or more, although support was higher among younger drivers (ages 18 to 34) and lower among older drivers (65 and older). There were small but no significant differences between the opinions of male and female drivers. Drivers who said the roundabouts improved safety or traffic flow, or both, had more favorable opinions of roundabouts 1 to 5 years after construction.” (Kyrychenko, Retting, & McCartt, 2008)

People often have problems with change. They usually come up with reasons that are usually not mired in fact, but instead, emotional attachment to what they know. What they find is that there fears are not always warranted. Instead, they are please to find that the change has improved the situation and as a result, their individual lives.

Different locations may be similar, but they will never be the same. This difference can be the reason why a roundabout is a good idea in one place, and a bad idea in another place.
Pedestrians are able to proceed through a roundabout by using the crosswalks. Bicyclists can proceed through a roundabout by proceeding through the roundabout like a car (obeying the rules of the roundabout as if they were a car) or they can walk their bicycle through the pedestrian crosswalks of the roundabout. This is illustrated in the Figure 6.
However, multilane roundabouts add a level of complexity that makes crossing the roundabout more difficult for non-motorized users.

“Research indicates that while single-lane roundabouts may benefit bicyclists and pedestrians by slowing traffic, multi-lane roundabouts may significantly increase safety problems for these users, especially those who are disabled.” (Arnold, et al., 2010)

There is no sidewalk along SR930 W Coliseum Blvd, or the portion of Lima Rd (beside the southern segment of Lima Rd) that crosses SR930 W Coliseum Blvd, or the portion of N Clinton St that crosses SR930 W Coliseum Blvd. However, the portion of Coldwater that crosses SR930 W Coliseum Blvd does have sidewalks. However, the Fort Wayne 2035 Transportation Plan does highlight these roads as locations that need sidewalks on both sides of the road.
A major concern that may arise is whether roundabouts can handle the Average Daily Traffic (ADT) that go through a signalized intersection. The roundabouts being proposed for the three intersections would have three lanes. This is because there are three through lanes per direction of traffic along this segment of SR930 W Coliseum Blvd. According to the Federal Highway Administration (FWHA), a two lane roundabout has an operational capacity just over 45,000 ADT depending on the number of cars that need to make left turns. This is shown in Figure 7. This is important because the intersections of Lima Rd and Coldwater Rd have two left turn lanes coming from the north at both intersections. There are roundabout designs that accommodate double left
turn lane movements. To accommodate this, the lane furthest left, as it travels through the roundabout, is designed not to allow for through traffic. This is illustrated in Figure 8.

![Figure 8: Three-Lane Roundabout with Two-Lane Exits](image)

Roundabouts with three lanes have been successfully implemented.
“Variable-sized roundabouts (e.g., one lane for part of the circulatory roadway, and two lanes at other parts within the same roundabout), roundabouts with peak-period metering, and three-lane roundabouts have been successful in some locations.” (Federal Highway Administration, 2010)

One such example of a three lane roundabout in the United States is located in Michigan. This is illustrated in Figure 9. However, there have been concerns about the three lane roundabout. These concerns include, higher speeds due to the large radius, angles of impact in three-lane roundabouts can be more severe when errant vehicles stray across multiple lanes from their assigned lane, and traffic volumes will be higher, and thus, more vehicles will be affected by incidents (Bared, 2012).

Figure 9: Michigan three-lane roundabout (Bared, 2012)

Level of Service

One of the ways to measure the efficiency of a road is by measuring its “Level of Service” (LOS). LOS is a qualitative measure of how well a roadway and or intersection is operating. LOS uses a letter grading metric – “A” being the best and “F” being the
worst (Transportation Research Board, 2010). The letter grade is determined by number of passenger vehicles per mile per lane. This is demonstrated in Figure 10.

![Figure 10: LOS for Freeway](image)

“A” means traffic is flowing freely. Drivers are free to drive at or above the speed limit (within reason), and have complete mobility to travel between lanes. “B” means traffic is flowing freely but with a bit of restriction on a driver’s ability to maneuver between lanes. “C” means that traffic flow is stable but noticeably congested. At this point, drivers must be aware of their environment because of the noticeable amount of other drivers on the road. “D” means that traffic flow is approaching an unstable level and that the road is at its operational capacity. “E” means traffic flow is unstable and the roadway is at capacity. At this point, driver speed is inconsistent and lane maneuverability is limited. “F” means that traffic flow has experienced a complete breakdown. At this point traffic is at a crawl – bumper to bumper traffic.
Roundabout LOS is measured in a completely different way. Instead of lane capacity, intersection delay is used to determine LOS (Transportation Research Board of the National Academies, 2010). However, roundabout LOS still uses the same letter grading metric – “A” being the best and “F” being the worse. This is demonstrated in Table 1.

<table>
<thead>
<tr>
<th>Control Delay (s/veh)</th>
<th>Level of Service by Volume-to-Capacity Ratio*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>v/c ≤ 1.0</td>
</tr>
<tr>
<td></td>
<td>v/c &gt; 1.0</td>
</tr>
<tr>
<td>0–10</td>
<td>A</td>
</tr>
<tr>
<td>&gt;10–15</td>
<td>B</td>
</tr>
<tr>
<td>&gt;15–25</td>
<td>C</td>
</tr>
<tr>
<td>&gt;25–35</td>
<td>D</td>
</tr>
<tr>
<td>&gt;35–50</td>
<td>E</td>
</tr>
<tr>
<td>&gt;50</td>
<td>F</td>
</tr>
</tbody>
</table>

* For approaches and intersection-wide assessment, LOS is defined solely by control delay.

Roundabouts have completely different design features and geometries than the conventions four way stop intersections. For this reason, a new method of evaluations had to be developed. Roundabouts are praised as the next tool of traffic safety and efficiency. However, a report (Transportation Research Board of the National Academies, 2007) cast doubt of roundabouts and their perceived purpose.

“Perceived differences in driver behavior raise questions about how appropriate some international research and practices are for the United States. Therefore, additional information on the safety and operation of roundabouts in the United States will be very helpful to planners and designers in determining where roundabouts would reduce intersection crashes and congestion and in refining the design criteria currently being used. These design refinements can be
particularly important for bicyclists and pedestrians using the intersection.”

(Transportation Research Board of the National Academies, 2007)

This report also compares the capacity of U.S. roundabouts to that of countries like Australia and the U.K. Roundabouts in Australia and the U.K. are bigger compared to those in the U.S. This is because, in Australia and in the U.K., some roundabouts have traffic signals as part of their design. Also, because their roundabouts are larger, they allow for greater speeds. The larger the diameter of the roundabout, the more capacity it can hold, along with allowing cars to travel through at higher speeds.

This is in direct opposition to what U.S. roundabouts are meant to do. U.S. roundabouts are more about safety then speed. If U.S. roundabouts were designed to allow for greater through speeds, this would increase the risk to non-motorized users. The faster traffic moves, the more likely a non-motorized user is to be injured or die from a collision. This is illustrated in Table 2.

Table 2: Pre-crash Vehicle Travel Speed (Leaf & Preusser, 1999)

<table>
<thead>
<tr>
<th>Pedestrian Injury Severity</th>
<th>&lt;=20 mph</th>
<th>21 - 25 mph</th>
<th>26 - 30 mph</th>
<th>31 - 35 mph</th>
<th>36 - 45 mph</th>
<th>46+ mph</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fatal (K) injury</td>
<td>1.0%</td>
<td>2.9%</td>
<td>2.8%</td>
<td>4.9%</td>
<td>16.2%</td>
<td>35.2%</td>
<td>6.0%</td>
</tr>
<tr>
<td>Incapacitating (A)</td>
<td>32.5%</td>
<td>40.9%</td>
<td>47.1%</td>
<td>47.3%</td>
<td>44.9%</td>
<td>38.2%</td>
<td>38.9%</td>
</tr>
<tr>
<td>Nonincapacitating (B)</td>
<td>36.2%</td>
<td>34.5%</td>
<td>27.3%</td>
<td>29.2%</td>
<td>18.1%</td>
<td>18.2%</td>
<td>30.6%</td>
</tr>
<tr>
<td>Minor (C) or none</td>
<td>30.3%</td>
<td>21.7%</td>
<td>22.8%</td>
<td>18.6%</td>
<td>20.7%</td>
<td>8.4%</td>
<td>24.5%</td>
</tr>
<tr>
<td>Total frequency</td>
<td>28,699</td>
<td>7,000</td>
<td>7,566</td>
<td>7,126</td>
<td>8,413</td>
<td>3,791</td>
<td>62,595</td>
</tr>
</tbody>
</table>

A Roundabouts Effect on Roadway Network

Roundabouts, depending on where they are placed, may have either a negative or positive effect on an overall network. Consider how a network with traffic lights work. It works by moving cars past a segment of streets in groups. The group of cars is referred to as a platoon. A platoon is a group of vehicles traveling between signalized
intersections. Congestion inside the network usually occurs when the number of cars pass through the stop-light intersection exceeds the intersections ability to form an efficient platoon of vehicles. A platoon can become unstable for several reasons. This includes, interference at signalized intersection from other users, like vehicles having to wait for crossing pedestrians before turning, or there are more vehicles proceeding through the intersection than the signal phase allows.

The location of other signalized or un-signalized intersections, in close proximity to a roundabout, typically has a negative effect on the network. While stop-light intersections move traffic in a structured timed manner, roundabout do the opposite. Placing a roundabout into a network of four-way stop intersections can be just as debilitating to a road network as too many cars. If a roundabout is located too close to a four-way stop intersection, that intersection can cause traffic to back up right into the roundabouts. On the opposite end, a roundabout can pass cars too quickly through a roadway network causing four-way intersections to become congested and backed up (Fitzsimmons, Hallmark, Isebrands, & Stroda, 2008).

Consider a two lane roundabout. Splitter islands are located at each approach as drivers come to the intersection. This is illustrated in Figure 3. Splitter islands are designed to slow incoming traffic. However, the more lanes a roundabout contains, the larger the radius of the roundabout will be. Despite the intent behind the roundabout, the larger radius of a roundabout allows for cars to travel faster than is preferred.

When it comes to street LOS score for all the users of a network, including car, pedestrians, bicyclists, and transit, the improvement of one score is the degradation of another. Raising LOS for pedestrians and bicyclists can lower it for cars. One of the
recommendations for slowing cars inside the roundabout, especially, for two lane roundabouts is to construct the roundabouts with narrow lanes (Fitzsimmons, Hallmark, Isebrands, & Stroda, 2008). Roundabouts are constructed with truck aprons. This is illustrated in Figure 3.

“A truck apron is a raised section of pavement around the central island that acts as an extra lane for large vehicles. The back wheels of the oversize vehicle can ride up on the truck apron so the truck can easily complete the turn, while the raised portion of concrete discourages use by smaller vehicles.” (Washington State Department of Tranportation, 2014)

However, for double lane roundabouts, large vehicles including trucks and bus should use both lanes of the roundabout to turn. Along with narrower lanes inside the roundabout, this helps to slow car traffic. Also, cars should not drive next to trucks and buses as they are passing through the roundabout.

When considering the installation of a roundabout inside a corridor or network, it would be counterproductive to install just one inside a network. Instead, the bottlenecks inside the corridor or network must be examined (Fitzsimmons, Hallmark, Isebrands, & Stroda, 2008). If a system of roundabouts are to be successfully employed, they would be placed at the bottlenecks of the system along with evaluating potential effects to surrounding intersections and land uses.

When it comes to the future development and design of roads, intersections should be designed for potential future conversion of the intersections into a roundabout (Fitzsimmons, Hallmark, Isebrands, & Stroda, 2008). The roadways should be narrow while the nodes should be wide. Roadways are usually redesigned to accommodate
increase to traffic capacity by adding lanes. This results in a bigger footprint for the road and capacity issues at intersections.

Access management is important when considering the installation of roundabouts in corridors. Consideration must be given to access points, turn lanes and restrictions, and surrounding land uses. Despite the safety and efficiency a roundabout can grant a roadway, it can just as easily do the opposite. When driving through a roundabout, vehicles may proceed at any time, so long as they have the right of way and the roundabout is clear. Signalized intersections control when a vehicle may proceed through the intersection. Because of the random patterns that roundabouts cause by traffic passing through them when the driver deems it safe to proceed, cars from adjacent driveways and parking lots, might find it difficult to enter traffic, especially if traffic going towards or away from the roundabout is too dense. But this problem can just as easily be a design attribute for a roundabout corridor.

For an overall roundabout corridor to function, access must be minimized and controlled. The most dangerous actions that a driver can make are left turns. When considering access management, four featured should be consider (Fitzsimmons, Hallmark, Isebrands, & Stroda, 2008):

- Continuous raised medians
- Restricted turning movements
- Right-in-right-out movements
- Use of u-turns (at roundabouts for left turns)

With a continuous raised median, drivers can no longer commit the inherently dangerous act of turning left across traffic. As a result, this converts traffic into a right-in-
right-out pattern. Though this design blocks the other half of two way traffic it reduces the chances of t-bone collisions, drivers crashing the front of their cars into the side of another. Instead, access that was normally granted left is now moved to roundabouts where people will need to make u-turns to access their desired destination. Even with a two-way turn lane, a driver could spend a significant amount of time waiting for a gap in cross traffic before he/she were able to complete a left turn. With the restriction of raised median forcing drivers to use the roundabout to make left turns, it makes the corridor more efficient to drive through and more accessible.
Chapter 3: Methodology

To carry out this study, transportation simulation software was used. Before this software can be used, certain data was collected to plug into the model. This information includes, traffic counts (including turning counts), the number of through lanes, lane widths, and signal timing.

Another thing that was considered was the type of traffic that might drive through the roundabouts, for example trucks, bus, and public safety vehicles. At this point, geometry comes into play, but also, the uses of the properties around the roundabout must be considered.

Data collection might not show the effects of a roundabout on an adjacent intersection, or vice versa. Adjacent intersections might cause traffic to backup into the roundabout. The topography of the surrounding area could also hinder visibility. Depending on if a driver is entering or exiting the roundabout, circulation traffic or incoming traffic might be difficult to gauge. Another consideration was pedestrian traffic. A way to mitigate the pedestrian issue might be to incorporate midblock crossings. However, having to cross three lanes of dense traffic, especially at rush hour, at a time, might still pose an issue. If a roundabout has heavy traffic flow, it may have the added effect of blocking pedestrians from crossing the intersection. In either case, the benefits will need to be weighed.

To evaluate the three intersections within the SR930 corridor, two programs were used, Synchro 8 and Sidra Intersection 6. Intersections with signals were reassigned to
incorporate roundabouts at their respective intersections. This was used to determine whether or not changing the intersections from signal intersections to roundabouts can help alleviate traffic congestion that occurs at these intersections.

**About Synchro**

Synchro is a national leader in traffic modeling software. Its software gives users the ability to simulate current traffic conditions and to model potential changes to current roadway designs from number of through lanes and turning lanes to signal phasing. With this ability, users are able to understand the potential consequences of changes made to a roadway.

The Synchro software suit has multiple abilities including:

- A Macroscopic analysis and optimization program;
- SimTraffic, which simulates traffic models;
- 3D Viewer, a three-dimensional view of the traffic simulation;
- SimTraffic controller interface (CI) device to simulate operations.

Within Synchro, there are analysis tools for determining the capacity of intersections. Synchro uses Intersection Capacity Utilization (ICU) 2003 for determining intersection capacities. Synchro also uses the 2000 and 2010 Highway Capacity Manuals (HCM) for determining capacities for urban streets, Signalized intersections, and un-signalized intersections. Synchro 8, unlike Synchro 7, incorporates the 2010 HCM. The 2010 HCM is more advanced in determining the LOS of roundabouts.
About Sidra

Sidra, which stands for Signalised (and unsignalized) Intersections Design Research Aid, first came out in 1984. It came out with its sixth version in April 2013. Sidra is a micro-analysis tool for evaluating designs for intersections and networks. It also allows users to model the separate components of an intersection including passenger cars, trucks, buses, and rail vehicles. Users can estimate road capacities, level of service, fuel consumption, emissions, and operational cost.

How They Were Used

A lot more attention is being given to LOS, the grading metric on the service of a roadway and intersection. However, this is not a quantitative measure of demand for the roadway or intersection. If a road or intersection receives an LOS score of D – F, which mean the facility is approaching unstable traffic flow conditions to a complete breakdown of traffic flow, it does not quantify how congested the roadway facility is. For this, the vehicle (v)/capacity (c) ratio (or degree of saturation) must be observed. This measure is strictly for intersections. This means that an intersection with a 1:1 v/c ratio is at 100 percent capacity. When the ratio is greater than 1:1, capacity is greater than 100 percent of the intersections design capacity. However, traffic congestion occurs when the v/c ratio is greater than 0.85:1 or 85 percent of capacity.

Both Synchro and Sidra were used to determine v/c ratios (known as degree of saturation in Sidra) of the potential roundabouts. The three intersections of Lima Rd, Coldwater Rd, and N Clinton St, along SR930 W Coliseum Blvd were each modeled as roundabouts with the respective softwares. Once modeled, ADT were entered for each
intersection to determine v/c ratios. Those vehicle capacity ratios were measured against current vehicle capacity ratios of the intersections as they are now – signalized.

The current v/c ratios, obtained for this study from the Indiana Department of Transportation (INDOT), can also be obtained by modeling the intersections as they are in Synchro with ADT and signal timings.

Once roundabout models were created using Synchro, the v/c ratios of the intersections, as roundabouts, was compared to that of the current signalized intersections.

ADT and signal timings were obtained from the City of Fort Wayne traffic engineers. The traffic counts obtained from city traffic engineers have the counts for the intersection for all hours of a day ranging from 6am to 6pm. Peak hour times for travel within Fort Wayne is 6am to 11:45am and 12pm to 5:45pm. Throughout the ADT count sheets, for all intersections, the peak hours highlighted are 7:30am – 8:30am (11am – 12pm for Coldwater Rd) and 4:30pm – 5:30pm (4:45pm – 5:45pm for Coldwater Rd). The peak traffic counts of 4:30pm – 5:30pm was used for this analysis. The evening peak hour time was used because traffic counts were as much as 1,000 more ADT.

When it came to modeling roundabouts in either software, default designs had to be selected for the geometries of the roundabout. This is important because the design features have an effect on the speed at which drivers travel through the roundabout and weather all motor vehicles from cars to trucks can use the roundabout.

Table 3: FHWA Geometry Design for Roundabouts (Transportation Research Board of the National Academies, 2010)
The roundabouts that were used for the model had three through lanes for the SR930 W Coliseum Blvd roadway, and had two through lanes for the adjacent roadways of Lima Rd, Coldwater Rd, and N Clinton St. Based on recommendations from the Federal Highway Administration (FHWA), an inside circle diameter of 45m was used because these intersection are located in a urban zone that serves motor vehicles including, passenger cars, bus, and multi-level trucks. However, it is worth noting despite selecting 45m as the inside circle diameter, these roundabouts will have 3 lanes because of W Coliseum Blvd and Two left turn lanes from the north side of the intersections of Lima Rd and Coldwater Rd. Also, 12ft lane widths were used as well.

**Intersection Size Considerations**

Another thing that was considered was the size of the roundabout needed if they were to be installed with SR930 W Coliseum Blvd. When roundabout are installed, especially at intersections where signals once stood, consideration must be given to whether or not a roundabout can fit physically, in an urban setting. In urban settings, the space required for the installation of a roundabout can be expensive and difficult to acquire because of surrounding businesses, buildings, and land uses.
Figure 11: Roundabout Intersection Diameters of SR930 W Coliseum Blvd & Lima Rd
Figure 12: Roundabout Intersection Diameters of SR930 W Coliseum Blvd & Coldwater Rd
As seen in Figures 11, 12, and 13, the intersections of Lima Rd, Coldwater Rd, and N Clinton St, along SR930 W Coliseum Blvd, is enclosed by surrounding land uses which would make installation of a roundabout meeting the recommended standards difficult. There are no buildings directly in the way, but the area is owned by surrounding businesses that have parking right in the area that would be need for the construction of
a roundabout.

Another consideration is the speed of the corridor, which in this case is 40 mph. With the current design proposal, it is made for speeds between 15 – 20 mph. To accommodate higher speeds, the roundabout would have to be made larger. At that point, the footprint of the roundabout would start to encroach on the surrounding buildings.

Because of the overall width of SR930 W Coliseum Blvd, it can be intimidating for pedestrians to cross it. With the first design, with the low speeds of 15 – 20 mph through the roundabout, this can make it less intimidating for pedestrians to cross the intersection. However, if the roundabout was larger with higher speeds, this could make crossing the intersection for pedestrians just as daunting as the current signalized intersection design.
Chapter 4: Findings

After modeling all three intersections, it was found that each software had its own set of capabilities. Both software models are able to model different types of intersections including, signalized and un-signalized. However, after modeling intersections in both, it was determined, that one has far better ability for modeling roundabouts than the other. The results below show the stark difference in each software’s abilities to model roundabouts.

Table 4: v/c Ratios

<table>
<thead>
<tr>
<th>Intersections</th>
<th>AM (0600-0830)</th>
<th>Off-peak (0830-1100)</th>
<th>Lunch (1100-1500)</th>
<th>PM (1500-1800)</th>
<th>Sidra Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lima Rd</td>
<td>1.04</td>
<td>0.85</td>
<td>1.13</td>
<td>1.32</td>
<td>6.22</td>
</tr>
<tr>
<td>Coldwater Rd</td>
<td>1.04</td>
<td>0.87</td>
<td>1.21</td>
<td>1.17</td>
<td>4.84</td>
</tr>
<tr>
<td>N Clinton St</td>
<td>0.93</td>
<td>0.69</td>
<td>0.096</td>
<td>1.54</td>
<td>4.25</td>
</tr>
</tbody>
</table>

Synchro Findings

The deficiencies were most serious in Synchro and its ability to model roundabouts. This is because Synchro uses the HCM in determination of its intersection capacities. The HCM deficiencies comes from the fact that it does not take into account roundabout geometry. Also, traffic flow is unrealistic when ADT counts are too high. Finally, it is simply not a long-term tool for assessing roundabout LOS (Transportation Research Board of the National Academies, 2007).
Figure 14: Signalized Intersection of SR930 W Coliseum Blvd & Lima Rd in Synchro

Figure 15: Roundabout Intersection of SR930 W Coliseum Blvd & Lima Rd in Synchro
Figure 16: Signalized Intersection of SR930 W Coliseum Blvd & Coldwater Rd in Synchro

Figure 17: Roundabout Intersection of SR930 W Coliseum Blvd & Coldwater Rd in Synchro
Figure 18: Signalized Intersection of SR930 W Coliseum Blvd & N Clinton St in Synchro

Figure 19: Roundabout Intersection of SR930 W Coliseum Blvd & N Clinton St in Synchro
While modeling the intersections of Lima Rd, Coldwater Rd, and N Clinton St, Synchro is only able to make limited alterations to the design of the roundabout itself. These alterations include, number of lane within the roundabout, the diameter of the inside and outside circle, and the lane width. However, even when changes were made to certain geometric features of the roundabout, it had no effect on v/c ratios. This included changing the size of the diameter of the inside circle and the number of lanes within the roundabout which allows for a maximum of three lanes.

Any alteration to the design of the roundabout with Synchro proved to be unimpactful on the v/c ratio. Synchro produced v/c ratios that were worse for roundabouts than the current v/c ratios for the signalized intersections. For the Intersection of Lima Rd, the v/c ratio was 6.22 for a roundabout compared to 1.32 as a signalized intersection, almost five times worse. For the intersection of Coldwater Rd, the v/c ratio was 4.84 for a roundabout compared to 1.17 as a signalized intersection, over four time worse. For the intersection of N Clinton St, the v/c ratio was 4.25 as a roundabout compared to 1.25 as a signalized intersection, over three times worse. However, these v/c ratios were determined with Synchro using the HCM from 2000.

When the v/c ratios were determined using the 2010 HCM, a change in the v/c ratios did change because of the update to the capacity analysis tool for roundabouts for the 2010 HCM. Though the 2010 HCM has updates to LOS measuring methodology, the changes were not conducive for the purposes of this study. The numbers that the 2000 HCM produced compared to the 2010 HCM were different. However, no matter the HCM version, things that would be expected to have an effect on LOS, like
roundabout diameter or number of lanes within the roundabout, had no effect on the results produced.

Even with these updates, the v/c ratios for the 2010 HCM produced in Synchro, were still higher for a roundabout than that of the signalized intersections. For the Lima Rd roundabout, the v/c ratio fell slightly to 6.18. For the Coldwater Rd roundabouts, the v/c ratio rose slightly to 5.04. For the N Clinton St roundabout, the v/c reduced to 2.18. Overall, v/c ratios were still higher than the v/c ratios for the signalized intersections.

Sidra Findings

Figure 20: Roundabout Intersection of SR930 W Coliseum Blvd & Lima Rd St in Sidra
While modeling the intersections of Lima Rd, Coldwater Rd, and N Clinton St, as seen in Figures 20, 21, and 22, Sidra allowed for greater control over the design of the roundabouts. Control of design features in Sidra includes inner circle diameter and
number of lanes within the roundabout down to the side of the roundabout that has more through lanes.

Sidra, like Synchro, does determine v/c ratios using the 2010 HCM analysis tool. Just like Synchro, it produced v/c ratios that are worse for the roundabouts than they are for the signalized intersections. However, the v/c ratios were nowhere as high as they were as compared to Synchro. For the Intersection of Lima Rd, the v/c ratio was 1.67 for a roundabout compared to 1.32 as a signalized intersection. For the intersection of Coldwater Rd, the v/c ratio was 1.83 for a roundabout compared to 1.17 as a signalized intersection. For the intersection of N Clinton St, the v/c ratio was 1.76 as a roundabout compared to 1.25 as a signalized intersection.

Sidra was able to produce better v/c ratios than Synchro and here is the reason why. Unlike Synchro, Sidra Intersection 6, was specifically designed to do analysis on roundabouts. Sidra has a separate setting for analyzing roundabouts like the 2010 HCM called the Sidra Standard. This Sidra analysis tools produced degree of saturations (also known as v/c ratios) that were better than those produced by the HCM analysis tools of either software. For the Intersection of Lima Rd, the v/c ratio was 1.01 for a roundabout compared to 1.32 as a signalized intersection. For the intersection of Coldwater Rd, the v/c ratio was 1.19 for a roundabout compared to 1.17 as a signalized intersection. For the intersection of N Clinton St, the v/c ratio was 1.01 as a roundabout compared to 1.25 as a signalized intersection.
Chapter 5: Conclusion

After comparing the results of v/c ratios for roundabouts, determined using Synchro and Sidra, replacing the signals of Lima Rd, Coldwater Rd, and N Clinton St, along SR930 W Coliseum Blvd would be ill-advised. Even though Sidra was able to produce v/c ratios, with the Sidra Standard tool, relatively close to that of the signals already in place, there is no benefit rendered. The v/c ratios would suffer; traffic would worsen.

Synchro is a leader in traffic model simulation. However, it is fairly limited in its ability to simulate roundabouts with multiple lanes and approaches. With its limitations, it produced v/c ratios, as much as five time worse, which are undesirable for an intersection if the intersections were converted into roundabouts compared to the current signalized intersection.

Sidra is a leader in intersection analysis, especially when it comes to roundabout intersections. Even though Sidra produced v/c ratios that are more align with current v/c ratios of the current signalized designs, the ratios were not that much better than that of the signalized intersection.

In conclusion, installation of roundabouts would offer nothing in line with traffic congestion relief. Instead, results show that current congestion levels would worsen if intersections were converted to roundabouts. Also, as bad as it is now for pedestrians and cyclists to cross these intersections, they would still find crossing these intersection a daunting task.
Bibliography


