Roundabouts as Alternatives to Traditional Intersection Scenarios

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Abstract

This paper looks to study the alternative method of road intersection crossings known as roundabouts or traffic circles. While they have been embraced in Europe for many years, reception in the United States has often been standoffish despite the numerous advantages roundabouts present. There is also debate that this paper will explore as we seek to answers to concerns people have regarding how traffic flow is affected, are roundabouts safer than alternatives intersections, and is there a noticeable difference in emissions produced by cars at different intersections as well as other environmental impacts. This paper will also look at how public perception of roundabouts changes over time, and how people can become more receptive to roundabouts once they have been exposed to them and experienced first hand the benefits that they present. With more communities every day making the move to roundabouts from traditional two and four way stops, it is becoming more important that we are able to have accurate information on how to approach changes in our intersections.

Keywords: roundabout, traffic circle, traffic flow

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In the last decade, there has been a new interest generated in roundabouts and traffic circles in the United States. Numerous studies have been conducted which range from engineering models for the proper size and construction of roundabouts to the environmental impacts they cause. With such a wide variety of ways to approach the study of roundabouts, the focus of this paper has been narrowed down to a comparison of intersection types; a greater look at roundabouts in their advantages and disadvantages; the safety aspect for vehicles and pedestrians; environmental effects and carbon emissions as they relate to roundabouts; traffic flow adjustments; and how over time, fears that the general public has regarding roundabouts and traffic circles are overwhelmingly irrational. The fact that roundabouts are taking off in popularity should come as no surprise, as many European countries have already gotten a head start with new roundabouts. One example is France, which constructs somewhere around 1,000 roundabouts each year to improve the safety and efficiency of their roads (Isebrands, H. 2009).

Roads intersect in a variety of ways. Typical intersections that drivers may experience include a “cross”, a “t”, a “y” and “scissor”. A cross and scissor both consist of two roads that intersect and do not have end points at this intersection. A “t” intersection consists of two roads, which intersect, and one of the roads has an end point at this intersection, while a “y” intersection has three roads, all three of which will have an endpoint at the intersection. Additionally, multi-road intersections can occur as well where an intersection may appear to have spokes with such a great number of roads running through the intersection.

Stop control is commonly implemented in lower volume areas in the form of both two-way stops and four-way stops. The Florida DOT (1996) points out numerous problems with these intersections. In the form of two-way stops, the Florida DOT (1996) notes that once traffic has hit a certain capacity, a two-way stop system allows one road to have continuous traffic flow, while drivers on the other road struggle to find an opening in traffic to make it across. As traffic fluctuates even in lower areas of traffic (perhaps during the morning or evening commute), even areas with relatively low traffic most of the time can become a frustrating experience for motorists, and the Florida DOT (1996) makes note that this can anger motorists to the point where they will demand that a signal system over a stop system. For four-way stop situations, the situation is similar: while it may be sufficient most of the time, the time when people are most utilizing the roads is the time when people will determine the frustration level of the intersection.

An alternative to replacing these problematic intersections can be circular intersections, in particular, roundabouts. The National Cooperative Highway Research Program (2010) defines a roundabout as

> *"A subset of circular intersections with specific design and traffic control features. These features include yield control of all entering traffic, channelized approaches, and geometric curvature and features to induce desirable vehicular speeds."*

This is opposed to other circular intersections such as rotaries (larger circular intersections), signalized traffic circles (seen at Campus Martius Park in Detroit), or smaller neighborhood traffic circles (used mostly for traffic calming or aesthetics).

Roundabouts offer much in terms of cost savings over signalized intersections. This can be seen in both the maintenance costs, such as electricity, as well as the indirect costs associated with signal systems. One such cost is the event of an electrical outage that renders signalized intersections useless. While in many cases this will simply default to an all way stop control intersection, for places with a higher volume of traffic it is not uncommon for police to be dispatched to direct traffic. This takes resources away from the community, decreasing the overall safety of the municipality in addition to an added cost. Another indirect cost associated with signalized intersections is the amount of money paid out through insurance for claims as a result of high-speed intersection automobile collisions for automobile damage and personal injury. While such costs are not completely eliminated with the implementation of roundabouts, they are greatly reduced.

Roundabouts can also work well for improving urban design and pleasing aesthetics if utilized properly. By creating a circular space in an intersection, a municipality may elect to use that space for landscaping, fountains, public art and sculptures, or if large enough, public open space. While not a roundabout, Campus Martius Park in Detroit is an excellent example of what you can do to make a circular intersection, so much so that it was named one of the top 2010 Great Public Spaces in America by the American Planning Association (2010). However, this can add to the overall maintenance cost of the roundabout that was originally saved by switching from a signalized intersection. In addition, there may be additional costs with keeping roundabouts illuminated (National Cooperative Highway Research Program, 2010), especially if there is something in the center of the roundabout (fountain, statue, etc.) that is to be put in display for public enjoyment. Such things should be taken into consideration when designing roundabouts as well as deciding how to fund roundabout development.

Due to their design nature, roundabouts will be less susceptible to damaging automobile collisions. With no way for the cars to directly collide either head on or at a 45-degree angle, motorist fears of another driver running a red light or stop sign disappear. The design is also of aide to municipal services in a number of ways. No intersections means less chance that a fire engine or ambulance will cause a collision at an intersection, as well as police that would be chasing a suspect. There is little question that roundabouts are a safer alternative, it is simply a question of by what measure.

In a report done for the *Insurance Institute for Highway Safety,* Persaud et. all (2000) studied motor vehicle collisions following intersection conversions at 24 intersections to see if the safety increase was as high as they had anticipated. The intersections in the study are located in Maryland, Colorado, Maine, South Carolina, Vermont, Kansas, and California. The results were just as one would expect: out of the 24 intersections, 20 of them showed reductions in automobile collisions. There appears to be no correlation between the number of crashes and the location or the type of intersection control that existed prior to the roundabout. Many of these crash reduction figures were quite drastic, with one intersection in Anne Arundel County, MD going from 34 to 14 crashes and another in Avon, Colorado going from 48 to 18. Persaud et. all (2000) have shown us that for urban intersections, there is approximately a 61% reduction in all collisions, and a 77% reduction in injuries. Although for urban multi-lane roundabouts the percentage of collisions reduced drops to 15%, there is no denying a substantial drop in crashes is the direct result of roundabout intersections.

Isebrands, H. (2009) showed even more promising results in her study of roundabouts in rural intersections at high speed roadways. Despite the fact that the roads are high speed (over 40mph), the roundabouts are not, with speed limits at a modest 10-25mph. While this may concern some people about the ability of motorized vehicles (particularly large trucks) to slow down in time to reach the intersection, such fears are unwarranted when you consider the number of factors that reduce the speed of vehicles on rural roads, such as farm equipment on driving on rural roads. The study of 17 rural roundabouts was conducted in Maryland, Washington State, Minnesota, Kansas, and Oregon. With the number of rural roundabouts in the United States being very limited, the study was dictated by what states have the roundabouts available to study as opposed to deciding what areas of the country to focus on.

The results speak for themselves. Over a 4.6-year period of observing these intersections, the number of crashes prior to the implementation of roundabouts was 414 and 264 crashes resulting in injury. In the 5.5-years after the construction of roundabouts at the same intersections, that number dropped to 200 total crashes and only 41 injury crashes. This is a substantial reduction, showing that the number of collisions dropped by 52% (67% in the crash rate) and injuries resulting from these collisions fell by 84% (89% in the injury crash rate) (Isebrands, 2009). The kinds of crashes that occurred as a result of roundabout placement also changed as well. While angle, head on, and turning movement collisions were reduced drastically, the number of rear-end collisions showed only a slight drop and a few categories, such as sideswipes showed a slight increase. There is no denying that the trade off of 0 head on collisions and a drastic drop in angled collisions is worth the trade off of increased sideswipes and fixed object collisions.

While there are obvious safety advantages for motorists, the effect roundabouts have on pedestrians cannot be ignored. Often, there are crosswalks with small islands away from the inner ring were pedestrians can safely cross from one side of the road to the other. However, in compliance with the American's with Disabilities Act, we need to make sure that physically impaired pedestrians are able to walk across the road safely regardless of what kind of intersection is in place. There are, however, only two ways that a pedestrian can cross a roundabout: if there is a break in the traffic long enough for them to cross, or if a motorist yields to the pedestrians so they can cross.

Inman V.W. et. all (2005) conducted a study to determine the safest access for visually impaired pedestrians at roundabout crossings. They broke the problem down into three parts:

1. If there is no signal control, motorists are less likely to yield to pedestrians
2. A visually impaired person must rely on their other senses to determine vehicle location. Circular traffic direction makes this very difficult.
3. Large gaps in traffic that can be detected aurally can be infrequent.

With seven visually impaired people who travel with either a cane or a leader dog, they set out to see how the drivers and pedestrians would react.

What Inman V.W. et. all (2005) found was that overwhelmingly, drivers would not stop to allow a visually impaired person to cross the street. In the control environment, only 115 motorists stopped while 881 motorists continued without stopping. In the treatment environment, those numbers were only slightly more encouraging, with 158 motorists stopping and 790 continuing without stopping. Due to the fact that all the roundabouts tested where two-lane roundabouts, findings also showed that it became much more difficult for the pedestrians to detect the vehicle locations once they were more than 6 meters away, suggesting that single lane roundabouts would be much safer. While this could not be tested, Inman V.W. et. all (2005) hypothesized that placing the crosswalks further back from the actual circle would yield better results, and suggested placing them at least 2 car lengths back from the motor vehicle entrance to the circle.

In 2006, Cohelo, M.C. et. all set out to study the effects on roundabouts on pollution emissions using data gathered in both Lisbon in Portugal and Raleigh in North Carolina. The conclusions of their research can be expressed with the following statement:

> *"The emissions generally increase as conflicting traffic increases, when queuing conditions prevail; however, for low values of conflicting traffic there appears to be an increase of CO, NOx and HC emissions, since the acceleration rate back to cruise speed appears to be high at low conflicting traffic volumes. Finally, emissions predictably increased as the difference between the cruise and circulating speeds became larger."*

This goes in hand in hand with conventional logic, that says that if there is little traffic, emissions will be lower per vehicle due to the lack of conflicting traffic. Conventional logic also dictates that with a larger roundabout, there will be a greater need for acceleration in order to make it to the other side as opposed to "cruising" through the roundabout intersection, which would yield fewer emissions. The long and the sort of it is that once a certain level of traffic is hit, roundabouts show no level of fuel emissions savings.

Diving deeper into the energy and environmental impacts of higher speed roundabouts, Kyoungho. et. all (2009) set out to study environmental an energy impacts caused by roundabouts as opposed to stop controlled or signaled intersections. They discovered that roundabouts do good things for air quality because they both improve mobility and reduce longer stops. However, the findings of Kyoungho. et. all (2009) are very consistent with those of Cohelo, M.C. et. all (2006). Building off the work of Cohelo, M.C. et. all (2006), Kyoungho. et. all (2009) worked to apply two different microscopic traffic simulation models, the INTEGRATION model and the VISSM model.

What they found was that fuel consumption increased by 13% when going from a stop-controlled intersection to a roundabout and by 8% when going from a signalized intersection to a roundabout. It also found that by implementing stop sign control over a roundabout, fuel consumption could be reduced by up to 18%. Using the VISSIM and INTEGRATION models, Kyoungho. et. all (2009) also found that pollutants may increase over stop controlled intersections as well as signal controlled intersections. Compared to a stop controlled intersection, a signal-controlled intersection will cause an extra 80% in HC emissions, 108% in CO emissions, 28% NOx emissions, and an 8%

increase in CO_2 emissions. When they compared a the stop controlled intersection with a roundabout, the increases were even greater: an extra 155% in HC emissions, 203% in CO emissions, 38% NOx emissions, and an 10% increase in CO_2 emissions. However, we must consider that fuel consumption and carbon emissions are relative to vehicle characteristics, including engine, drivetrain, and transmission technologies. Different models also showed differences in vehicle emissions, which is another thing to take into consideration: no matter what the models say, it is difficult to project real-world conditions as they relate to fuel economy.

In 2002, Wang R. et. all set out to look at the models for traffic flow at single land roundabouts. They found that overall, the output figures increase linearly with the amount of traffic occurring until a saturation point is hit. Simply put, until there is too much traffic at any of the roads leading to the roundabout, traffic will flow fairly seamlessly. Their models incorporated an X factor, which was the number of drivers who are driving irrationally, either through means of their own driving habits, unfamiliarly with roundabouts as a whole, or some other external factor. The presence of an irrational driver will also cause congestion, similar to the way that road saturation will.

When examining the wait, the conclusions made (Wang, R. et. all, 2002) found that "Speed of queue formation increases as arrival rates increase. Maximum queue length occurs within a few hundred time steps for arrival rates are greater than CAR." In addition, during their study on energy and environmental assessments, Kyoungho. et. all (2009) discovered through their VISSIM and INEGRATION models that the queue length for stop controlled intersections was over 100m, while roundabouts and signals were projected to have similar queue lengths (with the VISSIM model showing less than

5 meters per queue and the INTEGRATION model showing approximately 20m queue lengths). The same study by Kyoungho. et. all (2009) also shows that the average intersection delay is 16 seconds for stop controlled intersections, eight seconds for signalized intersections, and 5 seconds for a roundabout.

Managing the public perception of roundabouts is becoming a large issue, as people become more and more familiar with roundabouts popping up in their communities there is more and more resistance as people fear these new intersection changes. The National Cooperative Highway Research Program (2010) describes public education as "one of the most important aspects of planning a roundabout construction". It is important that people feel comfortable with change, and there are numerous ways to prepare the public for roundabout transformations:

- Public meetings and forums
- Literature in the form of fliers, brochures, etc. explaining how a roundabout works.
- Informative media such as websites, videos and others.

Some municipalities have even designed smaller scale-models of roundabouts the public can access at public meetings where they simulate driving scenarios by walking through roundabouts as opposed non-interactive forms of education.

Knowing that drivers have negative prejudice against roundabouts, Retting, A. et. all (2007) set out to see how the public's perception will change over time as roundabouts are implemented in their communities. The method used was surveying people in six different communities in Maryland, Kansas, Nevada, Washington State, New York and

New Hampshire shortly before, shortly after, and at an extended period of time after the construction of the roundabouts. Participants were chosen randomly and then narrowed down to those who fit the needs of the survey, as well as had a diverse age range and equal gender representation. The data they collected clearly shows that the figures go to the opposite ends of what they were at the beginning of the survey.

Retting, A. et. all (2007) found that six weeks prior to the roundabout construction, the percentage of people who either strongly of somewhat favored the roundabout was 34%, while 54% either somewhat opposed or strongly opposed while 12% were unsure. Six weeks after the roundabouts were implemented and the drivers had a chance to use them, the numbers quickly started to shift in public favor. The total number of people in favor of the roundabout jumped from 34% to 57% while the number of those opposed to roundabouts dropped from 54% to 32%. During this period, the number of those who were not sure only dropped 1% point.

After an extended time following the implementation of roundabouts, the numbers grew even more diverse. After 1-5 years following the completion of the roundabout, the number of those total in favor went up to 69%. Even more impressive was that at the beginning of the study, those who strongly favored roundabouts were at 17%, and long after the roundabouts were built that number increased to 40%. At the same time, the total number of those opposed to the roundabouts decreased down to 24%, while those who were “strongly opposed” dropped from 38% at the beginning of the study down to 14%.

Common perceptions prior to the construction were that roundabouts were either unsafe or confusing, Retting, A. et. all (2007). However the data shows that as time goes by, these fears are eradicated. Proper planning is important in the implementation of roundabouts, as incorrect signage, improper design, or poor road quality can decrease the effectiveness of roundabouts (Montella, A. 2007) and as such, the public perception and reception of roundabouts.

Roundabouts offer numerous advantages over stop controlled intersections or signaled intersections. However, more research is needed before we can solve all of the problems associated with traffic intersections, especially in the realm of public safety and pedestrian crossings as motorist behavior at roundabouts in the United States. There is also more research needed in the area of how to best increase traffic flow. In their research on traffic flow, Fouladvand M.E. et. all (2008) concluded that the size of the roundabout affects overall delay, and considering the makeup of motor vehicles in the United States is different than those in Europe (cars driven by Americans tend to be larger) more case studies in the United States are needed.

With that said, there are a great many reasons why roundabouts should be looked at as a legitimate intersection alternative. The benefits to both safety and traffic flow are enormous, with substantial decreases in queue length, time spent at an intersection, vehicle collisions, and the severity of those collisions affecting the damage done to the vehicles and their passengers. There is still more study to be done in the realm of carbon emissions, however at this time it appears that there is not enough significant findings to see if the amount of carbon expelled from vehicles going through roundabouts is significant enough to be of notice. And with public perceptions shown to change over time, there is little reason why municipalities should not consider roundabouts a successful way to deal with their congestion and safety issues where they find it appropriate.

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