SAFETY BENEFITS OF MODERN SINGLE-LANE ROUNDABOUTS

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INTRODUCTION

As modern roundabouts continue to be implemented and gain popularity, it is important to understand what makes them a viable alternative. Roundabout safety, specifically the area of conflict point reduction, is often misunderstood. Adding to the confusion are conflicting definitions and incomplete descriptions of the benefits modern roundabouts provide, especially when examining conflict points. Many published conflict point explanations provide unclear figures and vague classifications, often contradicting themselves.

This paper will investigate modern single-lane roundabout safety, providing a comprehensive illustration of conflict points, examining how traditional intersections compare, and exploring other safety improvements roundabouts provide. Roundabouts are not a solution to every traffic situation. Many other facets of traffic analysis and comparison (operations, economic impacts, right of way, etc) should be examined on a case by case basis to determine if a roundabout is the best overall solution. This document will provide an illustration of the safety benefits of modern single-lane roundabouts. By reducing and separating conflict points and adding other safety benefits, properly designed roundabouts reduce the number and severity of crashes present with traditional intersections.

CONFLICT POINTS

In order to realize the safety benefits of roundabouts, traditional intersection safety must first be examined. One way of examining intersection safety is through the analysis of conflict points. There are four basic types of conflict points that are defined in order of increasing severity as follows: (1).

Queuing Conflicts: These conflicts occur when a vehicle crashes into another vehicle queued at an approach (1). Crashes commonly associated with queuing conflicts are rear end collisions (1).

Diverging Conflicts: These conflicts occur when a vehicle slows down to leave its current traffic stream (1). Crashes associated with diverging conflicts generally involve the front or rear of the vehicle (1).

Merging Conflicts: These conflicts occur when a vehicle joins with an existing stream of traffic (1). Crashes commonly associated with merging conflicts are sideswipe collisions (1).

Crossing Conflicts: These conflicts occur where two traffic streams intersect (1). Crashes commonly associated with crossing conflicts are head on and right angle collisions, which are the most severe and the most likely to cause injuries and fatalities (1).

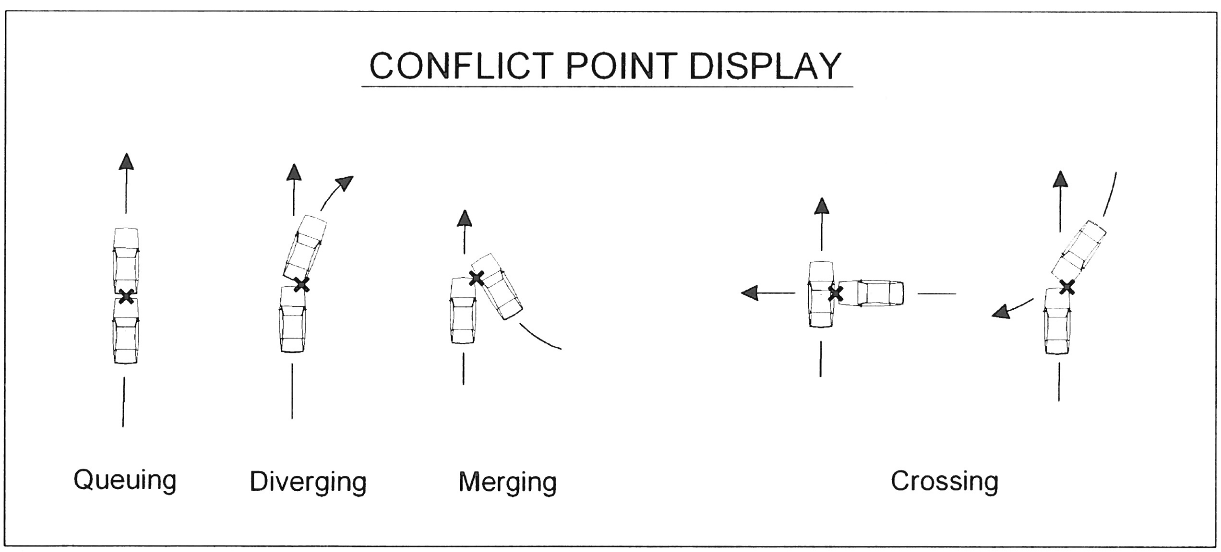

Figure 1

All conflict point types described thus far are conflicts that occur between two vehicles. There are also conflicts present between vehicles and pedestrians. These pedestrian conflicts are classified as crossing conflicts since they occur where a pedestrian's path crosses a traffic stream. It is important to separate these vehicle-pedestrian conflicts from vehicle-vehicle conflicts since the nature of these conflicts (and in turn, crashes) is very different.

Now that the types of conflicts have been established, traditional intersections and roundabouts can be compared. The same conflict point configuration exists for any traditional full access single approach four-leg intersection whether it is stop controlled or signal controlled. Figure 2 represents the conflict points that exist for this type of intersection.

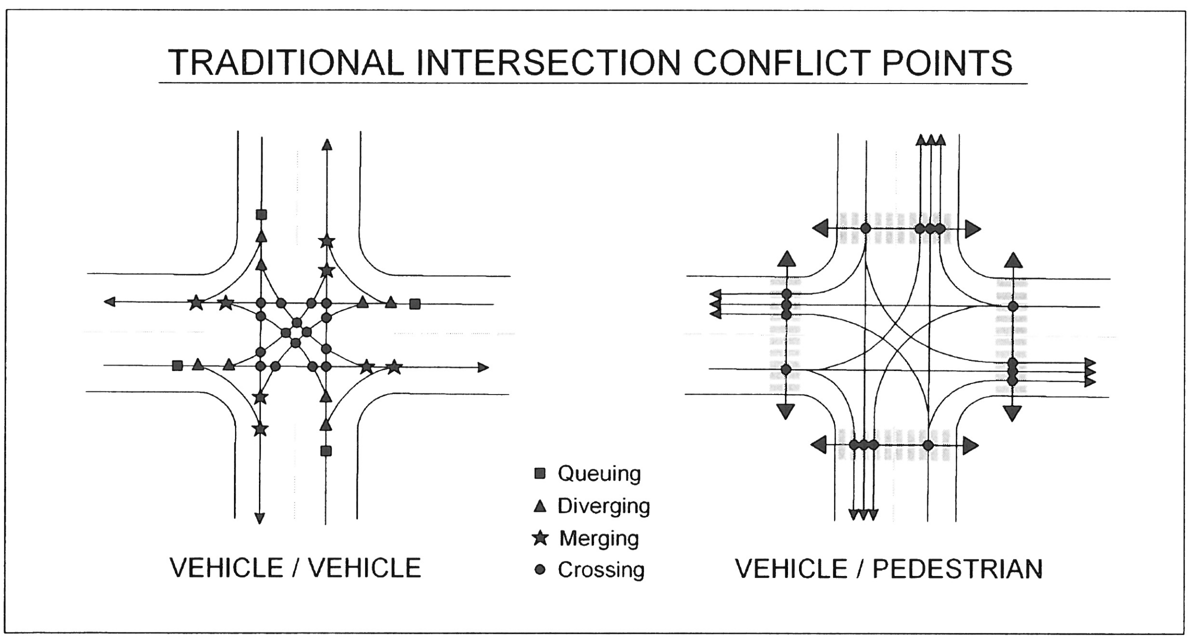

Figure 2

The conflict points present for a traditional single approach four-leg intersection are as follows:

4 Queuing Conflict Points
8 Diverging Conflict Points
8 Merging Conflict Points
16 Vehicle-Vehicle Crossing Conflict Points
16 Vehicle-Pedestrian Crossing Conflict Points

Closer examination of these conflict points reveals that there is a very high number of crossing conflict points, which are the most dangerous. Compared to unsignalized and stop controlled intersections, traffic signals take some steps to reduce these conflicts by using time to separate the movements. But because of red light runners, these conflict points still exist and must be taken into consideration when examining safety.

By design, roundabouts eliminate a significant number of conflict points. Figure 3 illustrates this concept.

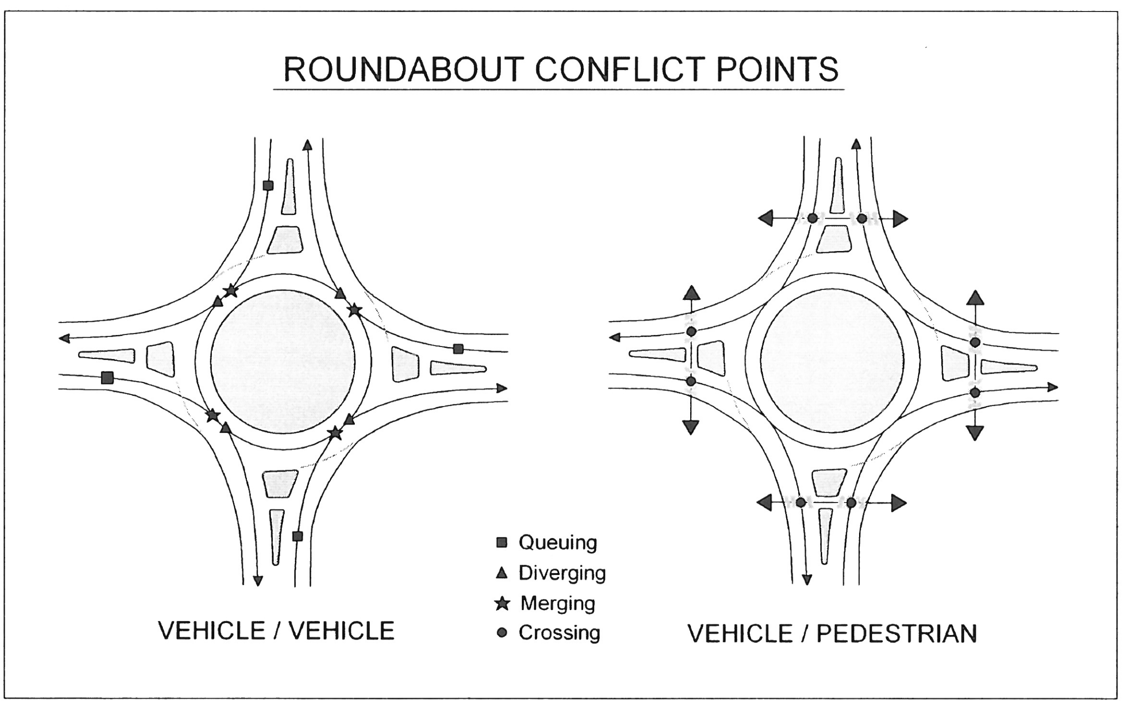

Figure 3

The conflict points present for a single approach four-leg roundabout are as follows:

4 Queuing Conflict Points
4 Diverging Conflict Points
4 Merging Conflict Points
0 Vehicle-Vehicle Crossing Conflict Points
8 Vehicle-Pedestrian Crossing Conflict Points

By comparing these conflict points to the number of conflict points present in traditional intersections, significant improvements can be seen. While queuing conflicts remain the same, all other types of conflicts have been reduced. Both diverging and merging conflict points have been reduced from eight to four, vehicle-pedestrian crossing conflicts have been reduced from 16 to eight, and vehicle-vehicle crossing conflicts have been eliminated from 16 present in traditional intersections. A visual illustration of these conflict point reductions is provided in Figures 4 and 5 at the end of the document. While these are significant reductions in pure conflict point numbers, it should be noted that the conflict points responsible for the most severe crashes have been the most significantly reduced.

In order to fully realize the benefits of conflict point reduction, it is important to look at each point type individually. Queuing conflict points are the same between a traditional intersection and a roundabout. However, some would point out that converting a traditional intersection to a roundabout has the potential to reduce approach lanes by eliminating turn lanes. An approach that has two lanes would have two queuing conflict points and thus a reduction to one lane would reduce the queuing conflict points to one on the approach.

Diverging and merging conflict points were both reduced from eight to four. These types of conflicts are in the middle of the severity rankings and a reduction by half is a significant benefit. Vehicle-Vehicle crossing conflicts (the most severe vehicle-vehicle conflicts) were eliminated. The elimination of these 16 conflict points is the most significant source of the improvement roundabouts make to intersection safety. By eliminating the possibility for head-on and right angle crashes, the opportunity for severe crashes to occur is greatly reduced.

Pedestrian-Vehicle crossing conflicts were reduced from 16 to eight. Not only does this represent a reduction by half, it also changes the nature of the conflict. While crossing a traditional intersection, pedestrians have to cross through three conflict points simultaneously, then cross another from the opposing lane without any sort of a refuge. For example, a pedestrian crossing from south to north on the east side of the intersection would have to watch for a northbound right turning vehicle, an eastbound through vehicle, and a southbound left turning vehicle all while crossing the first lane of traffic. In addition to these conflict points, the pedestrian then must watch for traffic approaching the intersection from the east. Even with signal control, pedestrians must watch for left turning and right turning vehicles simultaneously (movements which approach the intersection from completely opposite directions).

Roundabouts provide a significantly safer solution. A pedestrian crossing a roundabout only encounters one conflict point at a time. A pedestrian crossing from south to north on the east side of the intersection looks to the left for vehicles exiting the roundabout, and then crosses to a refuge in the splitter island. Once in the refuge, they can check for vehicles approaching the roundabout from the east. A good illustration of the difference between these types of movements is to consider crossing a traditional intersection with a channelized right turn lane. It is fairly clear that crossing the right turn lane to the channelizing island is quite a bit easier than crossing the other lanes of traffic. This is the essential difference between a traditional intersection and a roundabout from a pedestrian's perspective. All vehicle-pedestrian crossing conflict points remaining in a roundabout are isolated so that each is navigated one at a time.

A reduced number of conflict points also results in simplified decision making. A vehicle turning left across a traditional intersection passes through 11 conflict points (although a protected signal phase effectively reduces this number). Not only does a roundabout reduce the number of conflict points, it spreads the remaining ones out. A vehicle making the same movement described above through a roundabout first checks for pedestrians on the approach, then proceeds to merge into the roundabout. The vehicle then encounters merging and diverging conflict points (one at a time) until it exits, passing through one more vehicle-pedestrian crossing conflict point on the way out. Separation of conflict points is a key safety improvement of roundabouts.

OTHER SAFETY BENEFITS

Conflict point reduction/separation is not the only safety benefit of roundabouts. There are several other benefits inherent in the design of roundabouts that lead to increased safety. Roundabouts require lower speeds to navigate than traditional intersections. Because of horizontal deflection, vehicles are forced to slow down. Slower speeds are directionally proportional to accident severity, not to mention that slower speeds require less reaction time from drivers for crash avoidance. Another benefit of roundabouts is the physical nature of control. Since the control comes from the geometry of the intersection, it does not depend on a system's operation to function. Electrical outages or hardware/software malfunctions do not affect roundabouts in the same way they affect traffic signals.

With traditional intersections, inattentive or drunk drivers often run red lights and stop signs, barreling into intersections a high rate of speed. These types of violations often lead to devastating head-on or right-angle crashes, the results of which are often major injuries and fatalities. The Federal Highway Administration estimated nearly 218,000 crashes at intersections due to red light running in 2001 (5). These crashes resulted in 181,000 injuries, 880 fatalities, and an estimated $14 billion per year in economic losses (5). It is not physically possible to "run" a roundabout. Someone who is inattentive, drunk, or even the target of a police pursuit approaching a roundabout at a high rate of speed is likely going to crash into the splitter island or central island. The result of this crash is commonly a less severe one-car accident involving only the offender.

Pedestrians also benefit from roundabout's reduced approach speed. A UK Department of Transportation Study found that a pedestrian's chance of death in a vehicle/pedestrian collision decreases from 85% at 40 mph to 15% at 20 mph (4). Researchers found that fewer than 2 percent of pedestrians struck by vehicles died in crashes that occurred where posted speed limits were slower that 25 mph while more than 22 percent of struck pedestrians died where the speed limits were 50 mph or higher (3). In addition, pedestrians see significant benefits from reduced crosswalk length. Not only do they have a shorter distance to cross (which is a significant improvement for elderly and handicapped pedestrians) most roundabouts involve a splitter island between the two directions of vehicle travel, which provides a refuge for pedestrians as they cross.

It should be noted that the safety benefits examined are increased in situations where an intersection has more than four legs or the approaches are skewed from 90 degrees. As more approaches are added or a skew is introduced, crossing movements become more dangerous and the driver's ability to see approaching vehicles and pedestrians becomes more difficult.

Not only are there theoretical safety improvements from roundabouts when compared to traditional intersections, but empirical data supports this assertion. A 1997 study by the U.S. Transportation Research Board showed that intersections converted to roundabouts saw an overall crash reduction of 37%, and injury crash reduction of 51% (1). A 2001 Insurance Institute for Highway Safety study showed a 39% decrease in all crashes, a 76% decrease in injury crashes, and a 90% reduction in fatality or incapacitating injury-producing crashes for 24 intersections converted to roundabouts in the United States (3). In the area of pedestrian safety, a study of 181 intersections converted to roundabouts in Norway showed a reduction in pedestrian casualties of 89 percent (4). It should be noted that these types of studies might have slightly inflated improvements, since the converted intersections were most likely problematic before conversion. However, it is not believed that this fully negates the benefits since these numbers represent such a substantial improvement, especially in the most severe types of crashes.

Other European countries have also seen vast safety improvements from roundabouts. Studies with much larger sample sizes from France and the United

Kingdom indicate that crash risks at roundabouts range from 10 to 30 percent of those at traditional intersections (2). This study included traditional intersections that consisted of 4 legs and 3 legs, both with and without traffic signals (2). Germany and the Netherlands have seen a 36% and 47% crash reduction respectively (1).

CONCLUSION

By reducing and separating conflict points and adding other safety benefits, properly designed roundabouts reduce the number and severity of crashes present with traditional intersections. Through a comprehensive definition and comparison of conflict points and an examination of other safety aspects inherent in the design of modern roundabouts, the theoretical advantages become quite clear. In addition, these theoretical benefits have been confirmed by empirical data. Though still somewhat new in concept, they have been proven to be a viable alternative for certain operating conditions, and in many cases, a substantial improvement in safety over traditional intersections.

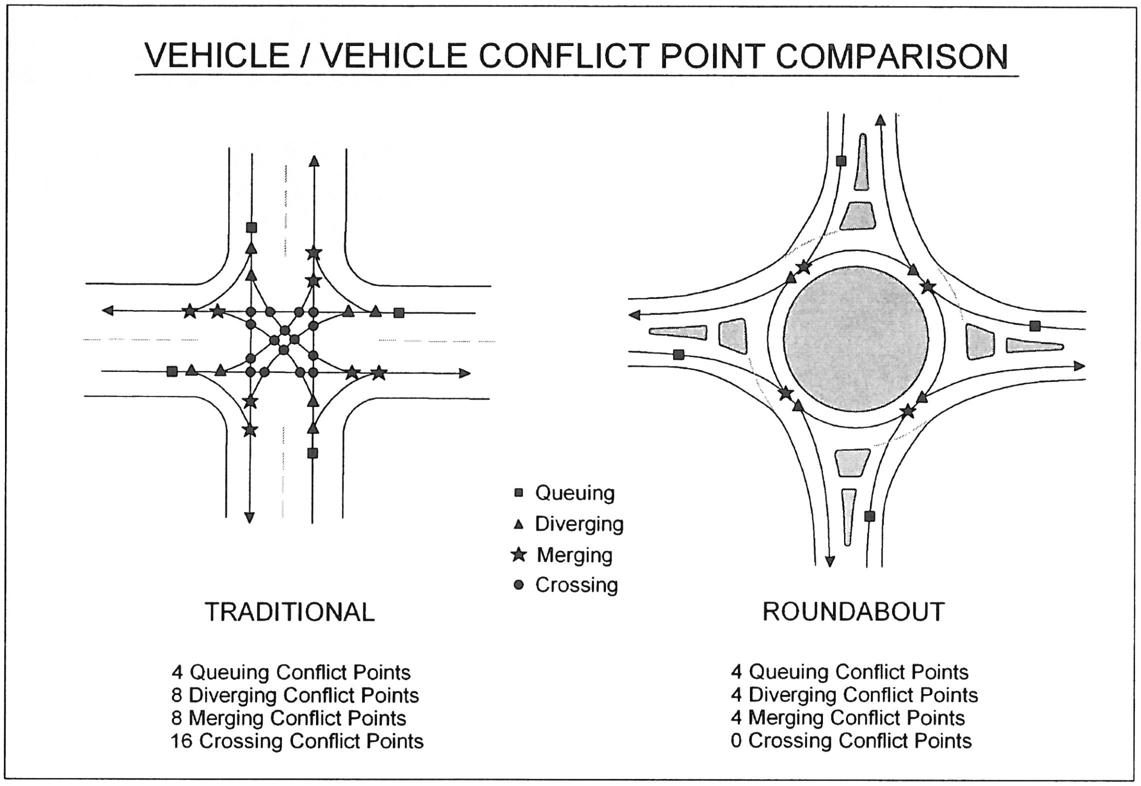

Figure 4

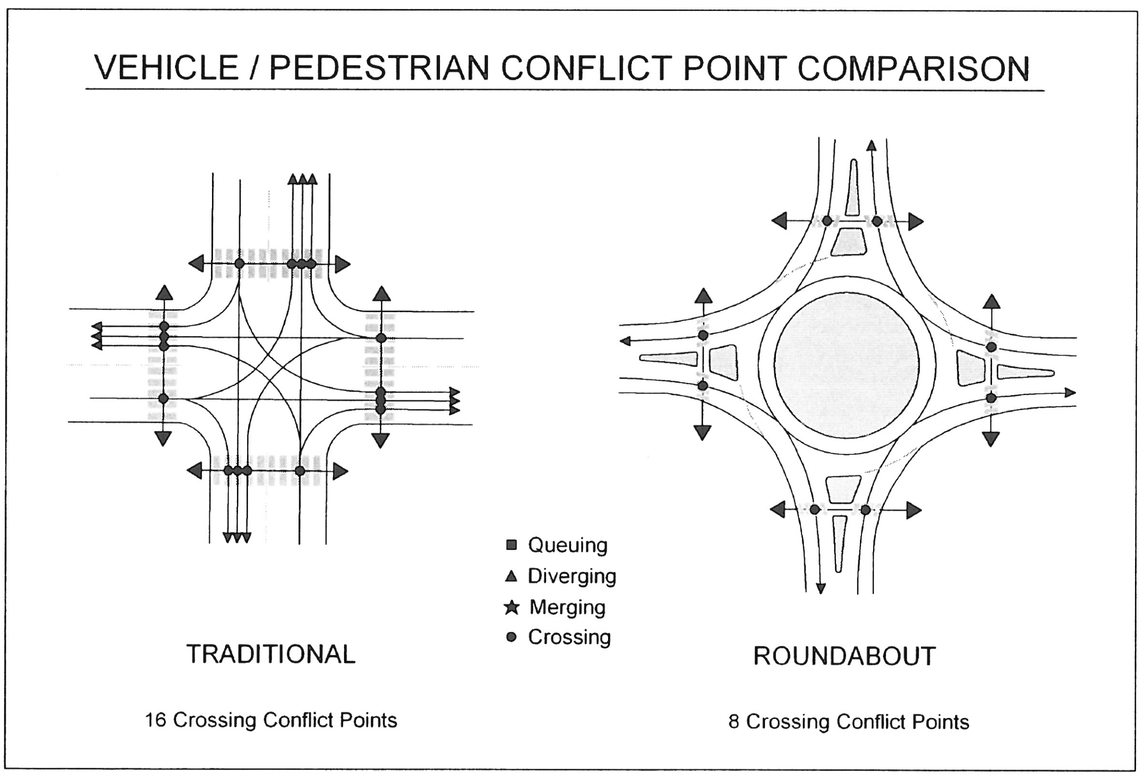

Figure 5

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