Chapter 5 – Safety

Safety benefits are touted by many as an advantage of a roundabout *(1, 2, 4, 9, 10, 11, and 12).* This study examined the issue of intersection safety in three ways: literature review, conflict analysis and crash review.

Section 5.1 – Literature Review

There were a number of safety and operational concerns expressed by citizens to the City staff prior to the construction of the Candlewood/ Gary roundabout. There were also a number of consistent issues raised in the literature with regard to roundabout safety and operation. Since the local safety concerns paralleled those found in the literature, they are presented here together (Table 13).

Table 13 - Safety and Operational Concerns of Roundabouts

Concern:	**Description at a Standard Intersection:**	**Description at a Roundabout:**
Non-compliance	Drivers not obeying traffic control devices	Drivers driving the wrong way around roundabout
Truck accessibility	Can trucks maneuver past curbs	Can trucks maneuver around the center island

Section 5.1.1 - Safety of Roundabouts

Previous studies of crash experience finds that roundabouts are safer than standard methods of intersection control. The following are examples of results from such studies:

- A 1975 study found that intersections where roundabouts had replaced standard major/ minor controls resulted in 39% fewer injury crashes, 64% less serious injury and fatal crashes, 51% fewer wet road crashes, and 46% fewer pedestrian crashes *(13).*
- A 1994 study found that annually 22.40 crashes occurred at three roundabouts producing 4.26 injuries. Three adjacent two-way STOP controlled intersections experienced 48.75 crashes producing 19.73 injuries per year. The STOP controlled intersections were found to have a crash rate almost double the roundabout intersections, 1.22 versus 2.41 *(12).*
- A 1998 study reports that where roundabouts have been installed in the United States, there has been a reduction in the number of property damage only crashes of from 10 to 32 percent, a reduction in injury crashes of from 31 to 73 percent and a reduction in fatal crashes of from 29 to 51 percent *(5).*

Overall, the findings of safety may be best stated by Wallwork, "The safest, most efficient and attractive form of traffic control in the world" *(2).* There is documented evidence to support the claim that roundabouts are a safe intersection control.

The safety benefits of roundabouts may be a result of simplifying the driving task. At a standard intersection, the driver is required to react to vehicles to the right, left, and ahead, and to pedestrians on all parts of the intersection. "The apparent reason for safety benefits of traffic circles are that the motorists, bicycles and pedestrians are required to check for traffic from only one direction at a time, thereby simplifying the task" *(12).* The term 'traffic circles' used by Savage describes what is referred to in this research as a roundabout.

Section 5.1.2 - Bicycle and Pedestrian Safety

There were safety issues raised prior to the roundabout being installed with regard to access for pedestrians and bicyclists. This fear appeared to stem from the unfamiliarity of the residents to the intersection design. Upon examination of the literature *(4, 5)*, it does appear that the operation of bicyclists and pedestrians through roundabouts is an issue that needs to be carefully considered.

Savage *(12)* found that roundabout intersections experienced less bicycle and pedestrian crashes than adjacent two-way STOP controlled intersections. Specifically, the roundabout intersections had a crash rate of 0.06 crashes per million vehicles for bicycle and pedestrian involved crashes. This compared to a crash rate of 0.27 for the two-way STOP controlled intersections. Other sources present similar findings *(2, 10).* Based on the published literature, properly designed roundabouts provide a safe environment for bicyclists and pedestrians *(2).*

Section 5.1.3 - Bicycle and Pedestrian Design

The physical design of a roundabout for bicyclists and pedestrians must be examined separately by mode.

Bicyclists can negotiate a roundabout as either a vehicle or pedestrian. Bicyclists that feel comfortable with travelling in the traffic stream can continue into the roundabout using the same path as vehicles. The Maryland roundabout design guide states that "cyclists use roundabouts in a similar manner to motor vehicles" *(1).* The other option for a bicyclist is to leave the street and travel on the sidewalk system. One suggestion for addressing these users is to install a bicycle ramp that transitions from the street bike lane to the sidewalk for these bicyclists (Wallwork).

Pedestrian design of roundabouts follows a design philosophy similar to standard intersections.

> "In respect to geometric design, the provision for pedestrians does not differ greatly to that required for other intersection treatments, however, certain roundabout designs, particularly large roundabouts, can result in greater walking distances, and thus inconvenience, of pedestrians" *(3).*

In general, pedestrian crossings (crosswalks) should be located one vehicle length back from the entrances and exits of the roundabout *(1, 2).* When crossing volumes of pedestrians are high, it may be desirable to move the crosswalk location farther back from the entrance/ exit to allow both the motorist and pedestrian a chance to see each other away from the activities of the roundabout *(2).* In addition to the location of the crosswalk, a properly designed splitter island is important to pedestrian safety.

> "Generally, the installation of well designed splitter islands of sufficient size to stage pedestrians, thus allowing them to cross only one direction of traffic at a time, will result in pedestrians being able to move more safely and freely around the intersection than was the case before the installation of the roundabout" *(3).*

In all cases, the splitter island plays a vital role to the safe movement of pedestrians and beginner bicyclists through a roundabout intersection.

Section 5.2 – Crash Review

Full year crash data was available from the City for the Candlewood Drive/ Gary Avenue intersection for the calendar years 1994 – 1996 prior to installation of the roundabout, and for 1998 - 1999 after installation. The number and type of intersection crash are shown in Table 14. While complete year data is not available, data was available for 29 months following roundabout construction. This 'after' data shows no reported traffic crashes at this intersection. This represents a statistically significant reduction in crash experience based on the methodology in the Kansas High Accident Location Manual *(14).*

Table 14 - Crash Records Before and After Roundabout Installation

Year:	PDO:	Injury:	Total:
1994	3	0	3
1995	0	2	2
1996	2	2	4
Roundabout Installed in 1997			
1998	0	0	0
1999	0	0	0

* PDO – Property Damage Only

There were nine reported crashes at the intersection of Candlewood Drive/ Gary Avenue from January 1994 to December 1996. All nine of these crashes involved a driver failing to yield the right of way or failing to stop for a STOP sign. All of the nine crashes were right angle. The literature indicates that right angle and failure to yield type crashes are the types that are reduced by installation of a roundabout as was found to be the case at the Manhattan roundabout.

The Manhattan roundabout experienced no reported crashes in 29 months of operation. The before condition experienced nine crashes over 3 years, 4 of which involved injuries. Using Kansas's HAL procedure *(14)* for calculating the cost of crashes yielded the values shown in Table 15. This table shows that the Manhattan roundabout has reduced the annual cost to society from vehicle crashes by $87,833. All amounts are in non-adjusted, 1994 dollars.

Table 15 - Before and After Crash Costs at Roundabout

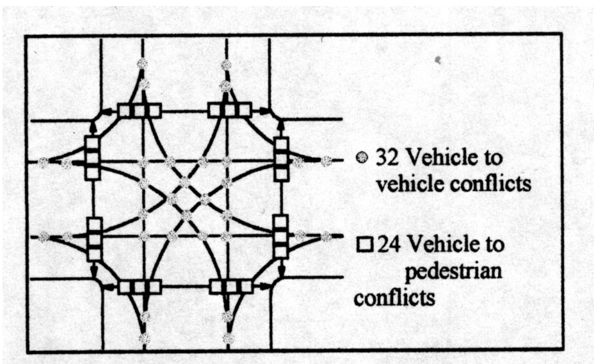
	Before	After
PDO Crashes @ $3,500 ea	5 x $3,500 = $17,500	0 x $3,500 = $0
Injury Crashes @ $61,500 ea	4 x $61,500 = $246,000	0 x $61,500 = $0
Total Cost of Crashes	$263,500	$0
Time Period	3 years	2 years
Crash Cost per Year	$87,833	$0

The monetary values in this table are not adjusted for inflation.

Section 5.4 – Conflict Analysis – Literature Review

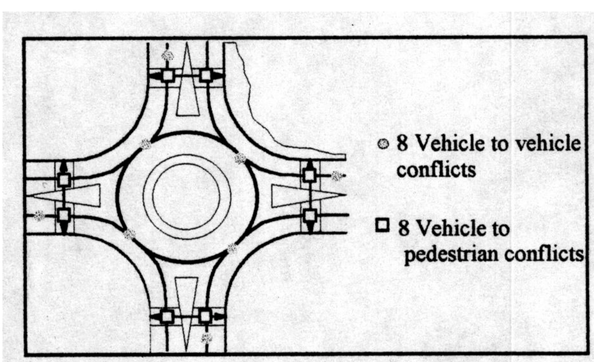
Intersection crashes are statistically rare events. It usually takes several years of crash data to make valid conclusions. As such, techniques have been developed to predict the relative safety of an intersection in the absence of sufficient crash data. This study used the conflict analysis technique to evaluate the safety of the three intersections under analysis.

One of the observational methods of determining the possible danger of an intersection configuration is to examine the number of conflict points *(2, 7)*. By definition, a conflict point is any point where a vehicle path crosses, merges, or diverges from another vehicle or pedestrian path. As can be seen in Figure 13, a standard 4-leg intersection has 32 vehicle and 24 pedestrian conflict points. Figure 14 shows the conflicts for a roundabout. Note that a roundabout decreases the number of vehicle and pedestrian conflict points to eight each. Also note that for the roundabout, all left turn and crossing conflict points are alleviated. Theoretically, the roundabout should operate much safer than a standard intersection.



Source: *(2)*

Figure 13 – Standard Intersection Conflict Points



Source: *(2)*

Figure 14 - Roundabout Intersection Conflict Points

The definition of a traffic conflict leads to a sense that the traffic conflict is a measure of operational break points of the intersection being observed. Indeed, the reference states that this method of intersection analysis is "useful in diagnosing problem locations or measuring the effectiveness of a site improvement" *(7).* As used in this study, the traffic conflict analysis measured the comparative operation of multiple intersections, and the results of that analysis.

The results of the conflict analysis were used to make conclusions regarding safety of the roundabout under study.

Intuitive understanding of how a roundabout may be safer than a standard intersection lies in comparison of the conflict point diagrams. Another lies in examining the tasks placed on drivers as they pass through each type of intersection. To pass through a traditionally controlled intersection, a driver, must look for approaching/ conflicting vehicles to the left and right, as well as watch the opposing direction for vehicles that may turn into his/her path. Once a check for pedestrians is made, traversing a roundabout requires the driver to watch traffic only from the left. Therefore, the observational tasks placed on a driver at a standard intersection are much greater than they are at a roundabout intersection.

In NCHRP report number 219 *(7)*, thirteen basic intersection traffic conflicts are defined, arising from the 32 vehicle/ vehicle intersection conflict points (Table 16). Also shown are how these typical intersection conflicts apply to an intersection configured under roundabout control. This table shows that by using a roundabout at an intersection, all but three of the 13 basic intersection conflicts are alleviated.

In one sense, the roundabout tends to be both a geometric design feature, and a traffic control device. The roundabout affects the speed of vehicles traveling through the intersection by its design components. The roundabout also provides for a logical yield control of vehicles at the intersection. In many cases however, roundabouts are considered an alternative where traffic signalization is needed. Therefore, the primary consideration of the roundabout is as a traffic control device.

Table 16 - Basic Intersection Conflicts - Standard Intersection and Roundabout Control

Conflict Type	**Standard Intersection***	**Roundabout**
1. Left turn, same direction	Yes	No
2. Right turn, same direction	Yes	Yes
3. Slow vehicle, same direction	Yes	Yes
4. Lane Change	No	No
5. Opposing left turn	Yes	No
6. Right turn cross traffic, from right	Yes	Yes
7. Left turn cross traffic, from right	Yes	No
8. Thru cross traffic, from right	Yes	No
9. Right turn cross traffic, from left	Yes	No
10. Left turn cross traffic, from left	Yes	No
11. Thru cross traffic, from left	Yes	No
12. Opposing right turn on red (during protected left turn phase)	Yes	No
13. Pedestrian	Yes	Yes
Total:	12	3

* Standard intersections include YIELD, STOP and signal control

Section 5.5 – Conflict Analysis – CG, DW and JP

Many of the tapes were reviewed by members of the study team for the presence of conflicts. Despite these efforts, and the observation of over 180 hours of videotapes, only one conflict was observed. The one conflict occurred at one of the two-way STOP controlled intersections. Due to the insufficient number of observed conflicts, conflict conclusions could not be made.

Section 5.5 – Intersection Travel Speed

The speed at which a vehicle travels through an intersection can have a great impact on the severity of any crash that may occur. The intersection travel speed can even have an impact on the number of intersection crashes. This is due to the shorter decision times allowed to motorists (and non-motorists) when vehicles operate through a high speed intersection. Therefore, any intersection design feature that would tend to consistently slow vehicles would have a positive impact on safety. Roundabouts through their design (splitter islands, deflection curve) slow vehicles down.

Section 5.6 – Summary of Safety Evaluation

The literature contains clear evidence that roundabouts are safer than other forms of intersection traffic control. Safety benefits were found to apply to all intersection users including vehicles, pedestrians and bicyclists.

There were nine reported vehicle crashes in the three calendar years preceding roundabout installation at the intersection of Candlewood Drive/ Gary Avenue. These nine crashes were all right angle and involved a driver railing to yield right of way at the STOP controlled intersection. There were no reported vehicle crashes in 29 months after roundabout installation. This reduction in crashes was found to be statistically significant at the 95% confidence level. This reduction in right angle/ failure to yield crashes matches the safety benefits of roundabouts suggested by the literature.

The reduction in crashes from an average of three per year to zero resulted in a savings to society of crash costs.

An examination of traffic conflicts was performed at all three intersections (CG, DW and JP). Insufficient data was obtained from the conflict study to perform analysis or make conclusions with regard to intersection conflicts.

Overall, the safety of the Manhattan roundabout has been as predicted by the literature. This may suggest that safety at U.S. roundabouts may be similar to other countries where they are in use. However, there is relatively limited data from U.S. roundabouts, requiring researchers and practitioners to supplement their findings with foreign safety studies. Additional data regarding of the safety of U.S. roundabouts will accrue as more and more are built.