Traffic Circles—A Viable Form of Intersection Control?

BY WILLIAM F. SAVAGE AND KHALED AL-SAHILI

Michigan State University, in East Lansing, Mich., is a university with about 40,000 students. A large number of students are housed on campus, with many more living in the immediate adjoining areas. Restrictions on student parking on campus are strictly enforced. Students are required to park in outlying lots and take a bus, walk or bike to their classes. This produces a heavy mix of cars, bicycles and pedestrians at all intersections within the campus environment.

Most of the intersections are controlled by two-way stop signs or traffic signals. There are however, three major intersections controlled by traffic circles (see Figure 1).

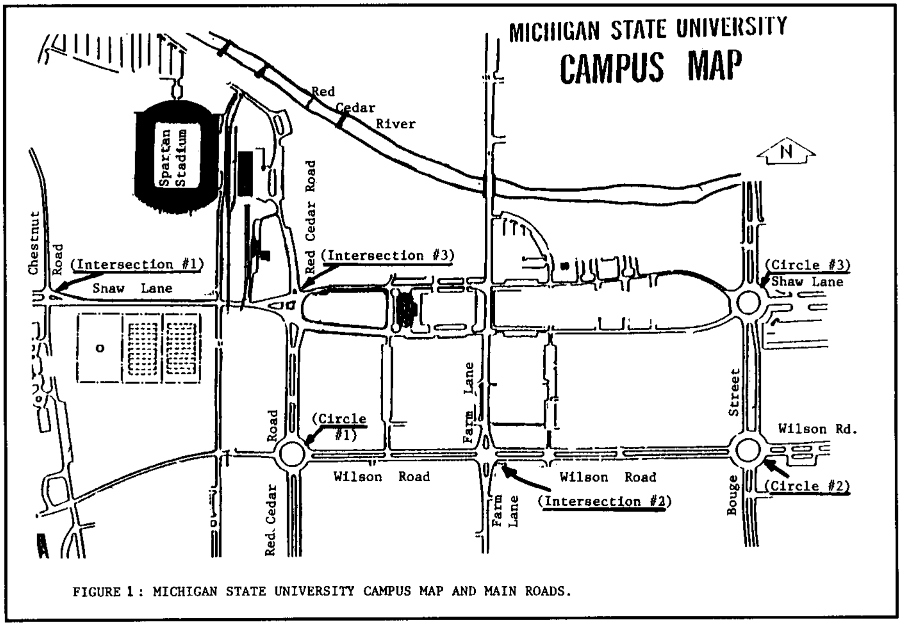


FIGURE 1 : MICHIGAN STATE UNIVERSITY CAMPUS MAP AND MAIN ROADS.

Figure 1. Michigan State University campus map and main roads.

With renewed interest and experience in this country using traffic circles and roundabouts (a more efficiently designed traffic circle), a formal comparison of these intersection types might be of assistance in selecting the most appropriate intersection design and operation.

Purpose of Study

This study originated as a result of operational problems at the intersection of Farm Lane at Wilson Road. This intersection was experiencing a number of right angle accidents, and the Wilson Road traffic suffered considerable delay because of turning conflicts and requiring traffic to stop two times at the intersection.

Because there are three traffic circles in the immediate area that have been in operation for many years, a suggestion was made to consider construction of a traffic circle at this location. Two other two-way intersections also carry similar traffic volumes near to Wilson Road.

To learn more about the existing three traffic circles and corresponding three two-way stop locations, complete traffic counts were conducted at each, and their accident records during the past several years reviewed.

Conversion Factors

To convert from	to	multiply by
ft	m	0.3048

The purpose of this study is to determine if it is feasible or desirable to recommend a change in right-of-way control. Or, to determine if the existing traffic circles would operate better under some other type of control.

Description of Intersections

The six intersections involved in this study are illustrated in Figure 2.

Traffic Circle 1—Red Cedar at Wilson. Wilson Road is a major east-west campus arterial, and Red Cedar Drive is a minor arterial. All roadways are divided with two lane approaches, except the west leg of Wilson, which is an undivided roadway and a single-lane approach. The traffic circle has a 150-foot (ft) diameter with a 35-ft wide circulating roadway.

Traffic Circle 2 —Wilson at Bogue. Both Wilson Road and Bogue Street are major campus arterials, and all four roadways are divided with two lane approaches. This traffic circle has the same dimensions as Traffic Circle 1.

Traffic Circle 3—Shaw at Bogue. Both Shaw Lane and Bogue Street are major campus arterials, with the north and south legs having four lane divided approaches. The east leg is four-lane undivided, and the west leg is the start of two-lane, one-way streets through campus. This traffic circle has the same dimensions as the other two circles.

Two-way Stop 1—Shaw at Chestnut. Shaw Lane is a four-lane divided major east-west campus arterial, and Chestnut Street is a two-lane undivided minor arterial. Chestnut traffic is required to stop for Shaw and then "yield" in the 25-ft median before crossing the far direction of Shaw.

Two-way Stop 2—Wilson at Farm. Both Wilson Road and Farm Lane are four-lane divided major campus arterials. Wilson traffic stops for Farm Lane and again in the 25-ft median.

Two-way Stop 3—Shaw at Red Cedar. The intersection is located near the west end of the Shaw Lane one-way street segment. Red Cedar Drive is a four-lane divided roadway to the south and a two-lane undivided roadway on the north. This intersection actually operates as a two-way "yield" intersection, with the Red Cedar traffic yielding for Shaw, and again in the 100-ft median.

Traffic Volume Studies

Eight-hour manual traffic counts were conducted at all six study locations for the hours 7 to 9 a.m., 11 a.m. to 1 p.m., and 2 to 6 p.m. The manual counts include all pedestrian and bicycle movements through the intersections. In addition, 24-hour machine counts were taken for inbound and outbound movements on all approaches.

The studies reveal that traffic volumes at the three traffic circles are similar to the three two-way stop intersections.The peak-hour volumes for each intersection are shown on Figure 1.

The eight-hour pedestrian and bicycle counts show that the traffic circles average 2,940 pedestrians and 502 bicycles, while the two-way stop intersections average 2,815 pedestrians and 889 bicycles.

Study of Accidents

Accidents were reviewed for the years Jan. 1, 1988 through Sept. 30, 1991 (3.75 years), for the six intersections.

As shown in Table 1, the total number of accidents for the three traffic circles is 22.40 accidents per year. These accidents produced a total of 4.26 injuries. The three two-way stop intersections had 48.75 accidents, producing 19.73 injuries.

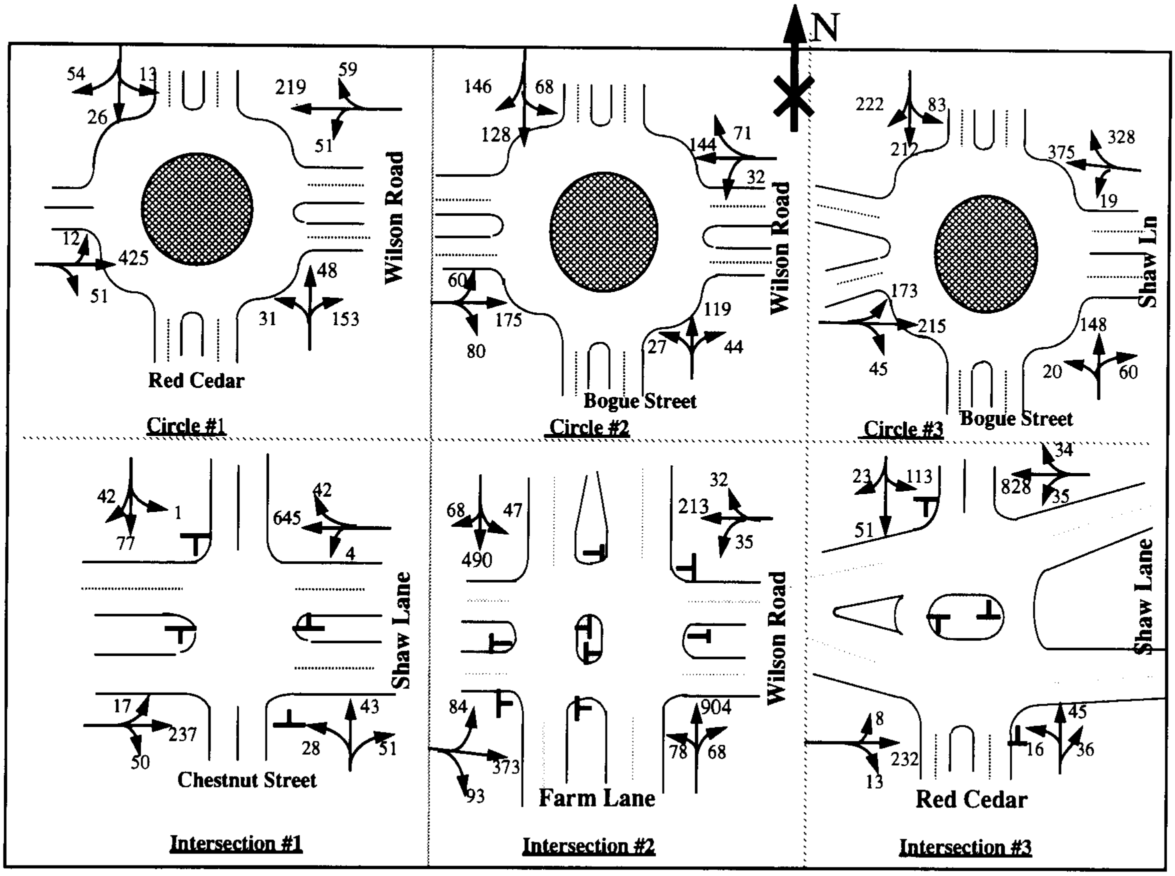


Figure 2. Geometrical sketches and the peak-hour volumes (vph) of the six intersections studied.

Table 1. Accidents During 3.75 Years Period

Intersection	*Total Accidents*	*Bike & Pedestrian*		*Injury Accidents*	*Persons Injured*	*Accidents Per Year*	*Average Daily Volume*	*Accident Rate*
		Bikes	*Peds*					
Circle #1	9	1	0	2	2	2.40	14,633	0.45
Circle #2	20	0	0	2	3	5.33	11,934	1.22
Circle #3	55	2	1	11	11	14.67	23,710	1.60
Intersection #1	52	4	0	18	24	13.87	14,985	2.54
Intersection #2	63	9	0	23	29	16.80	21,598	2.13
Intersection #3	67	10	0	17	21	17.87	18,543	2.64

There were only 1.07 bicycle and pedestrian accidents per year at the traffic circles, while there were a total of 5.60 bicycle and pedestrian accidents per year at the three two-way stop intersections.

Table 1 also shows that the accident rates at all of the traffic circle intersections are less than at the two-way stop intersections. As a group, the three traffic circle intersections combine for an average accident rate of 1.22, while the group of two-way stop locations have a 2.41 rate (almost double).

Accident Severity

The severity of accidents at the traffic circle intersections were considerably less than at the two-way stop locations. There were only 15 injury accidents at the traffic circles (Severity Ratio of 0.18), compared to 58 injury accidents at the two-way stops (Severity Ratio of 0.32). The Severity Ratio is the number of injury accidents divided by the total number of accidents.

In addition, each injury accident at the two-way stops produced 1.28 injuries vs. 1.07 injuries at the traffic circles.

Bicycle and Pedestrian Safety

There were fewer pedestrian and bicycle accidents at the traffic circles (four at the circles and 21 at the two-way stops). The accident rates of .06 and .27 accidents per million vehicles for these kinds of accidents indicates that traffic circles offer considerable safety benefit.

Fuel, Delay and Emission Measurement

Comparisons were made of the efficiencies of the traffic circle and two-way stop designs, by using the NETwork SIMulation (NETSIM) analysis.[1] This analysis simulates the intersection operation and measures the effectiveness of each by determining the fuel consumption, average speed, stops per vehicle

Table 2. Measures of Effectiveness at the Intersections Controlled by Traffic Circles and Stop Signs

	Intersection Number								
	Circle #1	*Circle #2*	*Circle #3*	*Inter-section #1*	*Circle Conversion*	*Inter-section #2*	*Circle Conversion*	*Inter-section #3*	*Circle Conversion*
# Stops/vehicle	0.01	0.02	0.02	0.27	0.00	1.33	0.02	0.27	0.00
Average speed, mph	15.36	16.00	14.53	14.47	15.36	2.83	15.45	10.90	14.68
Avg. delay/veh (sec)	2.25	1.88	1.85	3.91	1.89	31.40	1.88	6.03	1.75
Total delay (minutes)	7.20	5.70	9.40	13.40	6.60	157.0	9.90	24.00	6.00
Delay/veh-mile (min)	0.80	0.80	1.23	2.03	1.24	18.88	1.15	2.92	1.14
T-time/veh-mile (min)	3.91	3.75	4.13	4.15	4.12	21.20	4.03	5.50	4.09
Fuel consumption (M.P.G.)	11.61	9.88	8.99	5.81	8.80	3.54	9.04	7.64	9.11
Fuel emissions* (grams/veh-mile)									
HC	0.183	0.214	0.245	0.364	0.248	0.639	0.242	0.281	0.243
CO	3.080	3.822	4.405	7.306	4.355	10.352	4.348	5.000	4.399
NOx	0.763	1.099	1.207	2.395	1.245	2.423	1.203	1.413	1.204

#Through and left-turn traffic of East-West direction have to stop twice (as shown in Figure 1) before crossing the intersection
*For composite autos

and so forth of each design. Figure 3 shows the NETSIM Link/Node Diagrams used for the two-way stop and traffic circle control.

The measures of effectiveness as produced by NETSIM are shown in Table 2. The traffic circles generally produced better results than even the best two-way stop intersection. Even though it was suspected that Two-Way Stop 2 was not operating well, the results were much worse than expected.

The study also shows that the measures of effectiveness can be improved by converting the two-way stop intersections to traffic circles.

Capacity Analyses

The capacity and level of service (LOS) of each approach of all six inter-

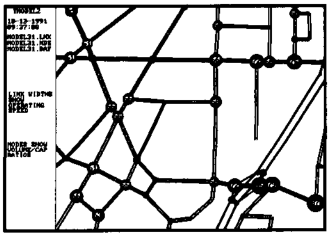
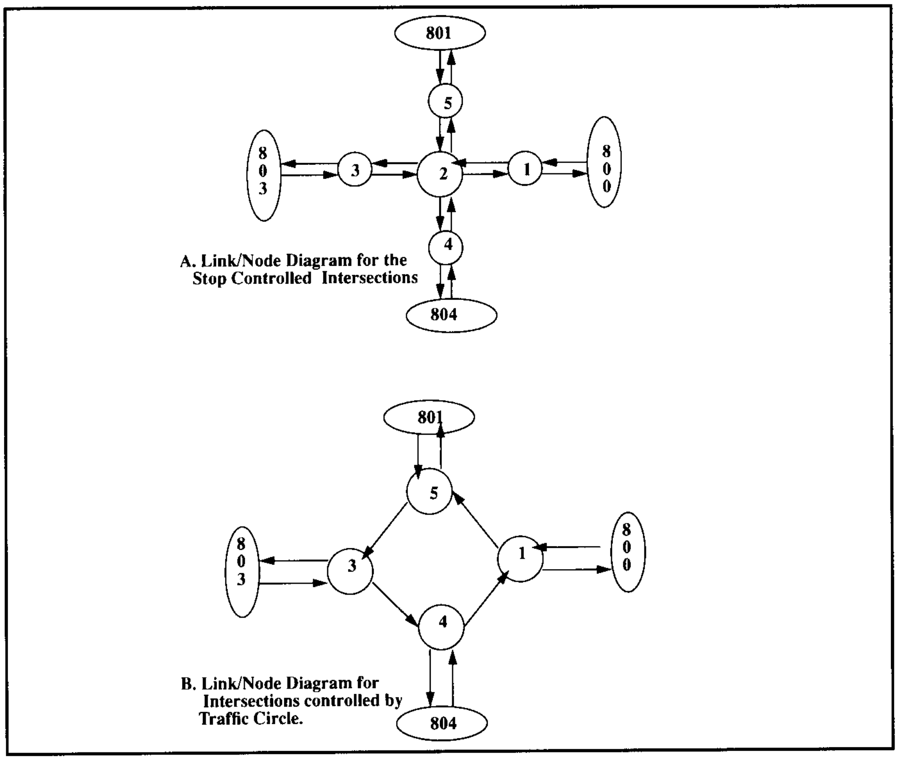


Table 3. Capacities and Levels of Service (LOS) for the Intersections Studied

	North Bd.		*South Bd.*		*East Bd.*		*West Bd.*		*Overall*	
	Capacity	*LOS*	*Capacity*	*LOS*	*Capacity*	*LOS*	*Capacity*	*LOS*	*Capacity*	*LOS*
Traffic Circle #1	2,117	A	2,360	A	1,186	A	1,879	A	7,542	A
Traffic Circle #2	1,032	A	2,324	A	2,278	A	2,123	A	7,757	A
Traffic Circle #3	1,126	A	1,266	A	1,084	A	1,640	A	5,116	A
Intersection #1	205	E	272	D	1,949	A	2,281	A	4,707	C
Circle Conversion	1,083	A	954	A	1,932	A	2,207	A	6,176	A
Intersection #2	2,021	A	1,729	A	437	F	195	F	4,384	C
Circle Conversion	1,307	B	755	C	1,308	A	614	B	3,984	B
Intersection #3	500	C	254	E	1,810	A	1,918	A	4,482	C
Circle Conversion	2,000	A	754	A	1,693	A	2,062	A	6,509	A



A. Link/Node Diagram for the Stop Controlled Intersections

B. Link/Node Diagram for Intersections controlled by Traffic Circle.

Figure 3. NETSIM's link/node diagrams for stop control and traffic circle control.

sections were analyzed, and the results are shown in Table 3.

All three traffic circles have an overall LOS of "A," while the two-way stop intersections have a LOS of "C." The analysis shows that the capacities of the two-way stop intersections can be improved by converting them to traffic circles.

The *Highway Capacity Manual* (HCM 1985)[2] method and the Highway Capacity Software were used to analyze the capacity of the three intersections controlled by the two-way stop.

The capacities of the traffic circles were analyzed based on the Troutbeck (1988) recommended formula.[3] This formula is based on the National Association of Australian State Road Authority (NAASRA 1986) Guide. The Gap Acceptance concept forms the basis for the NAASRA Formula, which is shown below:

$$Q_{emax} = \frac{n_e \times q_c(1 - q_c\Delta)e^{-q_c(T-\Delta)}}{1 - e^{-q_c T_0}}$$

where,

n_e = number of entry lanes

Q_{emax} = the maximum entry capacity

q_c = circulation flow (vehicle/second)

T = the critical gap (s), set to 4 seconds

T_0 = follow-on time (s), set to 2 seconds, and

Δ = minimum headway in the circulation streams, set to 2 seconds for single circulating flow and 0 seconds for multilane circulating lanes

LOSs per approach and overall were based on the HCM 1985 criteria, which are based on the reserve or unused capacity of the lane in question.

Conclusions

The three traffic circles studied are operating better than the nearby two-way stop intersections. The safety benefits show that the accident rate at the two-way stop intersections is double the rate of the circles. The severity rate is three times that of the circles, and the pedestrian-bicycle rate is more than four times greater.

The data also show, however, that the existing traffic circle with the highest volume (Traffic Circle 3) does not operate as well as the other traffic circles. This may indicate that as traffic volumes increase, the safety and efficiencies of traffic circles decrease. Or, it may be that the design or the different arrangement of roadway approaches to Traffic Circle 3 contributed to its less efficient operation.

The apparent reason for the safety benefits of traffic circles are that motorists, bicycles and pedestrians are required to check for traffic from only one direction at a time, thereby simplifying the task. Because of the lower speeds created by the traffic circles, the accidents that did occur were less severe.

This study also shows that the capacity and operation of all the two-way stop intersections can be improved by converting them to traffic circles.

Results and Recommendations

Michigan State University and the Ingham County Road Commission are aware of the need to improve Intersection 2 (Farm Lane at Wilson Road), because of the number of accidents and poor operation of the existing design. The plan being considered involved adding headed-up left-turn lanes and signalizing the intersection.

As a result of this study, the university and the county are seriously considering the construction of a 100-ft central diameter roundabout. A roundabout is a more efficiently designed traffic circle. The roundabout should provide the following advantages:

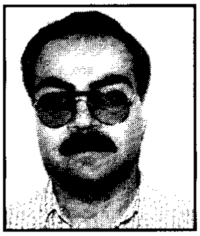
- Improved capacity
- Improved safety
- Retention or increase in existing median areas (the medians will be greatly reduced if left-turn lanes are constructed)
- Creation of a more aesthetic roundabout more in keeping with the beautiful campus setting.

Michigan State University and other jurisdictions should be more aware of the possible benefits of circles and roundabouts. Certainly not all intersections are appropriate for the installation of roundabouts, but their use should be studied as an alternate to a traditional intersection with signal control.

References

1. Federal Highway Administration. *Traffic Network Analysis With NETSIM: A User Guide.* Washington, DC: US Department of Transportation, January 1988.
2. Transportation Research Board. *Highway Capacity Manual.* Special Report 209. Washington, DC: TRB National Research Council, 1985.
3. Troutbeck, R.J. "Intersections—Roundabout and Minis." *Transportation Engineering* 121, A42, 1988: 45-66. ▮

__William F. Savage__, P.E., was employed for 27 years in various areas of traffic engineering by the Michigan Department of Transportation. He currently is a traffic engineering consultant. He received his B.Sc. in civil engineering from Michigan State University and his master's from the University of Michigan. He has been committee chairman and a member of numerous ITE committees. He is the past chairman of Technical Council's Department 4 Measures Division.



__Khaled Al-Sahili__ is a doctoral candidate in transportation, Department of Civil Engineering at Michigan State University. He received his B.Sc. in civil engineering from Yarmouk University, Jordan, and his master's in transportation engineering from Jordan University of Science and Technology. His areas of interest are traffic operations and safety. He is a Student Member of ITE.