Conflicts at Traffic Circles in New Jersey

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Traffic circles create irregular traffic patterns characterized by continuous vehicle weaving and lane changing. Because of this, circles are a potential source of confusion to drivers. Therefore, a study was conducted to determine whether improvement of guidance signing used at traffic circles would lessen confusion and increase safety. Five circles were selected as test sites, and diagrammatic guidance signs were installed at the approaches under study. The five circles were individually videotaped for 2 days before and 2 days after installation of the signs. The results of conflict analysis at all five circles indicated that the diagrammatic signs effectively reduced the number of confusion-oriented conflicts.

In 1925 New Jersey became the first state to develop and construct traffic circles. Various other states and cities soon followed its lead. Today, some 70 of these are still in operation in New Jersey.

Traffic circles, by nature, create irregular traffic patterns, characterized by continuous vehicle weaving and lane changing and attended by a large variance in vehicle speeds. Because of this, circles are a potential source of confusion to drivers.

Traffic circles as originally designed worked well at low volume and low speed flow, but the growth of traffic over the years has reduced their effectiveness. Improving circle effectiveness has often required major changes, such as changing a regular circle to a cut-through circle by continuing a major road entering the circle through the central island and producing two at-grade signalized intersections at the points where this road crosses the original circle. However, in some instances, traffic conditions at circles may be improved by minor, less expensive changes, such as improving the motorist information system.

STUDY OBJECTIVES

In 1985 the New Jersey Department of Transportation (NJDOT) initiated an in-house study in which diagrammatic guidance signs similar to the ones used at traffic circles in the United Kingdom (with minor modifications for adopting U.S. standards) were placed at five circles in New Jersey (see Figure 1). The purpose of this study by NJDOT was to determine the effectiveness of diagrammatic signs on the basis of percentage of vehicles making preferred maneuvers. The result of this study concluded that diagrammatic guidance signing was more effective than conventional signing in reducing driver confusion at circles (*1*).

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Before-and-after studies were conducted, consisting of data collected with existing conventional signing (before) and data collected after diagrammatic guidance signs were installed (after).

The preferred maneuvers were determined on the basis of safety and effectiveness. Percentages of vehicles making the preferred maneuvers were measured for both before and after the sign changes and then compared to determine the effectiveness of the new signing.

This paper is a supporting study on the study by NJDOT. The main objective of this research was to determine the effect of improved guidance signing at traffic circles on conflicts at these circles. Conflicts can be used as additional measures of effectiveness for determining the effects of the new signing on safety and effectiveness of traffic circles.

LITERATURE SEARCH

A Highway Research Information Service search by NJDOT turned up 112 articles related to traffic circles. However, most of the articles concerned either the design of traffic circles or the calculation of capacity for traffic circles, neither of which was pertinent to this study. Only six articles addressed the topic of either guidance signing at circles or measures of effectiveness useful for analyzing traffic flow at circles.

Two of the three articles about guidance signing described a study that compared two improved methods of signing—diagrammatic and modified stack (*2*,*3*). However, the improved signing was not compared with conventional signing. The third article was an analysis of the effect of diagrammatic signing on traffic at one circle in Washington, D.C. (*4*). It used a driver survey rather than measures of effectiveness to determine sign effectiveness.

In regard to measures of effectiveness, two of the articles were concerned mainly with vehicle paths through circles (*5*,*6*). The other studied the use of traffic conflict techniques to assess the safety of road design elements, which eventually became the major measure of effectiveness used in this study. The article contained some information about the use of this technique at a miniroundabout (small circle). Although several articles addressed some pertinent aspects, the fact remains that very little work has been done concerning guidance signing at traffic circles.

STUDY PROCEDURES

Traffic Conflicts

The term "conflict" in traffic engineering was introduced by Perkins and Harris in 1967. They defined traffic conflict as

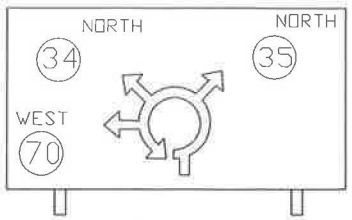

FIGURE 1 Diagrammatic guidance sign.

any potential accident situation that leads to evasive actions such as braking or swerving (*7*). In studies the criterion for evasive actions is simply to determine brakelight indications or lane changes under various sets of circumstances.

A traffic conflict is an observable situation in which two or more road users approach each other in space and time to such an extent that there is a risk of collision if their movements remain unchanged. In other words, a conflict may not lead directly to a collision, but it is an event parallel with a collision.

For conflict studies to serve as an analytical tool, they should be made before and several months after the device is implemented. If outside influences are held relatively constant, the effects of the device change can then be estimated by the observed changes in conflict risks. Many problems related to analysis of accidents can be solved by estimating risks by a conflict technique. The traffic conflicts technique is a device for indirectly measuring safety. It requires a count of conflicts occurring, which gives the basis on which the conflict rate is estimated. The conflict method is especially suitable when the effects of safety devices and measures are to be investigated.

The results of the literature search and traffic observation indicated that measures of effectiveness based on various types of conflicts would be useful for determining changes in the level of driver confusion at a circle.

In this study, brakelight indication was used as one of the measures of traffic conflicts at circles before and after installation of new guidance signs. Brake applications can be identified and counted easily. Because brakes are applied in almost all categories of conflicts, subjectivity in data collection can be avoided. Using brake application as a measure has the following disadvantages:

1. Braking habits vary from driver to driver. Some drivers are very cautious and may apply brakes on entering a circle, regardless of hazard present; others may not brake even when a hazardous situation is present.
2. Braking information does not give us information about the severity of a conflict situation.
3. Common procedure of observing brake application by only one of the vehicles involved in a conflict situation would not consider the information describing the actions of the other vehicles.
4. Brakelights may not be visible because of mechanical failures.

Characteristics of Conflicts

For the purpose of this study, all types of conflicts observed at regular or cut-through circles were divided into the following two categories:

Confusion-Oriented Conflicts

This type of conflict can be characterized as one resulting from a driver's difficulty in making the right decision in time. The following types of conflicts are categorized as confusion-oriented conflicts:

Left-turn conflict A left-turn conflict is a situation in which a left-turning vehicle crosses directly in front of an opposing through vehicle. The criterion of the conflict is the evasive action, braking, or lane changing of the through vehicle.

Lane-change conflict Lane-change conflict is defined as a situation in which a vehicle changes lanes into the path of another vehicle. The offended vehicle must brake to avoid a collision.

Cross-traffic-from-left conflict It is defined as a situation in which a vehicle crosses or turns into the path of a through vehicle, causing the through vehicle to brake to avoid a collision.

Erratic maneuvers A more severe form of confusion conflict is an erratic maneuver, which is any sudden, unexpected vehicle movement that could cause an accident. An erratic maneuver usually involves only one vehicle making an unsafe move independent of other vehicles. Such a maneuver may result in a conflict if another vehicle is forced to brake or weave to avoid it. Poor signing and inadequate geometric design often cause erratic maneuvers.

An erratic maneuver can also be defined as any movement that involves a sudden disruption in the continuity of direction or speed of a vehicle or a deviation from the traveled path intended by design and traffic engineers responsible for geometric configuration and marking in the area of interest.

Following are different erratic maneuvers found at circles:

Use of painted gore area Examples include

- *Cross painted gore*: Vehicle traverses the gore pavement marking while either exiting or continuing through.
- *Stop in painted gore*: Vehicle comes to a complete stop in any part of gore before exiting or continuing through.
- *Back up*: Vehicle passes the gore area, stops, and then backs up to change direction.

Lane change Vehicle traverses one or more full lanes within the deceleration lane area in order to exit.

Traffic-Oriented Conflicts

Traffic-oriented conflicts can be characterized as conflicts that are caused by existing roadway geometry and traffic conditions at a particular moment. These conflicts are primarily due to heavy traffic rather than confusion. The following types of conflicts are categorized as traffic-oriented conflicts:

Cross-traffic-from-right conflict This type of conflict occurs when vehicles entering the circle obstruct the path of circulating traffic and vehicles exiting.

Red-light–violation conflict It is a situation in which a vehicle enters the intersection on a red signal. Vehicles that have entered the intersection legally and complete their movements after signal changes are not considered violators.

Vehicle-passing-on-amber conflict When a vehicle enters the circle intersection after the traffic signal has changed from green to amber, it might confuse the driver of the following vehicle in deciding to cross or to stop at intersection.

Rear-end conflict When a vehicle stops unexpectedly and causes a following vehicle to take evasive action to avoid a rear-end collision, it is defined as a rear-end conflict. Such conflicts are primarily due to heavy traffic rather than confusion. Rear-end conflicts are further divided into the following subcategories:

Stop-on-amber–rear-end conflict This occurs when a vehicle stops unexpectedly because of an amber traffic signal, causing the following vehicles to apply brakes.

Slow-vehicles–rear-end conflict A slow-moving vehicle causes the following vehicle, which is moving at regular speed, to apply brakes to avoid collision.

Slow-for-traffic conflict It happens when a vehicle slows or stops because of a traffic conflict and causes a following vehicle to take evasive action to avoid a rear-end collision.

SITE SELECTION

A guideline consisting of four criteria was set up for the purpose of determining test sites for guidance signing. The four criteria were

1. The traffic circle should be expected to have a significant number of unfamiliar drivers;
2. The approaches to the circle should be state highways, if possible;
3. The circle should have high weaving volumes; and
4. There should be some evidence of driver confusion that is susceptible to correction by improved signing.

Using these guidelines, five circles were selected as test sites, three of which are regular circles and two, cut-through circles. The three regular circles are Freehold (US-9 and NJ-33), Lakehurst (NJ-70 and NJ-37), and Brielle (NJ-34, NJ-35, and NJ-70). The two cut-through circles are Marlton (NJ-70 and NJ-73) and Livingston (NJ-10 and Eisenhower Parkway).

Freehold Circle has Freehold Raceway located just off the circle on one of its legs, and four out of its five approaches are state highways. This should account for a fair amount of drivers, many of whom are expected to be unfamiliar with this circle, traveling through the circle.

The next two circles, Brielle and Lakehurst, are on major routes leading to New Jersey–shore resort areas. All the approaches to these two circles are state highways. These circles, particularly during the summer months, experience heavy recreational traffic going to and from the New Jersey shore. It was assumed that a good percentage of this traffic is composed of drivers who are unfamiliar with these circles.

The Marlton Circle is a good representative of the typical cut-through design currently in use. The Livingston Circle, although exhibiting a typical cut-through design, is a five-legged circle. However, because anticipated cut-throughs include several circles that have more than four legs, it was decided to include Livingston Circle as a test site.

After completing before-installation traffic studies, the diagrammatic guidance signs were installed at the approaches under study for all traffic circles.

The new signs were placed on the approach at least 250 ft from the circle, along with circle warning signs and standard road junction signs.

DATA COLLECTION

Traffic studies were used to document traffic conditions preceding and following sign installation. Data were collected for 2 days at each circle during before and after periods.

The time selected for videotaping by NJDOT was based on its pilot study. The main aim was to obtain a high number of unfamiliar drivers. Therefore, the 12:00–1:00 p.m. period was excluded from the study because of the high incidence of lunch trips associated with this hour. So that the variation in traffic patterns could be studied, data were collected for selected weaving areas from videotapes recorded for morning and afternoon periods. The morning period ran from 10:30 a.m. to 12:00 p.m., and the afternoon period from 1:00 to 2:30 p.m. The after condition studies were conducted on the same day of the week and for the same day of the year as the before condition studies.

A minimum of 1 month was allowed to elapse between installation of the signs and the after condition studies to allow drivers to familiarize themselves with the new signing.

During the 3-hr observation periods for two different days of week, data were recorded for traffic flow in 15-min intervals. Fifteen-min periods appear to be quite representative for collecting data from videotapes.

After preliminary viewing of the tapes, different types of conflicts found at circles were defined. It was not possible to measure the distances between conflicting vehicles or the relative speeds of conflicting vehicles, so it was decided to observe vehicles with brakelight indication criteria. Because data were collected for only two legs out of four or five at the circles, all conclusions were made based on data collected for those two legs.

Conflicts were classified on basis of traffic flow. Two types of traffic flows were found at circles: entering traffic and circulating traffic. Entering traffic flow consisted of vehicles

entering the circle from an approach, and circulating traffic flow consisted of vehicles already on the circle.

One of the most important aspects to consider when using conflict data is the reliability of data collected by observers. There are many factors that will account for variations in conflict counts, such as alertness, experience, traffic volumes, and different driving attitudes of the observers.

During data collection, initially all the videotapes were observed to classify different conflicts as they occurred and to help to ensure consistency during final observation of conflict counts.

CONFLICT ANALYSIS

After studying traffic patterns, traffic conflicts were classified in various categories. At circles, conflicts due to stopping or slowing of vehicles, cross-traffic movement, sudden lane change, and use of painted gore area for right turns or lane changing were most frequent.

Because of differences between traffic operations at cut-through and regular circles, different types of conflicts had to be collected at each circle. During the initial period of observation, it was necessary to classify conflicts between those based on confusion and those that were based on traffic.

These conflicts would be useful in showing any changes in the level of driver's confusion at a circle.

All five circles were individually studied for 2 days before and 2 days after diagrammatic signs were installed. The following section describes each site and lists different types of conflicts observed in each site.

Freehold Circle

Freehold Circle is a typical regular circle with five approaches. It is in the town of Freehold, New Jersey (Figure 2). With four state highway approaches and Freehold Raceway just off on one of its legs, it receives a fair volume of unfamiliar drivers. At Freehold, two routes—US-9 and NJ-33—were studied. There was concentration on two approaches, US-9 northbound (NB) and NJ-33 eastbound (EB). After reviewing the before-and-after studies, the following types of conflicts were found:

1. *Confusion-oriented conflicts*: (a) cross traffic from left and (b) lane changes;
2. *Traffic-oriented conflicts*: (a) cross traffic from right, (b) rear-end, and (c) sudden slowing of circulating traffic.

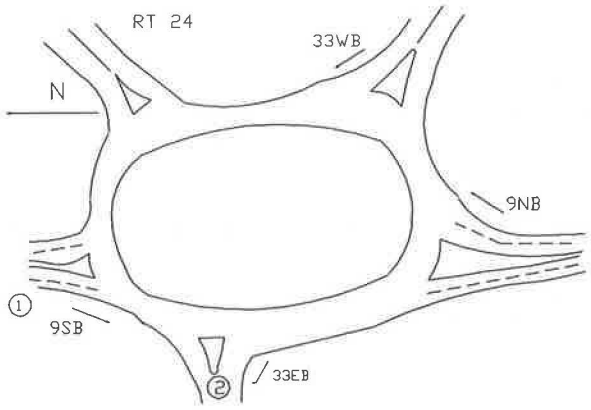

FIGURE 2 Freehold Circle.

Lakehurst Circle

Lakehurst Circle is a three-legged circle. All three approaches are state highways (Figure 3). The diagrammatic sign was installed on NJ-70 EB approach, and NJ-70 and NJ-37 were studied. The concentration was on two approaches: NJ-70 EB and NJ-37 westbound (WB). The following types of conflicts were found at this circle:

1. *Confusion-oriented conflicts*: (a) cross traffic from left and (b) erratic maneuvers (lane changes);
2. *Traffic-oriented conflicts*: (a) cross traffic from right and (b) rear-end.

Brielle Circle

Brielle Circle is a four-legged regular circle connecting NJ-34, and NJ-35, and NJ-70 (Figure 4). Diagrammatic signs were installed on the NJ-70 EB and NJ-35 NB approaches, and the study concentrated on NJ-35 NB and NJ-35 southbound (SB) approaches. The following types of conflicts were found at this circle:

1. *Confusion-oriented conflicts*: (a) cross traffic from left, (b) erratic maneuvers (including sudden change of lane due to confusion and entering or leaving circle from a wrong lane);
2. *Traffic-oriented conflicts*: (a) cross traffic from right and (b) rear-end.

Marlton Circle

Marlton Circle is a typical cut-through circle with four approaches; it connects NJ-70 to NJ-73 (Figure 5).

At Marlton Circle, diagrammatic signs were located on NJ-70 EB and NJ-70 WB approaches. The study concentrated on the NJ-70 EB and NJ-73 approaches. Erratic maneuvers

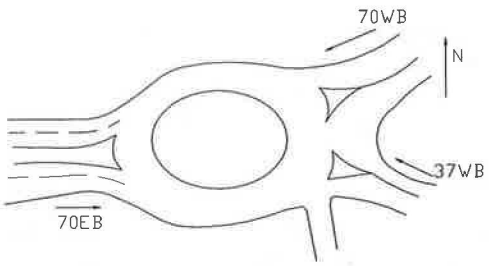

FIGURE 3 Lakehurst Circle.

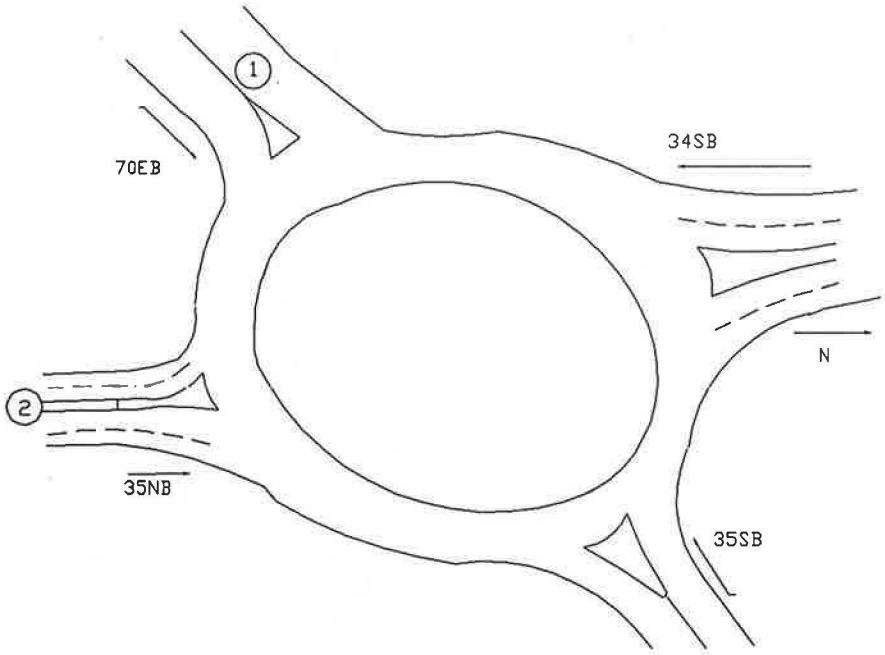

FIGURE 4 Brielle Circle.

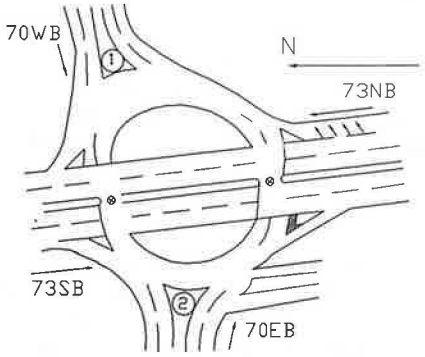

FIGURE 5 Marlton Circle (cut-through).

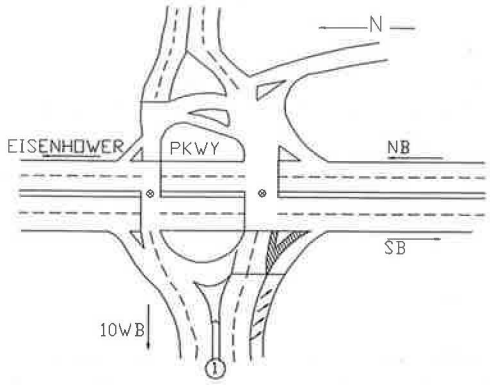

FIGURE 6 Livingston Circle (cut-through).

and conflict occurrence by vehicles were obtained through videotape. The following types of conflicts were compared:

1. *Confusion-oriented conflicts*: (a) cross traffic conflicts, (b) vehicles stopped for right turn, and (c) lane change;
2. *Traffic-oriented conflicts*: (a) vehicle passing on amber and (b) use of painted gore area.

Livingston Circle

Livingstone Circle is a five-legged cut-through circle connecting NJ-10 to the Eisenhower Parkway (Figure 6). The diagrammatic sign was placed on the NJ-10 EB approach, and the study concentrated at the NJ-10 EB and Eisenhower Parkway approaches. The following types of conflicts were observed at Livingston Circle:

1. *Confusion-oriented conflicts*: (a) use of wrong lane for left turn and (b) erratic maneuvers (lane change);
2. *Traffic-oriented conflicts*: (a) rear-end and (b) use of painted gore area.

DISCUSSION OF RESULTS

Freehold Circle

The results of conflict analysis at Freehold Circle before and after diagrammatic sign installation are shown in Table 1. Two cases were compared in which each case included 1 day before and 1 day after installation of the signs. Volumes shown for this and all other circles were taken in the circle weaving areas where the conflict data was collected.

The results indicated that the number of confusion-oriented conflicts was reduced in both cases after installation of guidance signs: a 40 percent reduction in Case 1 and a 30 percent reduction in Case 2 were realized after sign installation.

During the two cases of before-and-after studies, there were reductions of 70 and 85 percent in lane-change conflicts after installation of the signs.

The reduction in the number of conflicts caused by sudden slowing of circulating traffic was countered by the increase in

TABLE 1 RESULTS OF CONFLICT STUDIES AT FREEHOLD CIRCLE

	CROSS TRAFFIC FROM LEFT	CROSS TRAFFIC FROM RIGHT	REAR END	LANE CHANGE	SUDDEN SLOWING OF TRAFFIC	TOTAL VOLUME	CONFUSION ORIENTED	TRAFFIC ORIENTED
BEFORE I (10/01/85)								
10:30 - 12:00	37	21	15	23	26	2465	60	62
13:00 - 14:30	41	28	30	40	63	3206	81	121
TOTAL	78	49	45	63	89	5671	141	183
AFTER I (09/30/86)								
10:30 - 12:00	32	38	17	10	17	2618	42	72
13:00 - 14:30	36	49	36	10	19	3301	46	104
TOTAL	68	87	53	20	36	5919	88	176
BEFORE II (10/11/85)								
10:30 - 12:00	46	25	15	30	30	2750	76	70
13:00 - 14:30	51	35	38	55	76	3278	106	149
TOTAL	97	60	53	85	106	6028	176	219
AFTER II (10/10/86)								
10:30 - 12:00	47	33	29	5	24	3033	52	86
13:00 - 14:30	73	47	48	9	35	3519	82	130
TOTAL	120	80	77	14	59	6552	134	216

the number of cross-traffic-from-right and rear-end conflicts that resulted in reductions of only 7 and 9 percent in the number of traffic-oriented conflicts after installation of the guidance signs.

Lakehurst Circle

The results of conflict analysis at Lakehurst Circle and after diagrammatic sign installation are shown in Table 2.

The results indicate that the number of confusion-oriented conflicts was reduced in each case after installation of the signs—by 24 percent in Case 1 and 26.4 percent in Case 2. These reductions were based mainly on 53 percent reduction in Case 1 and 52.3 percent reduction in Case 2 in the number of lane-change conflicts after installation of the signs, which indicated that drivers were more aware of their routes from the information obtained from the guidance signs.

Traffic-oriented conflicts, which were composed of cross-traffic-from-right and rear-end conflicts, showed 28 and 19 percent increases in the numbers of conflicts after installation of the signs. These increases were caused mainly by the growth of 22 percent and 26 percent in the number of rear-end conflicts, which was expected because of the increase in the volume of traffic.

Brielle Circle

Table 3 shows the results of conflict analysis at Brielle Circle. The results show reductions of 7 percent (Case 1) and 13.3 percent (Case 2) in the numbers of confusion-oriented conflicts.

The numbers of lane-change conflicts were reduced by 36 percent and 35 percent in both cases after installation of the signs, which supports the previous findings that drivers were

TABLE 2 RESULTS OF CONFLICT STUDIES AT LAKEHURST CIRCLE

	CROSS TRAFFIC FROM LEFT	CROSS TRAFFIC FROM RIGHT	REAR END	LANE CHANGE	TOTAL VOLUME	CONFUSION ORIENTED	TRAFFIC ORIENTED
BEFORE I (07/03/85)							
10:30 - 12:00	29	2	105	30	1070	59	107
13:00 - 14:30	13	1	125	18	496	31	126
TOTAL	42	3	230	48	1566	90	233
AFTER I (07/03/86)							
10:30 - 12:00	29	1	165	10	1108	39	166
13:00 - 14:30	20	1	150	14	558	34	151
TOTAL	49	2	315	24	1666	73	317
BEFORE II (07/25/85)							
10:30 - 12:00	20	1	121	23	1046	43	122
13:00 - 14:30	42	1	116	17	1024	59	133
TOTAL	62	2	237	40	2070	102	255
AFTER II (07/24/86)							
10:30 - 12:00	29	0	147	13	1064	42	147
13:00 - 14:30	29	0	162	7	1088	36	169
TOTAL	58	0	309	20	2152	78	316

TABLE 3 RESULTS OF CONFLICT STUDIES AT BRIELLE CIRCLE

	CROSS TRAFFIC FROM LEFT	CROSS TRAFFIC FROM RIGHT	REAR END	LANE CHANGE	TOTAL VOLUME	CONFUSION ORIENTED	TRAFFIC ORIENTED
BEFORE I (07/12/85)							
10:30 - 12:00	33	2	118	37	1886	70	120
13:00 - 14:30	30	2	141	65	2473	95	143
TOTAL	63	4	259	102	4359	165	263
AFTER I (07/11/86)							
10:30 - 12:00	40	0	138	35	2139	75	138
13:00 - 14:30	52	2	193	33	2405	85	195
TOTAL	92	2	331	68	4544	160	333
BEFORE II (07/01/85)							
10:30 - 12:00	27	7	71	34	2050	61	78
13:00 - 14:30	37	1	125	62	2228	99	126
TOTAL	64	8	196	96	4278	160	204
AFTER II (07/21/86)							
10:30 - 12:00	31	1	102	33	2309	64	103
13:00 - 14:30	44	4	151	29	1909	73	155
TOTAL	75	5	253	62	4218	137	258

more aware of their routes from information obtained from the guidance signs.

A 23 percent and 30 percent increase in the number of rear-end conflicts after installation of the signs largely contributed to the increases of 22 percent and 28 percent in the number of traffic-oriented conflicts.

Marlton Circle

The results of conflict analysis at Marlton Circle before and after diagrammatic sign installation are shown in Table 4.

The results indicate that the numbers of confusion-oriented conflicts were reduced by 10 percent (Case 1) and 17 percent (Case 2). These reductions were more obvious in the number of lane-change conflicts (reduction of 29 percent for Case 1 and 67 percent for Case 2).

The results also indicate that the numbers of traffic-oriented conflicts were increased by 69 percent (Case 1) and 37 percent (Case 2) after installation of the signs. The increase in the number of traffic conflicts was mainly caused by the sharp increases of 98 percent (Case 1) and 142 percent (Case 2) in the number of conflicts caused by the drivers using the painted gore area. These increases are due to the increase in traffic. Because of extensive queueing in the two lanes at the intersection, right-turning vehicles were forced to use the painted gore area to reach the right-turn slot.

The numbers of rear-end conflicts were reduced by 16 percent (Case 1) and 27 percent (Case 2), and the numbers of cross-traffic-from-right conflicts were increased in both cases.

TABLE 4 RESULTS OF CONFLICT STUDIES AT MARLTON CIRCLE

	CROSS TRAFFIC LEFT	CROSS TRAFFIC RIGHT	REAR END	LANE CHANGE	USE OF GORE AREA	VEHICLE PASSING ON AMBER	TOTAL VOLUME	CONFUSION ORIENTED	TRAFFIC ORIENTED
BEFORE I (07/25/85)									
10:30 - 12:00	13	17	17	9	24	12	1655	22	70
13:00 - 14:30	14	15	27	16	36	20	1661	30	98
TOTAL	27	32	44	25	60	32	3316	52	168
AFTER I (07/24/86)									
10:30 - 12:00	13	30	13	7	65	15	1843	20	123
13:00 - 14:30	20	64	29	13	70	36	1902	33	199
TOTAL	33	94	42	20	135	51	3745	53	322
BEFORE II (10/18/85)									
10:30 - 12:00	18	17	29	10	26	24	1889	28	96
13:00 - 14:30	17	34	34	23	38	34	1831	40	140
TOTAL	35	51	63	33	64	58	3720	68	236
AFTER II (10/16/86)									
10:30 - 12:00	25	36	29	6	70	24	2057	31	159
13:00 - 14:30	25	43	22	6	102	27	2053	31	194
TOTAL	50	79	51	12	172	51	4110	62	353

TABLE 5 RESULTS OF CONFLICT STUDIES AT LIVINGSTON CIRCLE

	REAR END	USE OF GORE AREA	USE OF WRONG LANE	LANE CHANGE	TOTAL VOLUME	CONFUSION ORIENTED	TRAFFIC ORIENTED
BEFORE I (01/08/86)							
10:30 - 12:00	199	20	6	29	1229	35	219
13:00 - 14:30	225	19	14	25	1829	39	244
TOTAL	424	39	20	54	3058	74	463
AFTER I (12/16/86)							
10:30 - 12:00	165	15	12	26	1336	38	180
13:00 - 14:30	227	13	6	24	2366	30	240
TOTAL	392	28	18	50	3702	68	420
BEFORE II (01/09/86)							
11:00 - 12:00	125	5	6	25	1415	31	130
13:00 - 14:30	231	16	9	22	2056	31	247
TOTAL	356	21	15	47	3471	62	377
AFTER II (01/14/87)							
11:00 - 12:00	74	6	2	11	1018	13	80
13:00 - 14:30	228	22	10	18	1917	28	250
TOTAL	302	28	12	29	2935	41	330

Livingston Circle

Table 5 shows the results of the conflict analysis at Livingston Circle. The results indicate 24.4 percent and 23 percent reductions for both cases, which were caused mainly by the reduction of 23 percent (Case 1) and 28 percent (Case 2) in the numbers of lane-changes conflicts (erratic maneuvers).

The results of the conflict analysis for the first case indicate a reduction of 23.5 percent in the number of rear-end conflicts and a reduction of 25 percent in the number of traffic-oriented conflicts. The results of Case 2 indicate no changes.

CONCLUSIONS AND RECOMMENDATIONS

The conclusions drawn from the results of the study of conflict analysis conducted before and after placing the diagrammatic signs are as follows:

- The numbers of confusion-oriented conflicts at regular and cut-through circles were reduced after installation of diagrammatic signs.
- The reduction in the numbers of confusion-oriented conflicts indicates that drivers were much more aware of the required route because of information obtained from the guidance signs. These signs, thus, helped drivers to make the right decisions in time.
- The numbers of lane-change conflicts at regular and cut-through circles were significantly reduced after installation of the signs.
- The numbers of traffic-oriented conflicts for all circles, except for Livingston Circle, were increased after installation of the signs. This result was expected because of the increase in traffic volume after installation of the signs, which caused more friction in the traffic flow.
- After installation of the signs, the numbers of rear-end conflicts increased for all the regular circles and reduced for the two cut-through circles.
- Traffic conflicts (brakelight indication, etc.) are not as useful measures of effectiveness at circles as confusion conflicts (maneuvers). This is because under heavy traffic conditions these types of conflicts are more the rule than the exception and appear not to be related to actual driver confusion.

The uniform results obtained at regular and cut-through circles indicated that the diagrammatic signs are effective in reducing confusion-oriented conflicts.

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