

Driver Performance Related to Interchange Marking and Nighttime Visibility Conditions

J. E. P. DARRELL, Minnesota Department of Highways, St. Paul; and MARVIN D. DUNNETTE, University of Minnesota, Minneapolis

● NIGHTTIME DRIVING CONDITIONS offer special problems of visibility. This is especially true at highway intersections. As a driver proceeds over any highway system, he continually arrives at a series of intersection choice points. Most drivers know where they want to go, but they do not always know exactly how to get there. It is, therefore, of obvious importance to develop and utilize systems which will enhance nighttime visibility and thereby provide drivers with optimal information about the route or routes they may be following.

These considerations point up the importance of providing adequate markings and conditions of visibility at highway intersections. Highway systems throughout the country have made wide and effective use of illumination and reflectorization to accomplish these aims. A good deal of research utilizing direct physical measurements has been performed in an effort to assess the degree of visibility improvement under a variety of conditions of illumination.

In addition to widespread research on levels of visibility and their relative effectiveness, attention has been given to the relative utility of different marking systems in directing or guiding driver performance. As mentioned previously, appropriate guidance of drivers is particularly important at intersections; the marking system should be sufficient to reduce any potential confusion or error on the part of the driver.

These considerations led to the present study designed to discover possible effects of different nighttime visibility conditions and different highway marking systems on driver performance. Studies reported here were undertaken over a period of seven weeks during the summer of 1959. The experiments were conducted in the State of Minnesota on a cloverleaf interchange formed by the intersection of US 61 and Minnesota State Highway 36. A variety of experimental conditions of varying visibility and using varying systems of highway markings were used and driver performance studied. All experimental studies were conducted during night driving conditions between the hours of 9:30-11:30 P. M.

EXPERIMENTAL METHOD

Five major experimental conditions were employed during the period of the study.

Condition I might be called the normal operating condition. Under this condition, the modern mercury-vapor luminars in use at this cloverleaf interchange were turned on as is usual. Condition I may be described, therefore, as the "fully illuminated" condition.

Condition II was the "dark" condition. Under this condition, the lights were turned off and no special treatment was used other than the reflectorized signs showing the various destinations and turn areas.

Condition III utilized a standard application of reflectorized delineation. Under this condition, the lights remained off, but reflective treatment was employed in the form of amber delineators in the loops and legs of the cloverleaf similar to the standards contained in the Manual on Uniform Traffic Control Devices. The treatment employed under this condition is shown in Figure 1.

Condition IV utilized an experimental method of reflectorization. The reflective treatment which was employed is shown in Figure 2. The luminars remained off, and blue and amber delineators and blue and amber reflective pavement paints were used to indicate areas of exiting and merging traffic. As may be noted, the entire cloverleaf interchange was not treated; only the portions which would be directly visible to a motorist traveling north on US 61 or traversing the ramps in the southeast quadrant received reflective treatment.

Condition V combined the treatments of full illumination and experimental reflector-

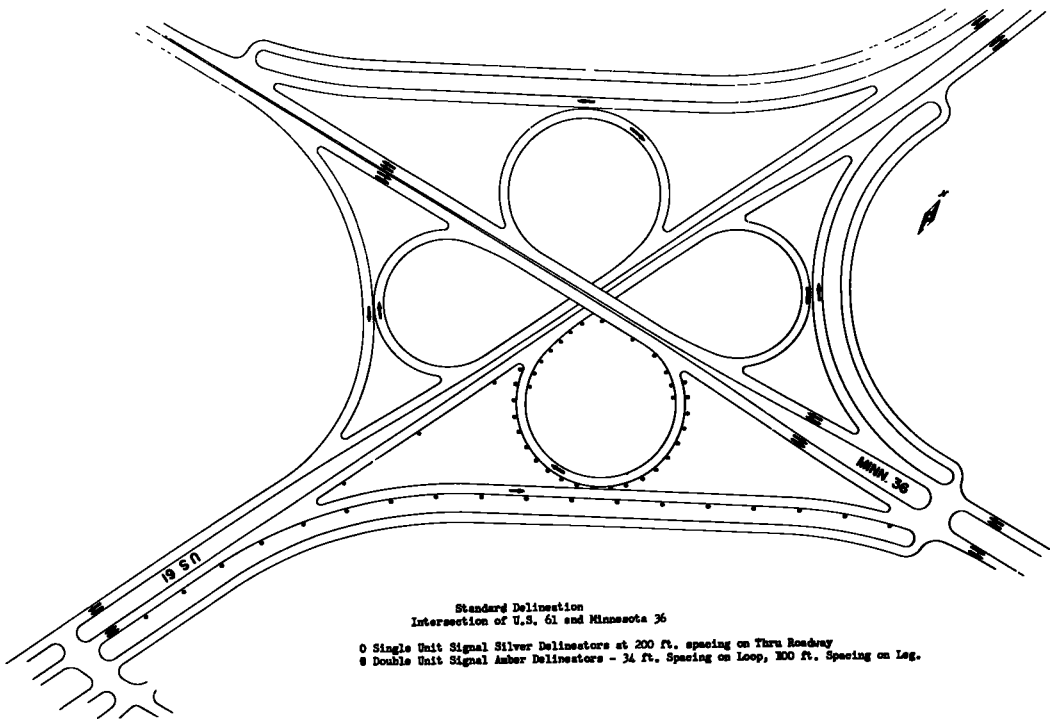


Figure 1. Cloverleaf interchange at intersection of US 61 and Minnesota 36 showing standard delineation treatment.

ization. The luminars were turned on. The reflective treatment was maintained as in Condition IV.

The intent of this study was to study driver performance under these various different conditions of visibility and highway marking systems. Performance was studied by using a carefully developed and carefully conducted interview schedule. Interviewing stations were located at points A and B shown in Figure 2. Motorists interviewed at Station A were those who had just left US 61 and were about to enter and proceed in an easterly direction on Minnesota 36. Motorists interviewed at Station B were those who had proceeded straight through the interchange from south to north on US 61 and also those who had just entered US 61 from Minnesota 36 via the cloverleaf loop in the south-east quadrant.

Prior publicity via press, radio, and TV referred to the fact that a study was to be conducted using various experimental conditions. None of the publicity described details of the conditions nor was any information supplied which could be helpful to local drivers in interpreting the meaning of the various experiments.

As motorists approached points A and B, they were signaled to stop and were asked to answer a series of questions requiring about 5 min (Questionnaires A and B). If a driver indicated he was in a hurry, he was permitted to proceed without delay. Only a few drivers chose not to take part in the study.

Driver performance was studied by interviews because it is believed that such procedures provide information not available by other means. For example, it was believed important to learn not only what the driver actually did in getting his vehicle through the intersection but also to learn of what he saw; whether or not he had difficulty getting through the intersection; and whether or not he became confused at any point. The interest was basically in driver performance plus driver impressions, feelings, attitudes and over-all responses to the total system as presented to him at the intersection.

THE QUESTIONNAIRE

After a series of planning conferences, interview schedules were developed which were designed to obtain information in six major areas (Questionnaires A and B).

First, data bearing on personal information, such as sex, age, and the extent to which the driver was familiar with the intersection were obtained.

Second, each driver was asked whether he had or had not experienced any difficulty in traversing the interchange.

Third, each driver was asked whether or not he could offer any suggestions for im-

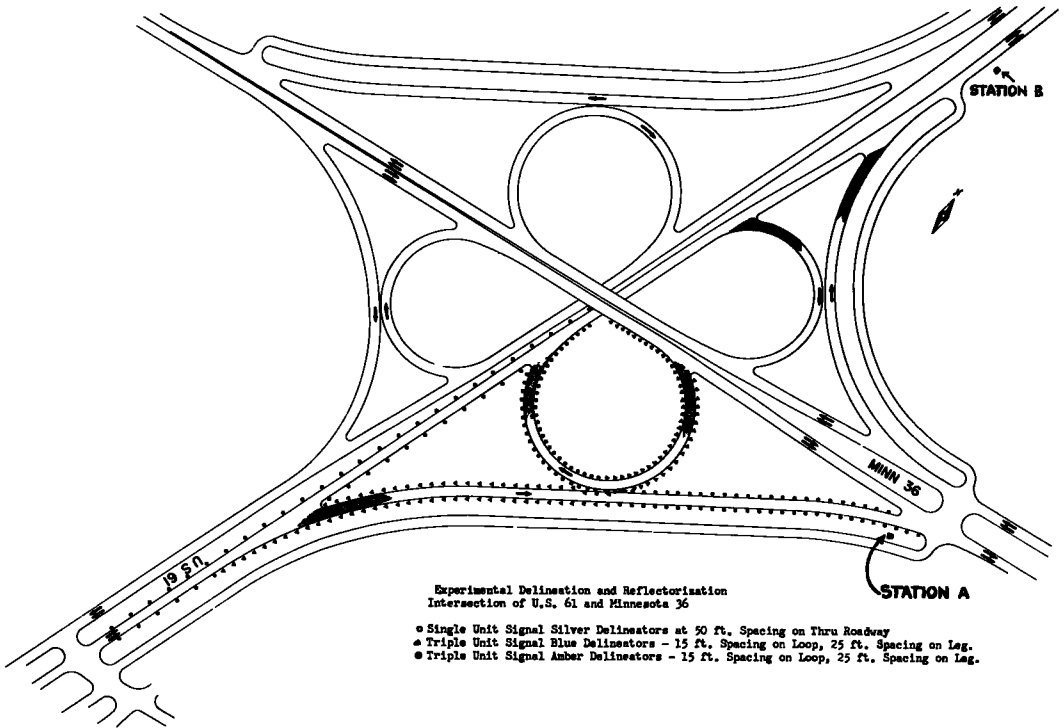


Figure 2. Cloverleaf interchange at intersection of US 61 and Minnesota 36 showing experimental reflectorization treatment.

proving the interchange to make it easier to recognize the proper route through the intersection.

Fourth, the driver was asked what helped him to recognize certain critical response zones such as areas of exiting and merging traffic.

Fifth, each driver was asked to describe the markings he had noted and how he had interpreted or utilized them in his travel through the interchange.

Finally, each driver was asked to give his own personal opinion or impression of the reflectorized treatment employed under Conditions IV and V.

SAMPLE CHARACTERISTICS

A total of 1,133 motorists was interviewed at the two stations, A and B. The numbers interviewed ranged from 199 under Condition V to 270 under Condition I.

A large majority of the motorists interviewed were men, comprising 970 of the drivers; only 163 were women. Somewhat fewer than one-half the drivers were in the age

range 26-40 with the remainder being distributed equally between the under 25 and over 41 groups. Sample characteristics with respect to sex and age are shown in Figure 3.

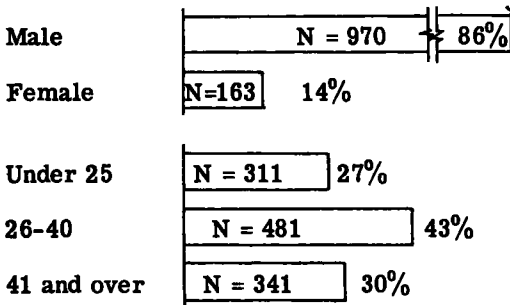


Figure 3. Sex and age distributions of motorists participating in the study.

A large majority of drivers participating in the study were familiar with the cloverleaf interchange. More than one-half said they used the interchange daily. An additional 30 percent reported using the interchange at least once a week or oftener. Fewer than one in six reported being totally unfamiliar with the interchange. These figures suggest that the performance and opinions obtained from respondents in this study were informed ones, and, as such, should reflect an awareness of particular driver needs in this specific driving situation.

Examination of the frequencies of use of the intersection by drivers under the different experimental conditions showed no differences. At both interviewing stations, Chi-Squared tests of significance suggest acceptance of the Null Hypothesis that frequency distributions do not differ under the various conditions. This is important because it shows that respondents under the various conditions are comparable with respect to their familiarity with this interchange.

RESULTS

Difficulty Experienced

Only a small minority of respondents said they had difficulty making their way through the intersection. The numbers and percents of persons saying they had some difficulty are given in Tables 1 and 2. It may be noted that at Station A, the highest incidence of driver difficulty occurred under Conditions II and III. Under these two conditions, nearly one out of eight drivers experienced difficulty locating the exit ramp to Minnesota 36. Under the "fully illuminated" and "experimentally reflectorized" conditions, practically no one (fewer than 1 in 50) experienced difficulty.

TABLE 1

NUMBERS AND PERCENTS OF DRIVERS INTERVIEWED AT STATION A WHO REPORTED SOME DIFFICULTY TRAVERSING THE INTERCHANGE

Condition	Had Some Difficulty		Had No Difficulty	
	No.	Percent	No.	Percent
I. Fully illuminated	2	2	84	98
II. Dark	10	14	62	86
III. Standard delineation	8	11	67	89
IV. Experimental reflectorization	0	0	67	100
V. Combined - illumination and reflectorization	2	4	50	96

Note: $\chi^2 = 15.4$ $P < 0.001$

This finding is important for two reasons: (1) lighting is shown to be an effective way of reducing driver confusion and possible error; and (2) the experimental reflectorization is shown also to be an effective means of reducing driver difficulty in traversing the interchange.

At Station B, only 12 drivers (about 1 percent) experienced any difficulty traversing

TABLE 2

NUMBERS AND PERCENTS OF DRIVERS INTERVIEWED AT STATION B WHO REPORTED SOME DIFFICULTY TRAVERSING THE INTERCHANGE

Condition	Had Some Difficulty		Had No Difficulty	
	No.	Percent	No.	Percent
I. Fully illuminated	1	1	183	99
II. Dark	3	2	185	98
III. Standard delineation	2	2	129	98
IV. Experimental reflectorization	5	4	130	96
V. Combined — illumination and reflectorization	1	1	146	99

Note: Data shown above cannot be tested for statistical significance because of low cell frequencies under the "Had Difficulty" column.

the interchange. This is an expected result because it is easier to drive straight through an intersection than to locate a particular point or turn off. It should be noted, however, that 5 of the 12 drivers reported having experienced difficulty under the condition of experimental reflectorization. Unfortunately, it is difficult to interpret this result because the extremely low cell frequencies preclude using the Chi-Squared test of statistical significance.

Suggestions for Improvements

Tables 3 and 4 give the numbers of motorists who volunteered suggestions for improving the marking or visibility of the intersection in some way. At both stations, fewest suggestions for improvement occurred under the two conditions employing experimental reflectorization. The differences among the percents given in both tables are statistically significant.

TABLE 3

NUMBERS AND PERCENTS OF DRIVERS INTERVIEWED AT STATION A WHO OFFERED SUGGESTIONS FOR IMPROVING INTERCHANGE VISIBILITY AND/OR MARKINGS

Condition	Offered Suggestions		Offered No Suggestions	
	No.	Percent	No.	Percent
I. Fully illuminated	26	30	60	70
II. Dark	34	47	38	53
III. Standard delineation	27	36	48	64
IV. Experimental reflectorization	13	19	54	81
V. Combined — illumination and reflectorization	7	13	45	87

Note: $\chi^2 = 21.6$ $P < 0.01$

It is noteworthy that a substantial decrease in suggestions for improvement occurred between Condition II and Condition I and that a somewhat larger and significant decrease occurred between Condition II and Condition IV. Apparently the reflectorized treatment is effective in offering both adequate visibility and guidance.

TABLE 4

NUMBERS AND PERCENTS¹ OF DRIVERS INTERVIEWED AT STATION B WHO OFFERED SUGGESTIONS FOR IMPROVING INTERCHANGE VISIBILITY AND/OR MARKINGS

Condition	Offered Suggestions		Offered No Suggestions	
	No.	Percent	No.	Percent
I. Fully illuminated	16	15	89	85
II. Dark	22	20	89	80
III. Standard delineation	16	20	66	80
IV. Experimental reflectorization	9	13	63	87
V. Combined — illumination and reflectorization	10	10	94	90

Note: $\chi^2 = 5.9$ $P < 0.20$

¹This question was not asked of drivers who had entered US 61 from Minnesota 36.

A study of the actual suggestions made by those motorists who offered them gives further meaning to these results. Under Condition I, the major suggestion was that more signs be placed at the intersection; a few motorists also suggested the use of marking such as arrows on the pavement, markers along the side of the road and more vivid center stripes. Under Condition II, the major complaint apparently was caused by the darkness. Although some motorists still mentioned the need for more signs and markings, most simply said "Turn on the lights." Under Condition III, suggestions for improvements included most of the factors mentioned under the first two conditions. Suggestions under Condition IV were fewer in number (as given in the tables), and seemed somewhat more specific than those offered under the first three conditions. Fewer suggestions were offered under the combined conditions of illumination and reflectorization than under any other condition. This is evidence that a large majority of drivers believed both visibility and guidance to be adequate.

Markings Useful to the Driver in Guidance

Regardless of the experimental condition, the vast majority of drivers exiting onto Minnesota 36 from US 61 believed the route markings gave them adequate information about where to turn. The percent of drivers saying this ranged from a low of 90 percent under Conditions II and III to a high of 97 percent for Condition IV. Most drivers, apparently because of their familiarity with the interchange, already knew where to turn. In addition, however, it appears that the sign indicating the approaching turn was a primary source of guidance for drivers encountering the first three conditions. Under the experimental reflectorization, however, the sign seemed less important, and the delineator and pavement treatments were mentioned more often. This could be due partly to the "newness" of the experimental treatment. It is possible that the pavement colors stood out so sharply as to attract driver attention and comment to a greater degree than might have been the case, had the drivers been more familiar with the experimental reflectorization.

Motorists who were driving through the intersection from south to north on US 61 were nearly unanimous in their belief that the through route was sufficiently well marked. Another significant need for through motorists, however, is to be clearly aware of areas of exiting and merging traffic. These are critical response areas for the motorist and it is in and near these areas that improved visibility and guidance may be most important. Data in Tables 5 and 6 give information about identification of these areas under the various experimental conditions.

It may be noted that areas of merging and exiting traffic were recognized by a high majority of drivers. The highest degree of recognition for merging areas occurred

under Conditions IV and V. Differences among the five conditions are highly significant statistically.

TABLE 5
NUMBERS AND PERCENTS OF THROUGH TRAFFIC DRIVERS SAYING THEY
COULD OR COULD NOT IDENTIFY AREAS OF MERGING TRAFFIC

Condition	Could Identify Merging Areas		Could Not Identify Merging Areas	
	No.	Percent	No.	Percent
I. Fully illuminated	92	90	10	10
II. Dark	102	94	7	6
III. Standard delineation	66	83	14	17
IV. Experimental reflectorization	69	96	3	4
V. Combined — illumination and reflectorization	101	97	3	3

Note: $\chi^2 = 16.0$ $P < 0.01$

The interview schedules also requested information about the methods used by drivers in recognizing areas of merging and exiting traffic. More than one-half the drivers under the last two conditions mentioned the colors on the pavement and on the delineators as important sources of information. Few drivers (just more than 1 percent) under the reflectorized conditions mentioned traffic flow as giving them evidence about merging and exiting areas; under the first three conditions, about 10 percent identified traffic flow as their major source of information. It is evident, therefore, that many drivers (more than one-half) do associate the experimental reflectorization treatment with the identification of areas of merging and exiting traffic. It is difficult, however, to judge whether or not this is of practical importance. Even under the "dark condition," 94 percent of drivers successfully identified areas of merging traffic; one may well question, therefore, whether the increase in successful identification to 97 percent for Condition V is of any practical consequence; further research is needed on this question.

TABLE 6
NUMBERS AND PERCENTS¹ OF THROUGH TRAFFIC DRIVERS SAYING THEY
COULD OR COULD NOT IDENTIFY AREAS OF EXITING TRAFFIC

Condition	Could Identify Exiting Areas		Could Not Identify Exiting Areas	
	No.	Percent	No.	Percent
IV. Experimental reflectorization	71	99	1	1
V. Combined — illumination and reflectorization	100	96	4	4

¹This question was not asked of drivers under the first three experimental conditions. Hence no meaningful comparison may be made.

Driver Responses to Fully Reflectorized Treatment

As explained previously, the interview schedules were designed, in part, to elicit opinions and impressions from motorists concerning the experimental reflectorization employed in Conditions IV and V.

A large majority of motorists recognized intended relationships among the various markings. For example, more than one-third of the motorists noted that the blue of the exit ramp matched the blue of the sign indicating the location of the exit. It also was common for motorists to associate the amber or yellow colors of the pavement and delineator treatment with SLOW or CAUTION. There was nearly unanimous agreement that the reflectorized treatment was helpful in driving. Many motorists volunteered comments indicating a generally favorable attitude toward this particular experimental treatment.

DISCUSSION

This study was undertaken to study driver performance and opinions under different conditions of night visibility and under the impact of various highway marking systems. Motorists taking part in the study were, as a group, highly familiar with the interchange chosen for study; and were in a position, therefore, to offer informed opinions concerning the effects of the several experimental conditions employed. Since differences in driver opinions and performance were obtained under the various conditions, it is evident that drivers show substantial concern and awareness of different night driving conditions. Opinions obtained from drivers in this study suggest that they are more confident, have less difficulty, and have a better opportunity to do a good job of night driving when visibility and guidance are improved either by illumination, reflectorization, or both. More drivers experienced difficulty in traversing the interchange and more drivers made suggestions for improvements under the "dark" and "standard delineation" conditions than under the other three experimental conditions.

The results of the study also provide clues concerning the possible effects on night driving performance of the experimental reflectorization employed in Conditions IV and V. It appears that the reflectorization treatment is readily related by the motorist to certain night driving needs. For example:

1. A significantly smaller number of motorists made suggestions for improvements under Condition V — the combined condition of full illumination and experimental reflectorization — than under any of the other four conditions. The proportions of motorists making suggestions increased progressively for conditions of "experimental reflectorization," "full illumination," "standard delineation" and "dark."

2. Conditions of "full illumination" and "experimental reflectorization" appeared equally effective in reducing the incidence of driver difficulty in traversing the intersection.

3. More than one-half the drivers under Conditions IV and V identified the pavement reflectorization as indicating areas of merging and/or exiting traffic.

4. It was the opinion of the large majority of drivers under Conditions IV and V that the experimental reflectorization was an effective and helpful means of providing night driving guidance.

The over-all results of this study suggest, therefore, that reflectorization as well as illumination can be regarded as an effective means of reducing driving problems related to nighttime visibility conditions. Apparently, a carefully planned and executed reflective treatment is highly accepted, easily followed, and generally helpful.

QUESTIONNAIRE A
FOR MOTORISTS EXITING FROM US 61 ONTO MINN. 36

1. CHECK THE SEX OF DRIVER

- Male
- Female

2. ESTIMATE DRIVER'S AGE

- Under 25
- 26-40
- 41-55
- 56 and over

3. Would you mind telling us what your destination is? _____

4. How often do you come over this intersection?

- | Daylight
(Check one) | Dark
(Check one) |
|--|--------------------------|
| <input type="checkbox"/> Every day | <input type="checkbox"/> |
| <input type="checkbox"/> Several times a week | <input type="checkbox"/> |
| <input type="checkbox"/> About once a week | <input type="checkbox"/> |
| <input type="checkbox"/> Only once in a great while | <input type="checkbox"/> |
| <input type="checkbox"/> Have never been over this intersection before | <input type="checkbox"/> |

5. Have you answered this questionnaire before tonight? _____

6. Did you have any difficulty at all finding the proper way through the intersection?

- Yes, some difficulty
- No, none at all

7. If yes, what difficulty did you have?

8. What first called your attention to the approaching turnoff for Hwy. 36?

9. Do you believe the route markings gave you adequate information concerning where you were to turn? Yes No

10. If no, why not? _____

11. Exactly how did you identify the point at which you were to turn? _____

12. Can you suggest any improvements that would make it easier for you to recognize turns such as this? _____

YOU HAVE JUST PASSED DIFFERENT ROADWAY MARKINGS.

13. Did you notice them? Yes No

14. What markings did you notice?

15. Can you recall the colors you saw?

16. What did the color(s) mean to you?

17. Did there seem to be any relationship among the various markings? Yes No

18. What relationships did you notice?

19. What do you think of this kind of marking system for intersections such as this? _____

20. Do you believe that this kind of marking system would help or hinder most drivers on intersections such as this?

- Help
- Hinder
- Wouldn't make any difference

Write comments: _____

QUESTIONNAIRE B

FOR MOTORISTS DRIVING THROUGH THE INTERSECTION FROM SOUTH TO
NORTH ON US 61 AND FOR MOTORISTS USING THE CLOVERLEAF TURN
TO ENTER US 61 FROM MINN. 36

1. CHECK THE SEX OF DRIVER
 Male
 Female
2. ESTIMATE DRIVER'S AGE
 Under 25
 26-40
 41-55
 56 and over
3. Would you mind telling us what your destination is? _____
4. How often do you come over this intersection?
 Daylight Dark
 (Check one) (Check one)
 Every day _____
 Several times a week _____
 About once a week _____
 Only once in a great _____
 while _____
 Have never been over this _____
 intersection before
5. Have you answered this questionnaire before tonight? _____
6. Did you have any difficulty at all finding the proper way through the intersection?
 Yes, some difficulty
 No, none at all
7. If yes, what difficulty did you have? _____
8. What first called your attention to the intersection? _____
9. Did you enter Highway 61 from the cloverleaf turnoff just now?
 Yes No
- IF NO, PROCEED WITH THE FOLLOWING QUESTIONS.
 IF YES, SKIP 10-16 AND ASK QUESTIONS 17-25.
10. Can you suggest any improvements that would make it easier for you to recognize intersections such as this? _____
11. Do you believe that the through traffic route was sufficiently well marked?
 Yes No
12. If not, why not? _____
13. Could you tell the points at which traffic left the highway?
 Yes No
14. If yes, how could you tell this? _____
15. Could you tell the points at which merging traffic joined your direction?
 Yes No
16. If yes, how could you tell this? _____
- END OF QUESTIONNAIRE FOR THROUGH TRAFFIC

- ASK THE FOLLOWING QUESTIONS OF MOTORISTS APPROACHING FROM THE WEST.
17. Do you believe the route markings gave you adequate information concerning where you were to turn?
 Yes No
18. Did you notice the reflecting posts along the side of the turnoff?
 Yes No
19. What colors did you notice? _____
20. What meaning did these colors have to you? _____
21. Did you notice the color on the pavement where you entered Highway 61?
 Yes No
22. What color was it? _____
23. What meaning did the color have to you? _____
24. What do you think of this kind of marking system for intersections like this? _____
25. Do you believe that this kind of marking system would help or hinder most drivers on intersections such as this?
 Help
 Hinder
 Wouldn't make any difference
- Other Comments: _____
