# A Study of the Feasibility of Using Roadside Radio Communications for Traffic Control and Driver Information

DONALD O. COVAULT and ROBERT W. BOWES
Respectively, Professor and Graduate Research Assistant,
School of Civil Engineering, Georgia Institute of Technology

A new method of roadside communication with the driver incorporates car mounted receivers and roadside transmitter installations. The primary aims of the research project were to measure the effectiveness of this as a traffic control and driver information device, to judge its acceptability by the driving public, and to arrive at a preliminary cost for the implementation of such a system.

Half the vehicles selected were used as test group and half as control group for each of three experiments in which the test group drivers receivedradio information on accidents and typical maintenance activities. In the route information experiment no control group was used. Both test and control group drivers received similar information from signs and other signals where they were employed. Data on traffic flow were collected using time-lapse motion picture photography at locations just beyond the points of information reception. In addition, test vehicle operators were interviewed at the end of 10 mi of the test section to determine their reaction to the radio communication.

Results of the experiments showed that radio communication is effective in controlling vehicle speed in hazardous areas. The difference in the lateral placement distribution between the test and control vehicles immediately prior to the hazardous areas was significant in some of the experiments. The route information given in one of the experiments was considered by drivers to be helpful and a possible future use of the radio system. Interview data revealed that the motorists considered radio communication useful and that it should be used in a variety of situations to provide a variety of information. Driver acceptance was indicated by the amount drivers were willing to pay for a radio receiver capable of receiving roadside communication, based on the assumption that this receiver would be constructed as an integral part of the usual car radio and would operate if the car radio was on or off.

• **THE PURPOSE** of this research was to investigate the feasibility of roadside radio communications as a device to control traffic and inform motorists. Measurements were made by means of the behavior of the test vehicle in the traffic stream, and of the test vehicle operator's answers to a public opinion-type questionnaire. This work was

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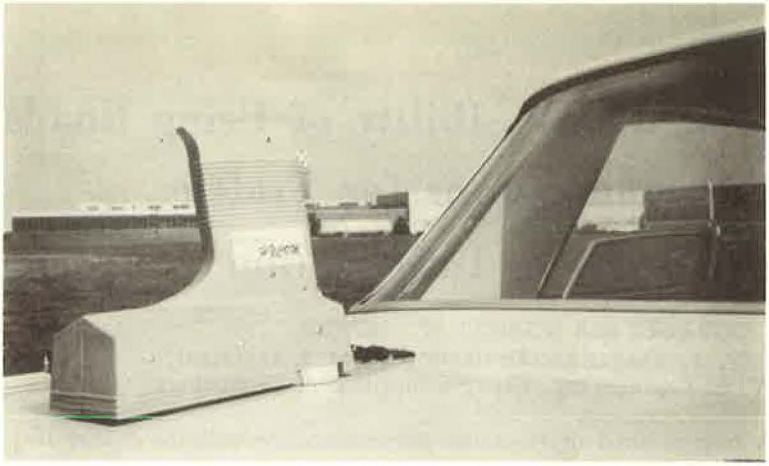

Figure 1. Radio receiver unit.

sponsored by the Bureau of Public Roads under a contract with the Engineering Experiment Station of the Georgia Institute of Technology.

The first phase of this research program was designed to measure the effectiveness of roadside radio communications as a traffic control and driver information device, to gage the drivers' acceptance of this type of roadside communications, and to obtain enough information to enable a preliminary cost estimate to be made for such a system. To accomplish these objectives a series of relatively simple but important experiments were designed and conducted on the Kentucky Toll Road from Shepherdsville to Louisville, Ky., in July and August 1963.

## TEST EQUIPMENT

The radio equipment used, Delco Radio Hy-Com, is a system designed to provide communications from the roadside to the driver. It consists of a car mounted receiver and a roadside transmitter installation.

The receiver system has two components, a receiver and a speaker. The receiving equipment (Fig. 1) is incased in a fiberglass and plastic case. On the bottom of the case are three circular magnets, each covered with a phenolic disk. The receiver is mounted on the rear deck lid of a typical automobile and the rubber-coated safety hook is placed in the crack between the trunk lid and the body of the automobile. The magnets and safety hook provide a secure method of attaching the receiver for most automobiles. Receivers were also taped to the top of buses or trucks, placed on the gas tanks or steps of trucks, or put in sport cars wherever room could be found.

The receiving unit is powered by four $1\frac{1}{2}$ v penlight batteries providing approximately 100 hr of continuous operation. A cable from the receiver housing to the speaker permits the speaker to be located on the interior of the automobile. A spring clip on the rear of the speaker housing enables it to be mounted on the sunvisor or other body trim.

A transmitter (Fig. 2) was positioned just off the shoulder of the highway. The associated antennas were positioned as shown in Figure 3. When a test vehicle approached from the south, the receiver mounted on it first encountered the magnetic field associated with the trigger antenna. This field was of a sufficient strength to turn the receiver on. A delay switch held the receiver in the "on" position until the test vehicle was in the area of influence of the information antenna's magnetic field, a 1,000-ft section along which the operator received the message previously inserted on the magnetic drum repeater in the transmitter. A more detailed description of the operation of the transmitter is given in the Appendix.

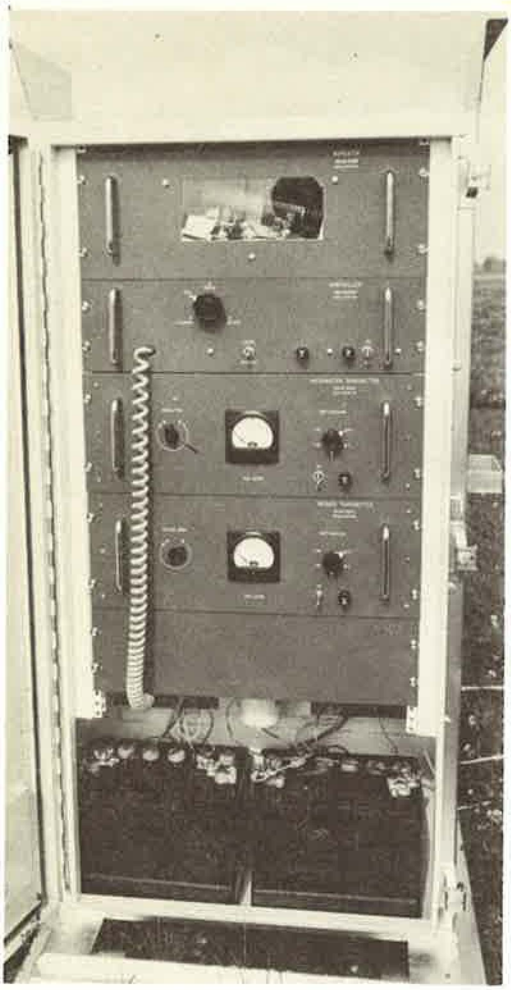

Figure 2. Inside view of transmitter cabinet.

## DATA COLLECTION

### Site Selection

Several conditions were required in the selection of a test site. It had to be a controlled access facility so that the driver could not leave the turnpike before he came to the interview area where the test radio could be recovered. Also the site had to offer good locations for time-lapse motion picture camera placement. Traffic volume had to be such that one could continue to draw a systematic sample all day without either too many or not enough vehicles to obtain reliable data. Proximity to Kokomo, Ind., was also important for convenience in equipment maintenance. A very important consideration was the willingness of the particular highway department to cooperate in the experiments. Based on these conditions, the Kentucky Toll Road was selected with the full cooperation of the Kentucky Highway Department.

### Study Site

The study area (Figs. 4, 5) was located on Interstate 65, Kentucky Toll Road, between the Shepherdsville, Ky., Toll Plaza and the Fern Valley Exit, just south of Louisville. This portion of the road is a divided 4-lane facility with 12-ft concrete lanes. The right-hand shoulders are 10 ft wide and are paved with asphalt. The inside shoulder is approximately 4 ft wide and is also paved with asphalt. The median is 16 ft wide and is of turf-type construction, raised approximately 1 ft. The horizontal and vertical alignments are consistent with the 70-mph speed limit.

The 10-mi test section had an average daily traffic of approximately 8,000 vehicles in the summer months and a truck composition of approximately 20 percent.

The experiments were conducted only when the pavement was dry and no rain was imminent. All experiments were conducted on weekdays between 8 AM and 5 PM.

### Filming Technique

Three cameras, located at bridges No. 1, 2 and 3 (Fig. 5), enabled collection of data by time-lapse motion picture photography. Each camera exposed several rolls of film at 9-min intervals randomly throughout the test days. Filming was scheduled so that camera No. 2 started 2 min after camera No. 1, and camera No. 3 started 2 min after camera No. 2. Thus it was theoretically possible, to follow a vehicle through all three camera locations. Should any situation develop that would affect traffic flow or otherwise impair the experiment, the camera operators were advised of the situation by walkie-talkie and given a revised schedule.

To facilitate film analysis, a grid system for each camera was painted on the highway shoulders perpendicular to the centerline at 40-ft intervals for a distance of 200 ft (Fig. 6).

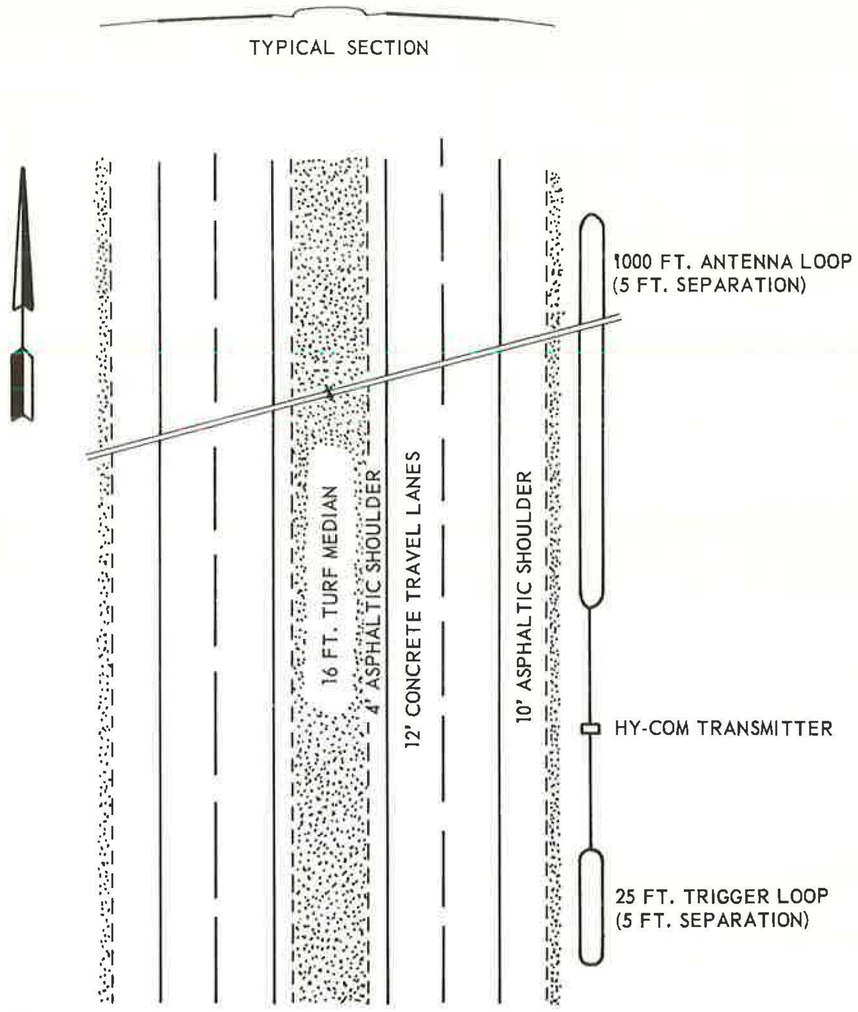


Figure 3. Typical transmitter and loop installation.

## Experiment Design

To consider the psychological factor that the behavior of persons directly involved in the experiment would differ from that of nonparticipating persons, a control group of vehicles was established. This control group received essentially the same information as the test vehicles but was not given a radio receiver.

The selection of test and control vehicles was made by a systematic sampling with every other selected vehicle designated as a control vehicle or a test vehicle. The selection of the vehicles was done by a Kentucky State Police Trooper who directed every fourth northbound vehicle passing through the Shepherdsville Toll Plaza to turn into the unused section of the inside lane where the vehicle was processed.

Each driver was given a short explanation of the purpose of the project and then asked for his cooperation. If the occupants of the vehicle elected not to cooperate, the project personnel simply asked for a refusal reason and waved him on, whereupon a vehicle other than the every fourth vehicle normally selected was asked to participate in the experiment.

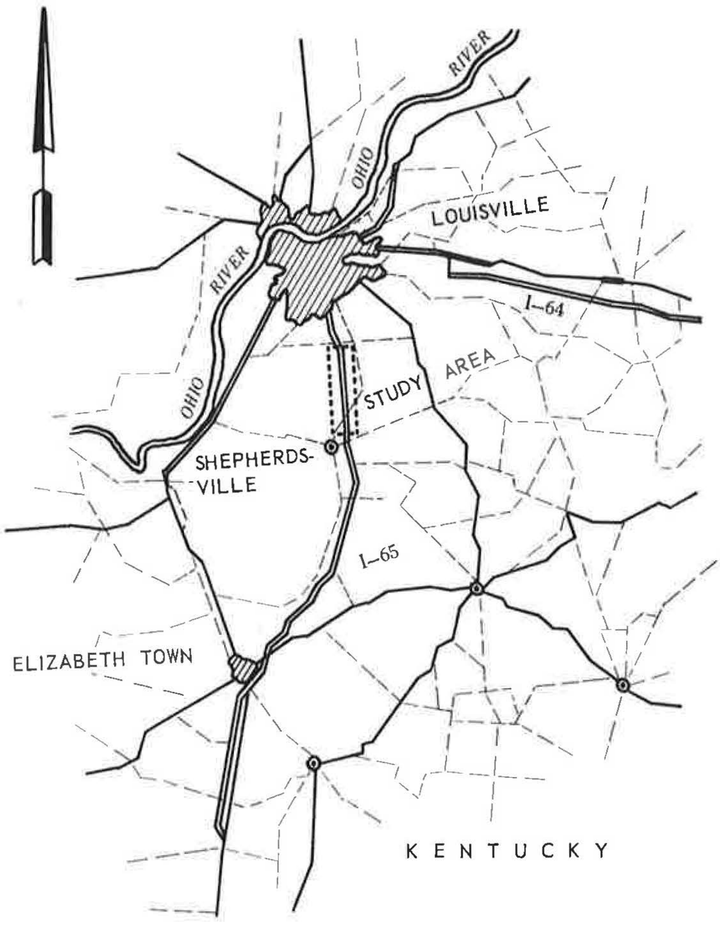


Figure 4. Location of study area, approximate scale: 1 in. = 12 mi.

If a vehicle designated as a control vehicle accepted the invitation to participate, an identifying bumper sticker was placed on the front bumper. The sticker was chartreuse so that it would be noticeable in color motion picture photography. The placement of the sticker identified the driver as being male or female. A sticker placed on the right side indicated a female driver; on the left side, a male driver. The driver of the control vehicle was then given a brochure explaining the project to read when time was available.

Test vehicles were similarly coded with bright red bumper stickers, positioned so as to identify the sex of the driver. In addition, the vehicle was outfitted with a radio unit. The motorist then drove through the test section where he was given several messages and asked to stop for an interview at the end of the test section. There he was given the information brochure.

At the end of the test section, the motorist pulled over at a well-marked area where he was subjected to an interview which took 3 to 5 min. The radio unit and identifying sticker were removed and the driver was allowed to continue after the interview was completed.

Questions were designed to evaluate the driver's acceptance of this form of communication based on his short exposure to it. Other uses were suggested and drivers were asked their opinion on its usefulness. Several questions were designed to measure the effectiveness of the radio communications. The choice of alternatives within the questions was varied from interview to interview so no position bias in the replies would be

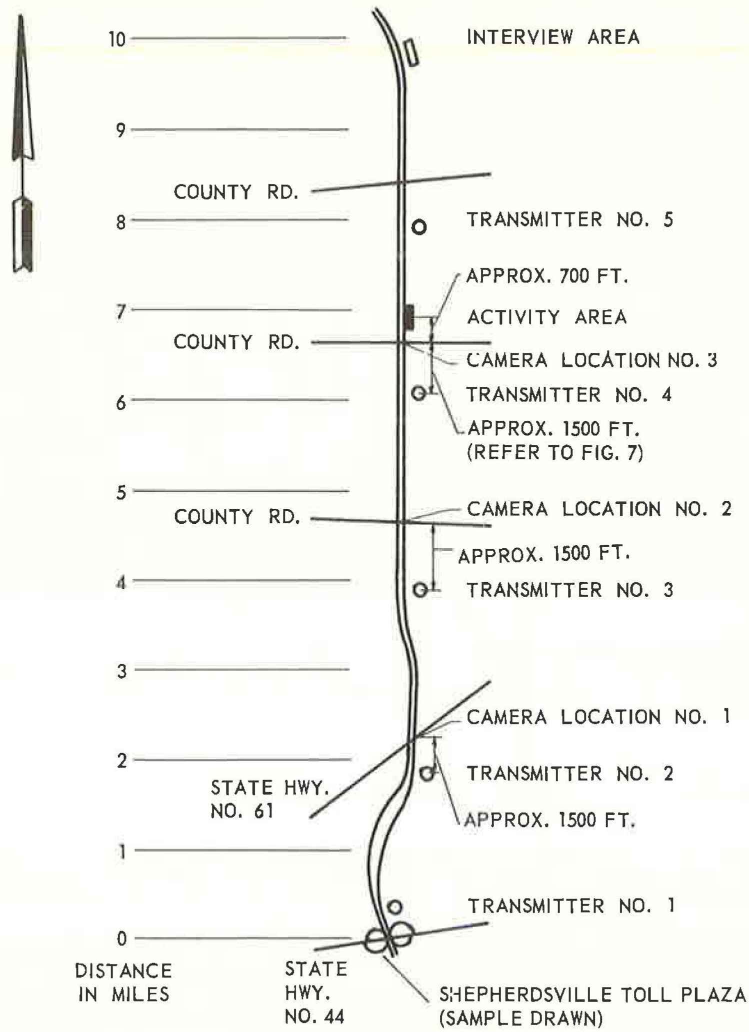


Figure 5. Study area.

created. The interviews were tabulated with respect to experiment, destination and sex of driver, and type of vehicle.

Four experiments were conducted, each dealing with a different road situation. Each experiment was repeated twice, once on each of two randomly selected days.

Experiment 1.—Experiment 1, dealing with an accident scene, was conducted on July 23 and August 1, 1963. To simulate actual conditions, a tow truck, wrecked vehicle and a State Police cruiser were positioned in the median lane of the toll road. A State Police Officer was available to direct traffic through the area should any congestion develop. The only other warning devices used were the red flashing lights on the police vehicle and the wrecker. Figure 7a shows the accident scene.

The messages given to the test vehicles were:

Transmitter No. 1—"This is Hy-Com Radio Communications. Several messages describing actual roadway conditions will be given in the next 10 mi."...repeated once in 10 sec.

Transmitter No. 2—Not used.

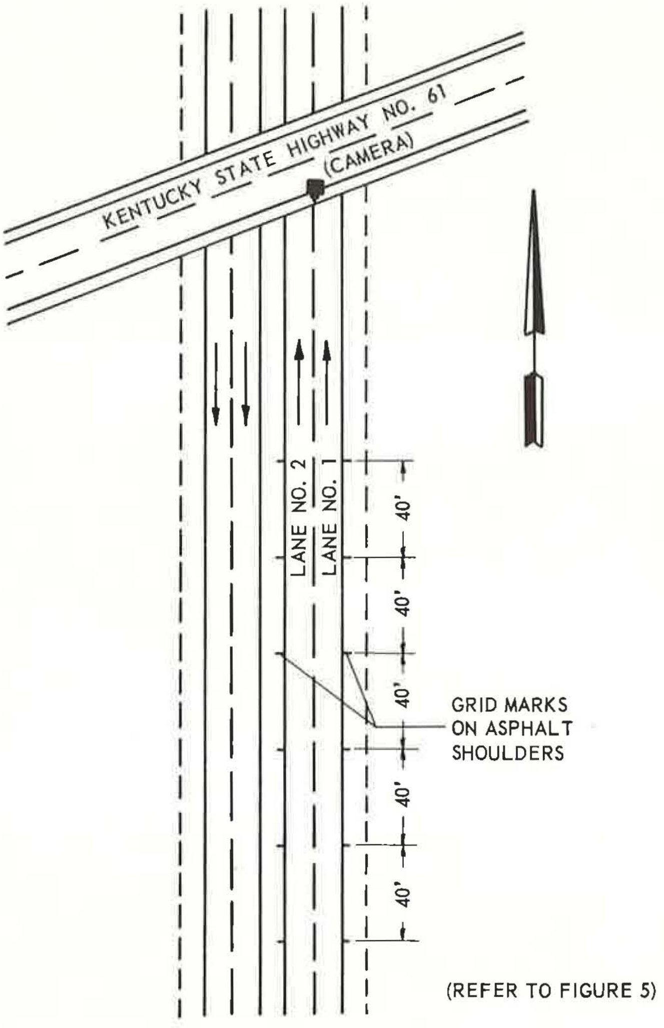


Figure 6. Typical camera and grid layout, scale: 1 in. = 60 ft.

Transmitter No. 3—"Accident ahead 2 mi."...repeated 4 times in 10 sec.
Transmitter No. 4—"Accident ahead, use right lane."...repeated 3 times in 10 sec.
Transmitter No. 5—"Drop off test radio 1 mi."...repeated 4 times in 10 sec.

Experiment 2.—Experiment 2 was conducted on July 24 and 26, 1963. In this experiment a normal maintenance activity, grass cutting, was chosen and the State Highway Department had a tractor mower working on the median. No lane blockage was necessary. A typical operation may be seen in Figure 7b. No warning signs were employed. The messages given to the test vehicles were:

Transmitter No. 1—"Messages concerning actual roadway conditions will be given in the next 10 mi."...repeated twice in 10 sec.
Transmitter No. 2—Not used.
Transmitter No. 3—"Grass cutting 2 mi ahead."...repeated 4 times in 10 sec.
Transmitter No. 4—"Grass cutting, slow to 40."...repeated 3 times in 10 sec.
Transmitter No. 5—"Drop off test radio 1 mi."...repeated 3 times in 10 sec.

Experiment 3.—Experiment 3 was conducted on July 25 and 30, 1963. In this test a typical maintenance activity, patching the shoulder, was simulated in the activity area.

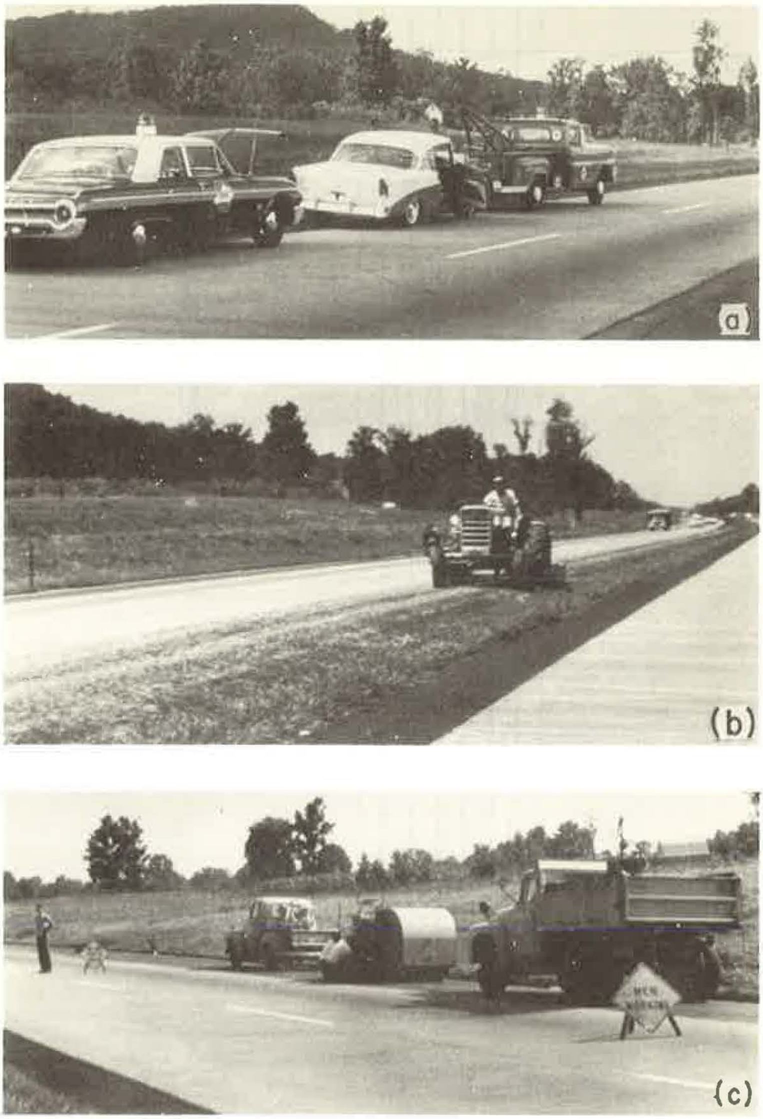


Figure 7. Activity area: (a) accident scene—Experiment 1; (b) mowing scene—Experiment 2; and (c) patching scene—Experiment 3.

The Kentucky State Highway Department supplied several trucks and the necessary personnel to realistically execute the work (Fig. 7). Half lane 1 was blocked in the activity area. A flagman and typical maintenance signing, visible to the approaching drivers while they were still in the grid of the camera at location 3, was used.

The messages given to the test vehicles were:

Transmitter No. 1—"Messages describing actual roadside conditions will be given in the next 10 mi."...repeated twice in 10 sec.
Transmitter No. 2—Not used.
Transmitter No. 3—"Men working 2 mi ahead."...repeated 4 times in 10 sec.
Transmitter No. 4—"Men working, slow to 40."...repeated 3 times in 10 sec.
Transmitter No. 5—"Drop off test radio 1 mi."...repeated 3 times in 10 sec.

Cameras were located in the same positions as in the other experiments.

Experiment 4.—This experiment, conducted on July 31 and Aug. 2, 1963, provided only route information. No roadway activity was described and, consequently, there was no reason for test vehicles to perform differently from the control vehicles in the traffic stream. For this reason no film data were taken and it was not necessary to use control vehicles. The messages given to the test vehicles were:

Transmitter No. 1—"Messages concerning route information will be given in the next 10 mi."...repeated twice in 10 sec.
Transmitter No. 2—"Louisville, home of Kentucky Derby, 15 mi."...repeated 3 times in 10 sec.
Transmitter No. 3—"Cincinnati, 135 mi on I-65."...repeated 3 times in 10 sec on recording drum.
Transmitter No. 4—"Indianapolis 125 mi on US 42."...repeated 3 times in 10 sec.
Transmitter No. 5—"Drop off test radio 1 mi."...repeated 3 times in 10 sec.

### Coordination of Experiment

Coordination of the experimental activities over the 10-mi test section was achieved by using Citizens' Band radio equipment. Each camera operator was equipped with a 1-w walkie-talkie unit. In addition, several 5-w units were used in automobiles. One unit was stationed at the interview area and the others patrolled the test section checking the operation of the transmitters and the camera operators. The radio units gave the project a unifying element that could not have been otherwise attained.

### Data Reduction

The film obtained in the experiments analyzed by means of a projector which allowed a frame by frame analysis of each roll of film. The film was projected onto a screen on which a grid, made to fit the grid painted on the pavement shoulders, was superimposed. Using the grid technique, it was possible to analyze the film for vehicle speeds, volume and lateral placement. Also available from the film analysis was the vehicle type and the sex of the driver which was determined from the placement of the colored bumper stickers.

## ANALYSIS OF DATA

In the design of the experiment consideration was given to the fact that equal representation of all elements would not be obtained. This means that when analyzing data for differences between male and female drivers, local and nonlocal drivers, or passenger vehicles and other types of vehicles, there would not be an equal number of observations for each group. There were six vehicle types considered: passenger, panel or pickup, station wagon, single axle truck, multiple axle truck, and bus. Thus in the collection and subsequent classification of the data it was expected that some comparative analyses would not be possible.

The data collected in the film analysis were carefully considered in view of these considerations. These limitations made it necessary to pool over-all vehicle types and the sex of the driver in the statistical computations. The average speed of the test vehicles and control vehicles in Experiments 1, 2 and 3 at the three camera locations for each of the test days is presented in Table 1.

### Analysis of Variance

After tabulation, the data were examined by analysis of variance methods. Because all main effects were fixed, the three factor interaction term should logically be used as the error term against which the initial tests would be made. However, this error term had only two degrees of freedom, which rendered the "F" tests rather ineffective. Therefore, a new error term, the "within cell mean error variance," was calculated, which had a greater number of degrees of freedom.

To use the analysis of variance techniques it was necessary to formulate a mathematical model in terms of the unknown parameters and the associated random variable.

TABLE 1

AVERAGE SPEED OF VEHICLES

| Experiment | Day | Vehicle Type | Avg. Speed (mph) Camera No. 1 | Camera No. 2 | Camera No. 3 |
|---|---|---|---|---|---|
| 1 | 1 | Test | 58.05 | 59.57 | 42.26 |
| | | Control | 57.79 | 61.58 | 50.89 |
| | 2 | Test | 56.93 | 55.45 | 46.69 |
| | | Control | 59.69 | 59.27 | 51.64 |
| 2 | 1 | Test | 60.16 | 58.53 | 52.69 |
| | | Control | 60.06 | 61.00 | 60.66 |
| | 2 | Test | 61.25 | 59.08 | 52.43 |
| | | Control | 61.12 | 61.94 | 62.02 |
| 3 | 1 | Test | 59.08 | 57.85 | 41.69 |
| | | Control | 59.73 | 61.09 | 52.94 |
| | 2 | Test | 59.47 | 57.32 | 41.79 |
| | | Control | 59.84 | 61.56 | 51.85 |

TABLE 2

ANALYSIS OF VARIANCE FOR SPEED[a]

| Variable | Level of Significance 5 % | 10 % | 20 % |
|---|---|---|---|
| Camera Location | Significant | Significant | Significant |
| Day | Nonsignificant | Nonsignificant | Significant |
| Vehicle type | Significant | Significant | Significant |
| Location-day | Significant | Significant | Significant |
| Day-vehicle | Nonsignificant | Nonsignificant | Significant |
| Location-vehicle | Significant | Significant | Significant |
| Location-day-vehicle | Nonsignificant | Nonsignificant | Nonsignificant |

[a]Includes all drivers and all vehicle classes in Experiment 1.

TABLE 3

RANK ORDER OF TEST AND CONTROL VEHICLE SPEEDS AT DIFFERENT CAMERA LOCATIONS (Experiment 3)

| Camera Location | Speed Highest | Lowest |
|---|---|---|
| 1 | No significant difference | |
| 2 | Control | Test |
| 3 | Control | Test |

TABLE 4

ANALYSIS OF VARIANCE FOR SPEED[a]

| Variable | Level of Significance 5 % | 10 % | 20 % |
|---|---|---|---|
| Camera location | Significant | Significant | Significant |
| Day | Nonsignificant | Nonsignificant | Nonsignificant |
| Vehicle type | Significant | Significant | Significant |
| Location-day | Nonsignificant | Nonsignificant | Nonsignificant |
| Day-vehicle | Nonsignificant | Nonsignificant | Nonsignificant |
| Location-vehicle | Significant | Significant | Significant |
| Location-day-vehicle | Nonsignificant | Nonsignificant | Nonsignificant |

[a]Includes all drivers and all vehicle classes in Experiment 2.

The quantitative physical characteristic (dependent variable) of interest was speed and the independent variables were day of experiment, test or control vehicle, and location of camera. The 10 percent level of significance was used for testing the variables. Duncan's "Multiple Range and Multiple F Tests" were used to investigate significant differences.

Experiment 1.—Results (Table 2) indicate that of the main effects, the location of the camera and the type of vehicle were significant. The location of the cameras with respect to the transmitter locations may be seen in Figure 5. Of the interactions, the camera location-vehicle and the camera location-day were significant.

Film analysis showed that the mean speeds of the test and control vehicles were not significantly different at camera locations 1 and 2, but there was a significant difference between the speed at camera location 3 and those at the other locations. Table 3 gives the rank order of speeds of the test and control vehicles observed at the different camera locations. There were significant differences between the speeds of the test and control vehicles at camera locations 2 and 3, but not at location 1. Therefore, up to the first camera location the presence of the test radio did not affect the normal operating speed of the test vehicle operator. By the time the test vehicle operator was in the range of camera location 2, he had received a message informing him of an accident 2 mi ahead. At this point his speed was significantly different from that of the control vehicle operator who heard no message. At camera location 3, prior to which the test vehicle operator had received the message, "Accident ahead, use right lane," the difference was again significant.

Experiment 2.—Table 4 gives the results of the analysis of variance for Experiment 2. Of the main effects, location of camera and vehicle type are significant, as well as the interaction of these two effects.

The control vehicle mean speed was not significantly different at any of the camera locations, but the test vehicle mean speed was lower at camera location 3 than at the other two camera locations. Table 5 gives the rank order of test and control vehicle speeds at the three camera locations. There exists no significant difference at camera location 1. However, at locations 2 and 3, there is a significant difference between the

TABLE 5

RANK ORDER OF TEST AND CONTROL VEHICLE SPEEDS AT DIFFERENT CAMERA LOCATIONS (Experiment 2)

| Camera Location | Speed | |
|---|---|---|
| | Highest | Lowest |
| 1 | No significant difference | |
| 2 | Control | Test |
| 3 | Control | Test |

TABLE 6

ANALYSIS OF VARIANCE FOR SPEED[a]

| Variable | Level of Significance | | |
|---|---|---|---|
| | 5 % | 10 % | 20 % |
| Camera location | Significant | Significant | Significant |
| Day | Nonsignificant | Nonsignificant | Nonsignificant |
| Vehicle type | Significant | Significant | Significant |
| Location-day | Nonsignificant | Nonsignificant | Nonsignificant |
| Day-vehicle | Nonsignificant | Nonsignificant | Nonsignificant |
| Location-vehicle | Significant | Significant | Significant |
| Location-day-vehicle | Nonsignificant | Nonsignificant | Nonsignificant |

[a]Includes all drivers and all vehicle classes in Experiment 3.

TABLE 7

RANK ORDER OF TEST AND CONTROL VEHICLE MEAN SPEED AT DIFFERENT CAMERA LOCATIONS (Experiment 3)

| Camera Location | Speed | |
|---|---|---|
| | Highest | Lowest |
| 1 | No significant difference | |
| 2 | Control | Test |
| 3 | Control | Test |

TABLE 8

SIGNIFICANT DIFFERENCES IN LATERAL PLACEMENT DISTRIBUTION OF TEST AND CONTROL VEHICLES

| Source of Variation | | | Level of Significance | |
|---|---|---|---|---|
| Experiment | Location | Lane | 10 % | 20 % |
| 1 | 1 | 1 | Nonsignificant | Nonsignificant |
| | 2 | 1 | Significant | Significant |
| | 3 | 1 | Significant | Significant |
| 2 | 1 | 1 | Significant[a] | Significant[a] |
| | 2 | 1 | Nonsignificant | Nonsignificant |
| | 3 | 1 | Nonsignificant | Nonsignificant |
| 3 | 1 | 1 | Nonsignificant | Nonsignificant |
| | 2 | 1 | Nonsignificant | Nonsignificant |
| | 3 | 2 | Nonsignificant | Significant[a] |

[a]Favors group control.

test and control vehicle speeds which can be attributed to the messages concerning the grass cutting operation received by the test vehicle operators prior to these locations.

Experiment 3.—The results of the analysis of variance for experiment 3, given in Table 6, indicate that only the main effects of camera location and vehicle type and their interaction were significant. These effects were significant even at the 5 percent level.

The mean speeds of both test and control vehicles were lowest at camera location 3, whereas there was little difference in speeds at locations 1 and 2. Table 7 gives the rank order of test and control vehicle speeds observed at the three camera locations. Only at location 1 is there no significant difference between test and control vehicle speeds, indicating that the presence of the test radio did not affect the speed of the test vehicles. However, the messages received by the test vehicle operators prior to camera locations 2 and 3 did contribute to the significant difference in speed between the test and control vehicles at these last two camera locations.

## Lateral Placement of Vehicles

In addition to the speed data secured from the analysis of the films, information was obtained for the first three experiments concerning the lateral placement of the test and control vehicles at the three camera locations. To gather this information, the grid used in the speed analysis was modified slightly. After vehicle speed was measured, the position of the right front tire was recorded with respect to the right-hand edge of the pavement. These data were then analyzed using statistical techniques for significant differences in the test and control vehicle lateral placement distribution. Based on amount of data collected and the distribution of lateral placement observations a contingency test was used to analyze the data.

Experiment 1.—At camera location 3, approximately 1,000 ft before the accident scene, the most desirable position for a vehicle was in lane 1; that is, the right-hand wheel should be near the right shoulder. Table 8 indicates that the lateral placement distribution of test and control vehicles at camera location 1 is not significantly different. A similar analysis of the vehicles in lane 2 yielded the same result.

At camera location 2, the test vehicles had received the message, "Accident ahead, 2 mi," which the control vehicles did not receive and a significant difference in lateral placement between test and control vehicles existed. The test vehicles tended to occupy positions closer to the right-hand side of the road than did the control vehicles. Results were similar at camera location 3.

These results indicate that the messages received by the test group did affect their lateral placement at camera locations 2 and 3 to such a degree that placement differed significantly from that of the control group who did not receive the messages.

Experiment 2.—Table 8 also indicates a significant difference during Experiment 2 in the lateral placement distribution of test and control vehicles at location 1. At this location, the control vehicles occupied a position closer to the right-hand shoulder than did the test vehicles. At the other camera locations, no significant differences existed between test vehicles who had received messages concerning the grass cutting operation, and control vehicles who had received no messages.

The results of the contingency tests for Experiment 2 indicate that the messages did not have any consistent influence on the lateral placement distribution of test and control vehicles, especially in the activity area.

Experiment 3.—The maintenance activity in this experiment caused the right-hand lane to be blocked, therefore, in the analysis of lateral placement, the most favorable wheelpath in the vicinity of the activity area was as close as possible to the left-hand shoulder.

At camera location 1, before any messages were received, the analysis of lateral placement (Table 8) indicated that even at the 20 percent level in the contingency test there was no significant difference between test and control vehicles in lane 1 or lane 2. At camera location 2, although the test vehicles had received the message "Men working, 2 mi ahead," the analysis of lateral placement showed the distribution of test and control vehicles were not significantly different.

Prior to camera location 3 the test vehicles received the following message: "Men working, slow to 40," and a flagman and signs were employed in the activity area. Although the test vehicles received messages prior to zone of activity, their lateral placement distribution from the right-hand edge of the pavement was not significantly different from the control group distribution at the 10 percent level.

In the film analysis of the three experiments a record was kept of the test and control vehicle activity—passing, weaving, and lane changes—in the zone from the transmitter to the grid section of the camera field of view. Results indicated that at camera locations 1, 2, and 3 for all experiments the behavior of the test and control vehicles was essentially similar. At the first camera location, no difference was expected. The message received just before location 2 did not request any lane maneuvering and, consequently, no difference was expected. At the third camera location the number of lane changes by the test group was 42 out of 106 vehicles appearing in the film. For the control vehicles, 45 out of 108 made some lane change.

In analyzing these data, cognizance of the many factors that could have biased these data must be made; for example, during the experiments trucks broke down at critical points and exerted influence upon the traffic stream.

## INTERVIEW DATA ANALYSIS

During the 8 days in which the tests were conducted, a total of 1,616 interviews were secured. The interview recording form is shown in Figure 8. Of the interviews taken however, 228 were invalidated for various reasons (Fig. 9). The most common reason for rejecting an interview was equipment malfunction. The receivers occasionally failed and so the test vehicles proceeded through the test section receiving some or none of the messages. This problem was especially evident with large trucks who many

INTERVIEW FORM
Project A-674

| INTERVIEW NUMBER | DATE | | INTERVIEWER | |
|---|---|---|---|---|
| | | AGE: | MALE (11) | FEMALE (12) |
| TYPE OF VEHICLE ______ (5-6) | | UNDER 25 | 1 | 1 |
| YEAR OF VEHICLE ______ (7-8) | | 26 - 35 | 2 | 2 |
| LICENCE NUMBER ______ | | 36 - 45 | 3 | 3 |
| STATE ______ (9-10) | | OVER 45 | 4 | 4 |

1. DESTINATION: LOCAL ☐ 1 OUT OF STATE ☐ 2 (13)
2. PARTICIPATE IN EXPERIMENT BEFORE: YES ☐ 1 NO ☐ 2 (14)
3. MESSAGES:
   ADEQUATELY UNDERSTOOD ......... ☐ 1
   EASY TO UNDERSTAND ............ ☐ 2 (15)
   DIFFICULT TO UNDERSTAND ....... ☐ 3

| | YES | NO | NO OPINION | |
|---|---|---|---|---|
| 4. MESSAGES DIFFICULT: | | | | |
| RADIO NOT CLEAR ................ | ☐ 1 | ☐ 2 | ☐ 3 | (16) |
| MESSAGE GARBLED ................ | ☐ | ☐ | ☐ | (17) |
| MESSAGE REPEATED ............... | ☐ | ☐ | ☐ | (18) |
| INSUFFICIENT INFORMATION ....... | ☐ | ☐ | ☐ | (19) |
| LACK WARNING ................... | ☐ | ☐ | ☐ | (20) |
| OTHER ( ) ............ | ☐ | ☐ | ☐ | (21) |
| 5. MESSAGES HELP IN DRIVING: | | | | |
| FELT SAFER ..................... | ☐ | ☐ | ☐ | (22) |
| INCREASED AWARENESS ............ | ☐ | ☐ | ☐ | (23) |
| SMOOTHER OPERATION ............. | ☐ | ☐ | ☐ | (24) |
| OTHER ( ) .............. | ☐ | ☐ | ☐ | (25) |
| 6. MESSAGES NO HELP: | | | | |
| NOT CLEAR ...................... | ☐ | ☐ | ☐ | (26) |
| ANNOYED BY RADIO ............... | ☐ | ☐ | ☐ | (27) |
| NOT NEEDED ..................... | ☐ | ☐ | ☐ | (28) |
| OTHER ( ) .............. | ☐ | ☐ | ☐ | (29) |

7. COMPARISON WITH SIGNS:
   BETTER ............ ☐ 1
   SAME .............. ☐ 2 (30)
   WORSE ............. ☐ 3

8. COMPARISON WITH NO SIGNS:
   BETTER ..... ☐ 1
   SAME ....... ☐ 2 (31)
   WORSE ...... ☐ 3

| | YES | NO | NO OPINION | |
|---|---|---|---|---|
| 9. FACILITATE DRIVING IN: | | | | |
| NIGHT ......................... | ☐ 1 | ☐ 2 | ☐ 3 | (32) |
| FOG ........................... | ☐ | ☐ | ☐ | (33) |
| SNOW .......................... | ☐ | ☐ | ☐ | (34) |
| RAIN .......................... | ☐ | ☐ | ☐ | (35) |
| OTHER ( ) ............ | ☐ | ☐ | ☐ | (36) |
| 10. SYSTEM USED FOR: | | | | |
| COMPLEX INTERCHANGES ......... | ☐ | ☐ | ☐ | (37) |
| SCENIC OR HISTORIC INFORMATION | ☐ | ☐ | ☐ | (38) |
| SERVICE AREA ................. | ☐ | ☐ | ☐ | (39) |
| DETOUR ....................... | ☐ | ☐ | ☐ | (40) |
| TRAFFIC CONGESTION............ | ☐ | ☐ | ☐ | (41) |
| OTHER ( ) ............ | ☐ | ☐ | ☐ | (42) |
| 11. GENERAL USE IN MAJOR HIGHWAYS: | ☐ | ☐ | ☐ | (43) |
| 12. CAR RADIO: | ☐ | ☐ | ☐ | (44) |
| 13. ADDITIONAL COST: WOULD NOT PURCHASE (DOLLARS) | ☐ | ☐ | ☐ | (45) |

14. REMARKS: ______________________________

______________________________

Figure 8. Interview form.

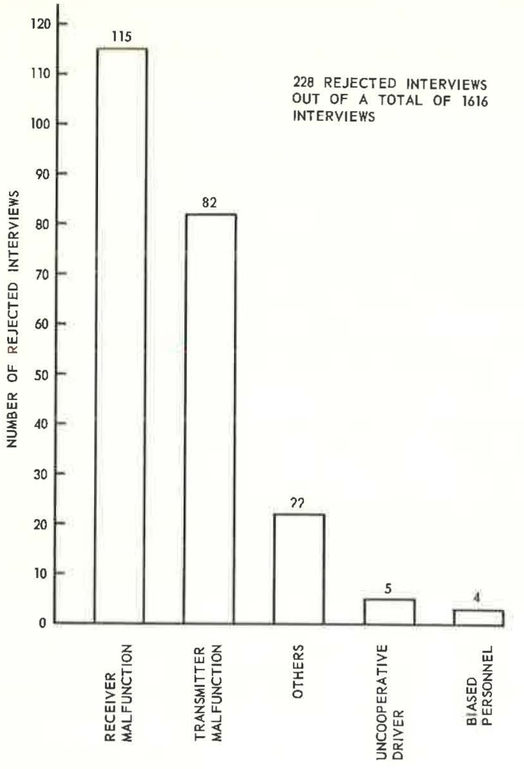


Figure 9. Number and causes of rejected interviews.

times heard only static. Another reason for interview rejection was malfunction of the transmitting equipment. In this case, the message repeater usually was the cause of the trouble. When a transmitter breakdown occurred, the test vehicles would receive an unclear message or no message at all at that location. The seriousness of the situation depended on which particular transmitter malfunctioned. The equipment malfunctions were a flaw in the experiments that allowed bias to enter into even the objective film analysis, because it was impossible to determine if the test car appearing on the film had received a message.

The traffic was predominantly composed of passenger vehicles, but the truck percentage on Tuesdays, Wednesdays and Thursdays represented approximately 30 percent of the volume. The male-female ratio of drivers in the test group was comparatively large. Of the 1,388 acceptable interviews taken, 1,136 were males and only 252 were females.

On the last day of testing, during the second part of the route information experiment, the interviewed drivers were asked the purpose of their trip. The results show a large percentage of recreational-type traffic, especially evident in the nonlocal destination traffic.

In response to the question concerning the ability of the messages to be understood by the test vehicle operators, the respondents generally indicated that the messages were well within the limits required for adequate comprehension, as over 95 percent of the drivers in every experiment thought the messages in general were of adequate quality. Of those drivers who had difficulty in understanding one or all of the messages, most of them indicated that the message was unintelligible or garbled because of malfunction of the receivers or transmitters. Other reasons given were insufficient number of repetitions of the messages and insufficient information contained in the messages.

The majority of the drivers indicated that the messages received did aid them in some way. Results showed that for Experiments 1, 2, and 3, the radio messages did make the drivers feel safer and more alert while at the same time contributing to a smoother operation of their vehicle. There were some drivers, however, who felt that the messages were of no help to them while driving over the test section. Message clarity, annoyance and the opinion that messages were not needed formed the majority of the dissensions.

The opinion of 90 percent of the respondents was that the joint use of radio and signs was better than just signs alone and also that the use of radio communications would be very advantageous in places where presently no signs are normally used. The latter situations arise principally at accident scenes and perhaps at some maintenance areas. Some drivers considered the radio communications an advantage in that messages could be kept up to date as contrasted to construction signs sometimes left in place after all hazards are removed.

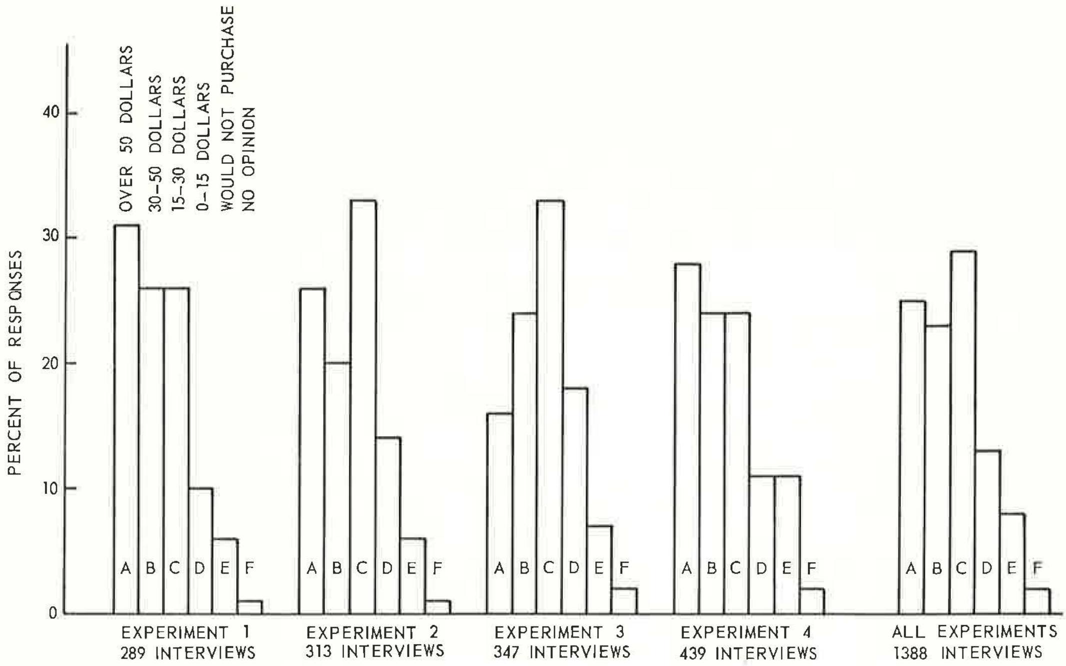


Figure 10. Amount drivers were willing to pay above cost of car radio for radio system comparable to test radio.

More than 95 percent of the drivers agreed that the use of roadside radio communications would be an advantage during inclement weather conditions. Other uses suggested by the drivers indicated a variety of applications. The possibility of using radio communications to inform drivers of scenic and historic locations, as well as service areas, was accepted very well and little difference was found between the responses given by local and nonlocal drivers. Approximately 70 percent of all drivers were of the opinion that the information on scenic and historic information would be useful, whereas more than 80 percent were receptive to the idea of receiving information about service areas. Perhaps some of the attractiveness of this information service could be attributed to the large percentage of recreational type traffic at this time of the year. More than 95 percent of the respondents thought that the system would be of help in the vicinity of complex interchanges. Similar reception was accorded the use of radio communications to warn of detours and traffic congested areas. The opinion that a radio communication system should be incorporated into all major highways in the nation was almost unanimous.

In order to properly formulate the question of willingness to pay, it was first determined if the vehicle was equipped with a radio. Approximately 15 percent of the vehicles interviewed did not have radios. Included in this figure are all the commercial trucks that ordinarily do not have radios.

To evaluate the driver acceptability of the radio communications system, the last question asked was how much more the driver would be willing to pay than the cost of his car radio for an installation of this radio equipment as part of a standard car radio, with the assumption that this installation would work automatically whether the radio was on or off and could be used on all of the major State highways.

The replies to this question were summarized in various groupings according to sex and destination of trip, that is, local or nonlocal. No significant differences were evident between the amount the male and female or the local and nonlocal drivers were willing to pay.

Figure 10 presents the cost results for each experiment summed over all drivers.

Greater than 75 percent of drivers in all four experiments were willing to invest from $15 to $30 in the system. Considering all four experiments together, approximately 48 percent were willing to pay more than $30, whereas 25 percent were willing to pay more than $50 for the system. The amounts over $50 varied up to $200, but for statistical analysis a mean value of $75 was used. Approximately 8 percent of the drivers indicated that they would not purchase such an installation. It is interesting to note that in Experiments 1, 2, and 3, there were only about 6 percent who would not purchase the system, whereas in Experiment 4, the route information experiment, 11 percent indicated they were unwilling to purchase the system.

## SUMMARY OF RESULTS

The results of the analysis of data collected in this study can be outlined as follows:

1. In the first three experiments, the analysis of the data using analysis of variance and multiple range tests indicated no significant differences in the speeds of the test and control vehicles at camera location 1. No information was transmitted immediately in advance of camera location 1.
2. In the first three experiments, a significant difference between speeds of test and control vehicles existed at camera location 2, where the transmitted message in advance of the camera location was advisory only, and at camera location 3, where the transmitted message was both advisory and directive.
3. In Experiment 1, significant differences in the lateral placement of test vs control vehicles occurred at camera locations 2 and 3 but not at 1.
4. In Experiment 2, significant differences in the lateral placement of test vs control vehicles occurred only at camera location 1 and favored the control group.
5. In Experiment 3, significant differences in the lateral placement of test vs control vehicles occurred only at camera location 3, but the significance was in the 20 percent level and favored the control vehicles.
6. Of the 1,616 interviews, 228 were considered biased and rejected. Of those rejected, equipment malfunction accounted for 197.
7. Ninety percent of the unbiased interviews indicated the broadcast messages were adequately or easily understood.
8. Most of the difficulty in understanding was caused by messages that were not clear or garbled in reception.
9. Messages helped in making the test vehicle operators feel safer, more alert, and contributed to a smoother operation of the vehicle through the test section.
10. Almost every interviewed driver thought that roadside radio communications in addition to standard signs were better than signs alone in most situations where it was necessary to give information or to caution drivers. The respondents also indicated that radio communications could be used effectively in situations where ordinarily no signing is used, such as in the vicinity of an accident.
11. It was almost the unanimous opinion of the interviewed drivers that roadside radio communication is a useful device in aiding the driver during inclement weather conditions.
12. More than 95 percent of the drivers favored the use of roadside radio communications in the vicinity of complex interchanges, traffic congested areas and detours. The use of the radio system to give information related to scenic and historic areas as well as service areas was acceptable to more than 70 percent of the drivers.
13. Most drivers would like to see this roadside radio communications system used on all major State highways.
14. Based on willingness-to-pay, most drivers indicated that the radio system had potentials. In response to the cost question, more than 25 percent of the operators were willing to pay in excess of $50 for an installation; 48 percent indicated that they would be willing to invest more than $30 for an installation; and only 8 percent of those vehicle operators interviewed indicated that they would not purchase such a system. In analyzing the willingness-to-pay for the various groupings of the data, it was found that no significant difference existed in the amounts that males and females or local and nonlocal drivers were willing to pay.

## CONCLUSIONS

An evaluation of data developed the following conclusions:

1. The speed of a test vehicle was not significantly affected by the presence of the test radio equipment mounted on the vehicle. This is evident from the fact that at camera location 1 in all three experiments, no significant difference was found between test and control vehicle speed.

2. The messages received by the test vehicle operators did have a significant effect on the speed of their vehicles when compared to that of control vehicles who did not receive the messages.

3. In general, the messages received by the test vehicle operators did not always cause them to operate their vehicles in a manner such that the lateral placement distribution of the test vehicles differed significantly from the lateral placement distribution of the control vehicles.

In Experiment 1, the radio messages had a significant influence on the lateral placement distribution of test and control vehicles at camera locations 2 and 3. The test vehicles gave a greater clearance to the accident than did the control vehicles. In the mowing experiment, the control vehicles were closer to the right-hand shoulder than the test vehicles at camera location 1, but at camera locations 2 and 3, no significant difference in lateral placement was observed. In Experiment 3, no difference existed at camera locations 1 and 2. At camera location 3, significance was encountered only at the 20 percent level and it indicated that the control vehicles were giving more lateral clearance to the maintenance operation than the test vehicles.

4. During personal interviews, the test group, in general, approved of the roadside radio communication system. They agreed that the system helped them while driving over the test section, that the system could give desirable and necessary information concerning a variety of conditions that exist on the highways, and that the radio system could supplement the signs in some cases and provide acceptable service in other cases where signs are not used. The radio system, even though in experimental stages of development, was not noticeably annoying to the driver.

5. Based on the results of the willingness-to-pay question, the driver acceptance for this system was considered good. Recognizing the limitations of the data collected, it may be concluded that if the roadside radio communications system did become a reality, and its performance was at least comparable to the equipment tested, at least half the motoring public with similar driving habits as those in the experiment would be willing to pay at least $30 for an installation.

## RECOMMENDATIONS

Additional research should be conducted to investigate the effect of radio communications on repeat traffic in an urban area. Also, research must be conducted into the number of transmitters needed to provide effective radio communication service for a typical freeway, the type and characteristics of messages given, and most important, the possibility of a central control system for the transmitters. The message repeater should be modified to eliminate the mechanical and electrical noises associated with the magnetic drum repeater assembly. Research also might be conducted to investigate the influence of field strength and configuration on the operation of receivers of various locations in the field.

## REFERENCES


1. Blankenship, A. B., "Consumer and Opinion Research." Harper and Brothers Pub., New York and London (1943).
2. Blankenship, A. B., "How to Conduct Consumer and Opinion Research." Harper and Brothers, Pub., New York and London (1946).
3. Covault, D. O., "Time-Lapse Movie Photography." Traffic Eng., 3:6 (March 1960).
4. Duncan, D. B., "Multiple Range and Multiple F Tests." Biometrics, 11:1-4 (1955).
5. Hanysz, E. A., "Highway Alert Radio." Res. Lab. Brochure. General Motors Corp., Warren, Mich.

6. Hanysz, E. A., Stevens, J. E., and Meduvsky, A., "Communication System for Highway Traffic Control." Electronics (Oct. 1960).
7. Hopkins, R. C, et al., "Long Range Research and Development Program for Individual Transportation Systems." Public Roads, 32:7 (April 1963).
8. "Hy-Com Highway Communicator." General Motors Corp., Delco Radio Div., Kokomo, Ind., Eng. Dept. Rep.
9. Keller, J. E., "The FCC and Radio Control of Traffic Control Devices." Traffic Eng. (May 1959).
10. Morrison, H. M., Welch, A. F., and Hanysz, E. A., "Automatic Highway and Driver Aid Developments." Presented at SAE Nat. Automobile Week, Detroit, Mich. (March 1960).
11. Olsen, P. L., "Road-Driver Communications—1980." Proc., Inst. of Traffic Eng. (1962).
12. Quinn, C. E., "New Voice System Alerts Drivers." Traffic Eng. (July 1959).
13. "Will Engineering Advances Reduce Our Traffic Deaths?" Amer. Eng. (Oct. 1959).

# *Appendix*

## OPERATION OF THE TRANSMITTER SYSTEM

The transmitting system consists of a transmitter cabinet and two loop antennas laid on the shoulder of the road. The transmitter cabinet (Fig. 2) is watertight and can be set up at any required point along the side of highway. The cabinet contains the message repeater and associated transmitting equipment and two 12-v storage batteries for a power supply.

The transmitter system is a single sideband, suppressed carrier, one-way communication link. Audio information to be transmitted is recorded on a magnetic drum in the repeater. The repeater records messages of any duration up to 10 sec and will automatically repeat them.

A handset, located in the transmitter cabinet, serves as a microphone to permit recording and as a receiver to allow verification of proper recorder operation. A message which the driver is intended to hear is inserted on the recording drum. With the control in the playback position, the recorded message is automatically inserted at the input of the information transmitter. At the end of the message, the repeater will reset itself and the message will be repeated. In the transmitter the 12.1 kc carrier is amplitude modulated. Suppression filters then remove the carrier and the lower sidebands and deliver the upper sidebands to the power output stage which energizes a loop antenna. The loop antenna establishes an inductive field which can be sensed by the receiver antenna as it passes the loop. To avoid the confusion of a southbound driver receiving a message intended for a northbound motorist, an additional trigger feature has been incorporated. This consists of a 12.1 kc trigger transmitter and its associated trigger antenna, a loop of plastic-coated 19-strand copper wire. When the induction field of the trigger transmitter is sensed by the receiver antenna, a trigger circuit in the receiver is activated which energizes the audio stages of the receiver. A time delay is designed into the system to hold the audio section in the "on" position to permit the automobile to pass the trigger loop and to reach the information loop. As the receiver enters the information loop, it senses the information signal and provides an audible message to the driver. With this system, a southbound driver would pass the information loop before he would pass the trigger loop. His receiver would be off and no audible message would be heard.

The information loop used in the experiments was 1,000 ft long and consisted of a loop of plastic-coated wire laid just off the shoulder of the turnpike. A distance of 5 ft separated the legs of the loop.

The trigger loop, made of similar wire, had seven turns of the wire in the loop with a similar separation. However, the trigger antenna loop was only about 25 ft long. The trigger loop was located before the transmitter, whereas the information loop was located after the transmitter. A sketch of the layout of the antennae is shown in Figure 3.