plateauing at about 18;

3. The south Philadelphia signal rate is plateauing at about 12.5;

4. The south Philadelphia four-way stop rate is plateauing at about 18.5, which is lower today than the other two but higher than they were in 1967;

5. The north Philadelphia two-way stop rate is plateauing at about 16; and

6. For several years the north Philadelphia signal and four-way rates have been on the decline, the latter always 30 percent lower than the former.

BEFORE-AND-AFTER ANALYSIS OF ALL TRAFFIC CONTROL CHANGES

To ensure a definitive evaluation of the before-and-after statistics at all locations where the control mode changed during the study period, we decided to compare the 2-year period both immediately before and immediately after the change. Thus all changes from 1970 to 1974 were evaluated; however, the seven newly signalized locations were insufficient for definitive conclusions.

Results for the 222 two-way to four-way conversions, which the Traffic Engineering Handbook (4) criteria labeled dangerous locations (that is, having an accident rate of nine), indicate the following:

1. Accident reduction conversion results in both study areas were similar;

2. In general, three of every four conversions from two-way to four-way stop control improved conditions, regardless of the before accident rate;

3. Half of the safe two-way conversions to four-way increased accidents;

4. Six of seven dangerous two-way conversions reduced accidents;

5. Total accidents decreased by 55 percent after conversion to four-way stop;

6. Occupant personal injury accidents decreased by 81 percent after conversion;

7. Pedestrian injury accidents decreased by 83 percent after conversion;

8. Right-angle accidents decreased by 83 percent after conversion; and

9. Rear-end, fixed-object, and sideswipe accidents were unaffected.

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Approach to Real-Time Diversion of Freeway Traffic for Special Events

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In Dallas, Texas, on July 4, 1976, freeway traffic bound for a fireworks display was diverted to an alternate arterial route. The object was to validate primary candidate messages and displays resulting from extensive laboratory studies of human factors. Two primary candidate messages were displayed at alternate times on matrix signs located on the Central Expressway. The first message caused 56.2 percent of the traffic to divert and the second 43.8 percent.

Special events at places such as stadiums generate large volumes of traffic and congestion at the site and on adjacent freeways. Practically every driver on the way to a ball game at a major stadium has experienced considerable delay in lengthy queues.

Less congested alternate routes are often available, however, and, if some of the approaching freeway traffic can be diverted to alternate routes, congestion can be reduced. This depends on several factors: (a) An acceptable alternate route must be available; (b) drivers must be made aware of the alternate route; and (c) guidance must be provided along the alternate route so that drivers, once diverted from the primary route (usually a freeway), can progress easily and confidently along the alternate. Research findings in real-time driver information transfer techniques that have been developed from human factors engineering principles are of critical importance to effective route diversion.

The purpose of this study is to develop effective information displays for real-time incident management and route diversion. Extensive human factors laboratory studies are being conducted to develop primary candidate messages and displays that will then be field validated. One phase of the research effort was directed toward route diversion messages and displays for special events. This paper discusses one such study conducted in Dallas, Texas, during a Fourth of July fireworks display at the Fair Park in 1976.

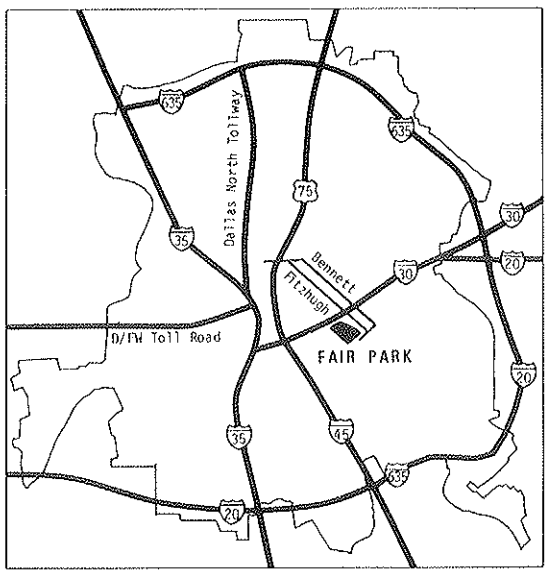
FAIR PARK CHARACTERISTICS

Fair Park, a 97-hm^2 (240-acre) area in south central Dallas, houses the Cotton Bowl and permanent buildings, facilities, and midway for the annual Texas State Fair. In addition it has several cultural buildings such as a music hall, museums, and the Texas Hall of State. Many college and professional football games are played in the Cotton Bowl (seating capacity of 73 000), which is often used for other events and exhibitions such as Fourth of July celebrations.

The location of Fair Park relative to the freeway system is shown in Figure 1. The primary access route to Fair Park and its parking facilities from the north, west, and south is provided by two exit ramps (Second Avenue and Haskell Avenue exits) from I-30. Traffic from US-75 (Central Expressway), I-35E, and the Dallas-Ft. Worth Turnpike must connect with I-30 and then exit via either Second Avenue or Haskell Avenue. Queues of exiting traffic to Fair Park will often extend back for 3.2 km (2 miles) during peak demand conditions and will affect I-30 and even US-75 and I-35E. This occurs regularly before the Cotton Bowl game on New Year's Day or the Oklahoma-Texas University game in October. Each of these games attracts more than 73 000 people. The October game also coincides with the Texas State Fair, which attracts an additional 225 000 people to Fair Park on the same day.

Fourth of July celebrations are held annually at the Cotton Bowl. The study year, that of the bicentennial celebration, attracted more than 65 000 people for various events, 42 000 of whom attended an elaborate fireworks display that began at 9:15 p.m. in the Cotton Bowl. This special event was selected as the first of three to evaluate how well the matrix sign messages accomplished route diversion.

Figure 1. Dallas Fair Park.



STUDY SITE

We chose to study the southbound Central Expressway (US-75), because a suitable arterial street was available as an alternate route to Fair Park. The primary route, Central Expressway, and the alternate route, Fitzhugh Avenue, are shown in Figure 2. The Expressway from Fitzhugh Avenue to I-30 is a six-lane facility with a direct two-lane ramp connection to eastbound I-30. Fitzhugh Avenue is a one-way arterial with eight traffic signals between Central Expressway and Fair Park. The street narrows from three to two lanes approximately 1.6 km (1 mile) east of the expressway. Alignment is straight. Traffic signals at the Fitzhugh-Central Expressway diamond interchange were timed to favor the expected left-turn demand, and the signals along Fitzhugh Avenue were timed and coordinated to provide steady progression. Parking was prohibited along Fitzhugh Avenue to provide a minimum of two operating lanes throughout the complete alternate route.

SIGNS

Matrix Sign Location

Two trailer-mounted lamp matrix signs were positioned on the overcrossing structures above the southbound

Figure 2. Primary and alternate routes.

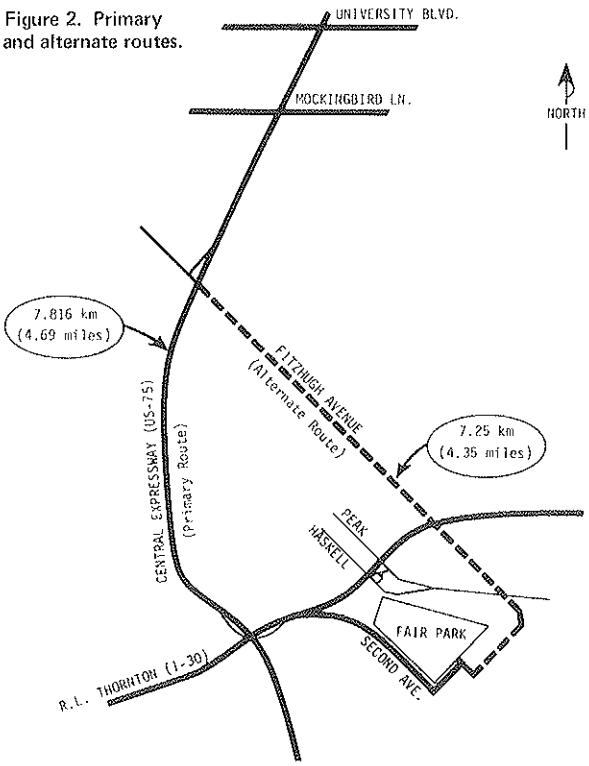
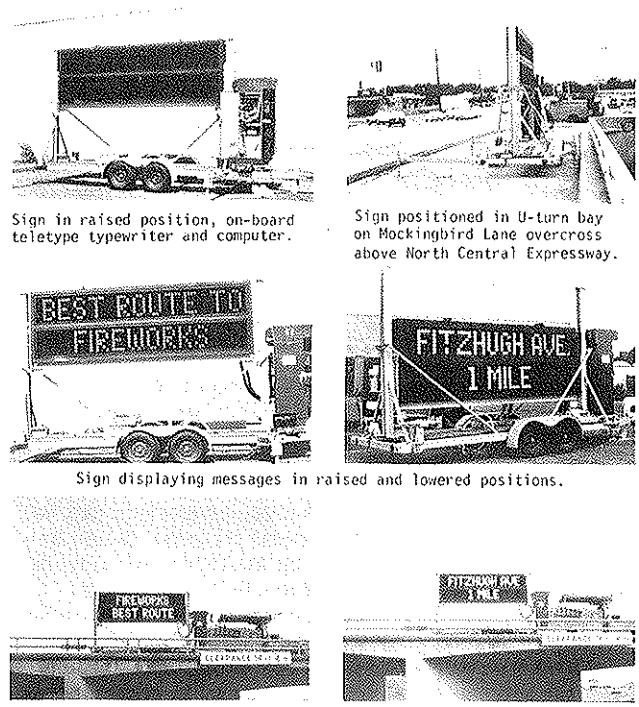


Figure 3. Trailer-mounted matrix sign.



Sign in raised position, on-board teletype typewriter and computer.

Sign positioned in U-turn bay on Mockingbird Lane overcross above North Central Expressway.

Sign displaying messages in raised and lowered positions.

Sign displaying messages during study.

lanes of Central Expressway. One sign was located on the University Avenue overcross, approximately 3.2 km (2 miles) north of the Fitzhugh Avenue exit. The second sign, on the Mockingbird Lane overcross, was approximately 2.4 km (1.5 miles) north of the Fitzhugh Avenue exit. Unobstructed sight distance to southbound traffic was greater than 366 m (1200 ft) at each location.

Matrix Sign Characteristics

The portable matrix signs are illustrated in Figure 3. The signs can display messages on two lines using 46-cm (18-in) characters. A computer located on the front side of the trailer provides almost unlimited message selections and displays. Messages can be displayed in a stationary mode or flashed or alternated with other messages. Message displays are commanded via a teletype on each sign trailer. Each sign system can be either hooked up to regular line power or connected to a generator.

Matrix Sign Messages

The two primary candidate messages shown below were selected for evaluation. These messages were the results of extensive human factors laboratory studies.

Sign	Message 1	Message 2
1 (University Avenue)	BEST ROUTE TO FIREWORKS	ROUTE TO FIREWORKS
	USE FITZHUGH AVE	INFORMATION AHEAD
2 (Mockingbird Lane)	FIREWORKS BEST ROUTE	FIREWORKS BEST ROUTE
	FITZHUGH AVE 1 MILE	FITZHUGH AVE 1 MILE

Message 1 was designed so that the two sign messages were so redundant that even if a driver saw only one sign the information would still be conveyed. Message 2 simulated a signing system where the first sign (most likely static) would alert drivers that information concerning the best route would be given downstream. The intent was to evaluate the need for redundancy.

Human factors laboratory studies indicated that care must be exercised in selecting the destination name used on the sign display. Although the Cotton Bowl-Fairgrounds complex in Dallas is locally called Fair Park, this name was ruled out for matrix signs because it might not have been understood by nonlocal drivers. Highway maps designate the area as Cotton Bowl-State Fairgrounds. Since the major event on the Fourth of July was the elaborate fireworks display, the decision was made to use FIREWORKS. COTTON BOWL would be the preferred choice for football games, whereas FAIRGROUNDS would be appropriate for the state fair.

Human factors laboratory studies also suggested that it would be better to break long messages into chunks than to display the entire message at once. In addition, the message chunks should each be a complete phrase. Chunks or phrases can be displayed alternately on the sign to form the complete message. Sequencing the message phrases has the added advantage of attracting the attention of the drivers.

Trailblazer Signs

Human factors laboratory studies indicated a great need for route guidance along the alternate route for drivers who diverted from their primary routes. Results of the studies also indicated that symbolic or logo signs helped provide trailblazing information to drivers along an unfamiliar route if these were proper transitions between the primary message on the freeway and the logo trailblazers.

The Dallas traffic operations personnel requested consideration of a unique Fair Park logo and word-message trailblazer they were developing. The trailblazer signs adopted cooperatively by the city of Dallas and the Texas Transportation Institute (TTI) research staffs for the study are shown in Figure 4.

The most difficult task in using trailblazers, particularly logo signs, occurs in the transition region where the driver first encounters the sign. To reduce the driving task load as much as possible during exit from a freeway and subsequent left-turn maneuver (an already loaded state), a series of transition signs was used to guide drivers through the signalized intersection and properly orient them along Fitzhugh Avenue.

Immediately after gaining correct alignment on the southbound service road, the driver was presented sign 1 in Figure 4. Sign 2 was displayed at the signal. After turning left at the Fitzhugh Avenue intersection and crossing the Expressway the driver could easily see sign 3 on the narrow separator median immediately beyond the northbound service road. Two subsequent signs of sign 4 style were located several blocks down Fitzhugh Avenue to guide the driver in the transition from the Fireworks supplementary panel to the logo trailblazer shown in signs 5 or 6. Signs with appropriate straight, advance turn, or turn arrows were located along Fitzhugh Avenue to near the entrances to Fair Park parking lots. In this vicinity, Public Parking signs with a P logo and directional arrows (signs 7 and 8) were added to the basic trailblazer sign for guidance to parking areas.

All trailblazers were fabricated of high-intensity reflective sheeting on aluminum panels 61 × 61 cm (24 × 24 in) in size. The supplementary Fireworks panels in signs 1, 2, 3, and 4 were 15.2 × 61.0 cm (6 × 24 in). The Fair Park sign was a brown panel supporting a yellow and orange logo, white Fair Park legend, and white arrow. Parking signs were green on white.

After the July 4 studies, the upper panels on signs 1, 2, and 3 were replaced by one saying COTTON BOWL and FAIRGROUNDS on a two-line panel. Likewise, the FIREWORKS legend on sign 4 was replaced with COTTON BOWL-FAIRGROUNDS. These more generalized signs then remained in position until subsequent special events.

FIELD STUDIES

Matrix Sign Operation

The intended plan was to display each of the two alternative messages on the University Avenue and Mockingbird Lane overcrosses according to the following time schedule:

Time (p.m.)	Message	Time (p.m.)	Message
6:30 to 7:00	2	7:50 to 8:05	2
7:00 to 7:10	blank	8:05 to 8:15	blank
7:10 to 7:40	1	8:15 to 8:30	1
7:40 to 7:50	blank		

Unfortunately, during the study the Mockingbird sign malfunctioned between 6:30 and 6:45 p.m. and was inoperative from 6:45 to 7:00 p.m. This required field adjustments to the display schedule.

The original intent was to display messages 1 and 2 twice each during the study period. Although message 1 was successfully replicated, the Mockingbird sign

Figure 4. Trailblazer signs.

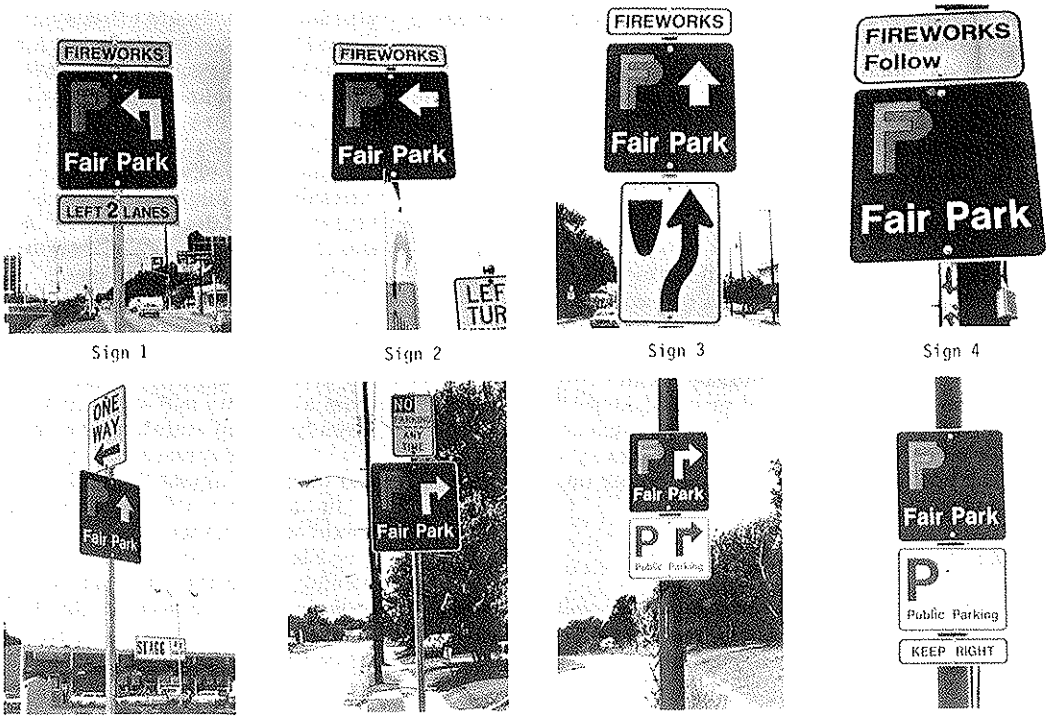
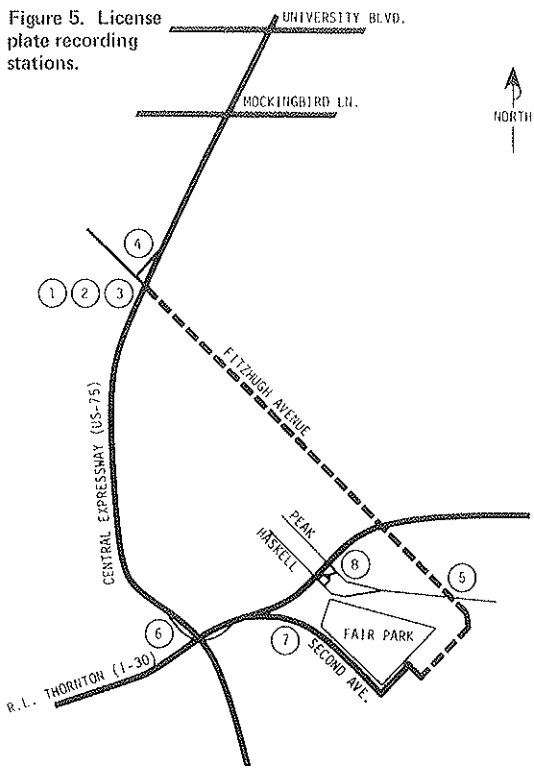


Figure 5. License plate recording stations.



failed to display the proper sequence of message 2 during the initial phase of the study. In addition, the field crew was trying to put up the correct message, which was therefore not displayed continuously throughout the 15-min period.

The actual message display schedule was as follows:

Time (p.m.)	Message	Time (p.m.)	Message
6:30 to 6:45	2a (malfunction)	7:55 to 8:10	2
6:45 to 6:55	blank	8:10 to 8:20	blank
6:55 to 7:00	1 (University only)	8:20 to 8:25	1
7:00 to 7:35	1	8:25 to 8:30	blank
7:35 to 7:55	blank		

Data Collection

Comprehensive origin-destination data were collected throughout the study. License plates of almost every vehicle passing the eight locations shown in Figure 5 were recorded continually throughout the 2 h 15 min study. The locations were selected to permit as accurately as possible a determination of travel patterns on both primary and alternate routes and to include all vehicles that passed the matrix signs on the way to Fair Park.

License plates were recorded on cassette tape for each location. The heavy volume of main lane traffic passing the Fitzhugh Avenue overcross necessitated individual lane surveillance. License plates were read from the overcross sidewalk through high-powered binoculars mounted on tripods. Recorders rotated every 10-min and provided better than a 95 percent count when compared to the main-lane volume data from the permanent detectors. Observers also recorded the time to ensure proper coordination with the sign messages.

License plate information was transcribed from the cassette tapes, punched on computer cards, and processed to identify matches at various recording locations. This allowed us to trace travel patterns of almost all the vehicles without spot-sampling and interviewing drivers at selected locations.

RESULTS

A comparison of the route choices by southbound Central Expressway drivers destined to Fair Park is presented in Table 1 and Figure 6. The data are presented by

Table 1. Route choices by Central Expressway drivers.

Message	Time Period (p.m.)	Drivers to Fair Park: Using Fitzhugh Avenue, No.	Using Fitzhugh Avenue, Percent	Using US-75/I-30	Total
Blank	6:17 to 6:32	8	10.1	71	79
2a	6:32 to 6:47	30	28.6	75	105
Blank	6:47 to 6:57	15	15.5	82	97
1	6:57 to 7:37	251	68.6	115	366
Blank	7:37 to 7:57	13	10.2	114	127
2	7:57 to 8:12	101	56.4	78	179
Blank	8:12 to 8:22	10	16.1	52	62
1	8:22 to 8:27	33	70.2	14	47

Table 2. Message effects on route diversion from Central Expressway.

Message	Drivers to Fair Park: Using Fitzhugh Avenue, No.	Using Fitzhugh Avenue, Percent	Using US-75/I-30	Total	Drivers Diverted to Fitzhugh Avenue (%)
Message 1	284	68.8	129	413	56.2
Message 2	101	56.4	78	179	43.8
Message 2a[a]	30	28.6	75	105	16.0
No message	46	12.6	319	365	—
Before study (May 22, 1976)	22	9.8	202	224	—

[a]Sign malfunction.

Figure 6. Percentage of drivers using Fitzhugh Avenue to Fair Park.

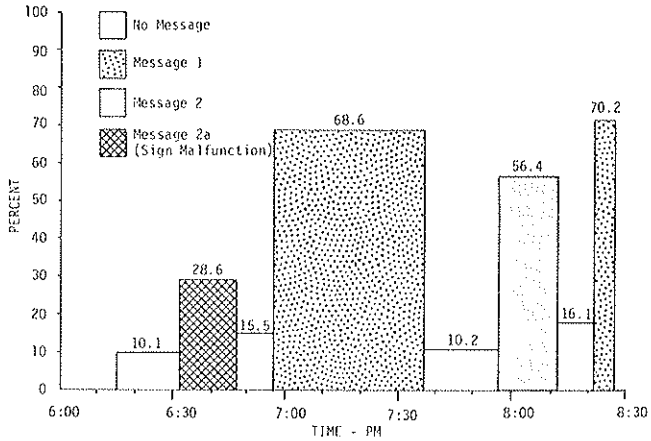
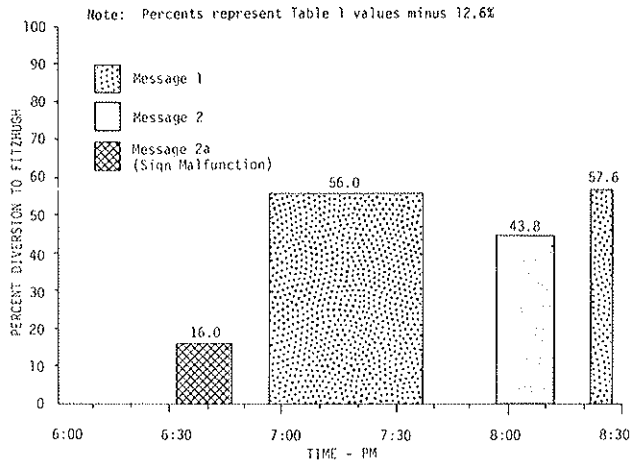


Figure 7. Effects of matrix sign messages on route diversion.



time periods in relation to times when matrix sign messages were displayed. Since the matrix sign nearest to the Fitzhugh exit ramp was about 2.4 km (1.5 miles) upstream, the effects of the messages would not be noticed at the Fitzhugh ramp until about 1.6 min after a sign message was displayed [assuming 88 km/h (55 mph) average speed], the time periods shown in Table 1 and Figure 6 have therefore been adjusted by 2 min.

The results reveal a very pronounced and positive effect on the number of drivers using the Fitzhugh Avenue alternate route when matrix sign messages 1 and 2 were displayed. The percentage of drivers using Fitzhugh when no messages were displayed ranged between 10.0 and 16.1 percent. In contrast, between 56.4 and 70.2 percent took the alternate route when messages 2 and 1 were displayed (these data do not include percentages for message 2a when the Mockingbird sign malfunctioned).

Table 2 and Figure 7 are presented to illustrate the amount of diversion resulting from the matrix sign messages. During the July 4 study an average of 12.6 percent of the drivers routinely chose the Fitzhugh route (no message displayed). This compares favorably with earlier studies conducted by TTI on Sunday, May 23, 1976, when 9.8 percent of the drivers used the Fitzhugh route (the midway is open every weekend).

Subtracting the 12.6 percent from the percentage using Fitzhugh Avenue when specific messages were displayed yields the following results: message 1 with its redundant sign messages influenced 56.2 percent (weighted average, Table 2) of the drivers to divert to the alternate route; message 2 and its advanced warning and route information resulted in 43.8 percent diversion. On the average, 52.4 percent of the drivers diverted when a message was displayed.

ACKNOWLEDGMENTS

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