Table 1. Average rating of message urgency and percentage of subjects understanding meaning.

Message	Urgency Rating	Radio Message Mentioned (%)	Traffic Conditions Mentioned (%)
A. RADIO ALERT TUNE 1606	4.5	95.2	19.0
B. RADIO TRAFFIC ALERT TUNE TO 1606 AM	4.4	81.0	66.7
C. TRAFFIC ALERT TUNE 1606	4.2	89.5	36.8
D. RADIO TRAFFIC ALERT TURN DIAL TO 1606	4.1	87.0	82.6
E. RADIO TRAFFIC ADVISORY 1606 ON YOUR AM DIAL	4.0	95.0	75.0
F. RADIO TRAFFIC ADVISORY TUNE 1606 FOR INFORMATION	4.0	68.8	50.0
G. RADIO TRAFFIC ALERT TUNE TO 1606	3.9	86.2	75.9
H. TRAFFIC ADVISORY TUNE 1606	3.8	100.0	42.1
I. RADIO ROUTE INFORMATION TURN DIAL TO 1606	3.7	76.2	71.4
J. RADIO ROUTE INFORMATION SET DIAL TO 1606	3.5	88.0	72.0

Table 2. Order of preferences for messages.

Message	Preference Rank	Preference Percent
RADIO TRAFFIC ALERT TUNE DIAL TO 1606	1	70.5
RADIO TRAFFIC ALERT TUNE TO 1606	2	68.6
TRAFFIC ADVISORY TUNE 1606	3.5	56.4
TRAFFIC ALERT TUNE 1606	3.5	56.3
RADIO TRAFFIC ADVISORY TUNE 1606 FOR INFORMATION	5	48.2
RADIO TRAFFIC INFORMATION SET DIAL 1606	6	45.8
RADIO ROUTE INFORMATION TUNE DIAL TO 1606	7	43.7
RADIO TRAFFIC ADVISORY 1606 ON YOUR AM DIAL	8	43.1
RADIO ROUTE INFORMATION SET DIAL TO 1606	9	35.2
RADIO ALERT TUNE 1606	10	31.7

revealed that 75 percent of subjects felt it meant AM only and all but one of the others felt it meant either AM or FM.

The second study investigated preferences among the messages by means of the paired-comparisons method. Table 2 presents the messages in rank order in terms of percentage of times the message was preferred to all other messages. The two messages preferred most often were almost identical. Messages containing RADIO ROUTE INFORMATION or RADIO TRAFFIC INFORMATION were preferred less often than by chance. The latter message was not investigated in Los Angeles but was included because it was used in the study by Brizell and Veale (2). Messages that involved TRAFFIC ADVISORY were intermediate in preference. The RADIO ALERT message was preferred the least. In general, the preference data, using an independent sample in a different state, supported the findings of the Los Angeles study.

RECOMMENDATIONS FOR MESSAGE DESIGN

When the design objective is to imply an urgency to tune to a radio frequency, the word alert is most effective. Both the interpretation and preference data suggest the word implies a nonroutine, incident-related situation that requires action.

Although the word radio is implied somewhat from the advisory, the preference data support its inclusion. Omission of the word traffic can result in misunderstanding the message RADIO ALERT. Based on the two studies, RADIO TRAFFIC ALERT is recommended for this purpose.

The advisory message may be understood effectively by simply stating, "TURN TO (frequency number)" or "TUNE DIAL TO (frequency number)." Long advisory messages with redundant words should be avoided. SET DIAL and TURN DIAL were not evaluated independently, but the single word tune is well understood.

REFERENCES

1. F. P. Gatling. Advisory Message Studies for Route Diversion. Federal Highway Administration, Rept. FHWA-RD-75-73, June 1975.
2. E. G. Brizell III and N. L. Veale. Highway Advisory Radio in the Philadelphia Area. Delaware Valley Regional Planning Commission, Rept. FHWA-RD-78-77, April 1978.

Publication of this paper sponsored by Committee on Motorist Information Systems.

Abridgment

Legibility Study of a Lamp Matrix Sign

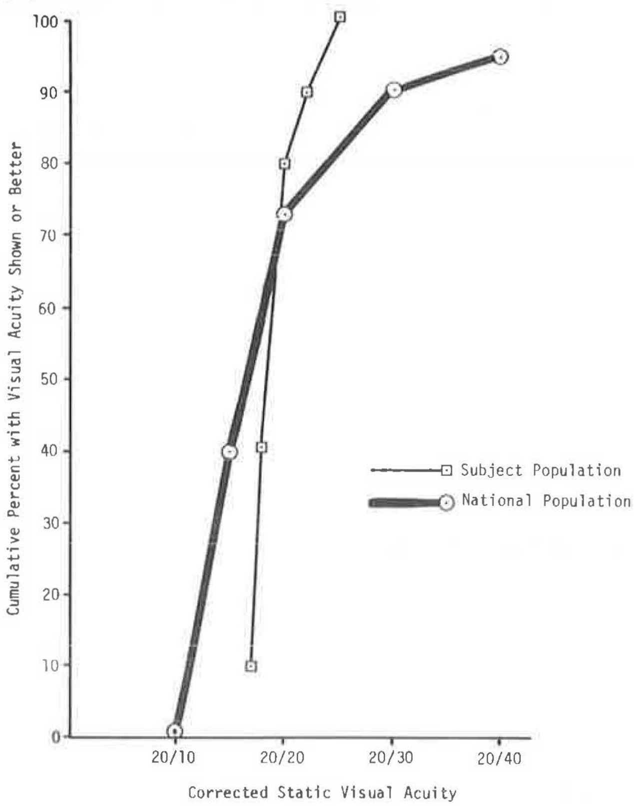
William R. Stockton and Conrad L. Dudek, Texas Transportation Institute, Texas A&M University, College Station

The legibility of painted signs has received considerable attention and thus has been well developed in recent years; however, a similar body of knowledge about the legibility of lamp matrix signs is nonexistent. This unfortunate circumstance has resulted in engineers' designing and installing lamp matrix displays according to rules of thumb or manufacturers' recommendations.

As a part of a study, the Texas Transportation Institute conducted numerous field studies using a lamp matrix sign (1). The availability of this display, which generated 46-cm (18-in) characters, afforded the opportunity to investigate legibility distance along with other display characteristics. As the study was limited to one sign and a relatively small number of subjects (20), the results of this research certainly do not constitute definitive guidelines for the design of lamp matrix signs. Rather, the study provides an indication of the approximate legibility of a 46-cm character lamp matrix sign. Inferences drawn from this study may be useful as a starting point in the design of other sizes of lamp matrix displays.

Figure 1. Subject vehicle approaching sign.

Figure 2. Comparison of visual acuities of subjects to national population.



BACKGROUND

The subject of legibility distance was first addressed when project researchers were concerned about the amount of time available to display information to a driver. Available reading time is determined by legibility distance and vehicle speed. As speed would be either a known or estimable quantity, legibility distance was the only factor that required definition.

The Illuminating Engineering Society recommends that letter height be computed as (2)

$$Hr = D/500 \quad (1)$$

where

Hr = minimum letter height (m), and
D = maximum distance at which letter is legible to a majority of people (m).

This equation suggests an assumed legibility distance of 4.99 m/cm of letter height (41.7 ft/in). Bogdanoff and Thompson (3) concluded from an undocumented field study that a 46-cm character lamp matrix sign was readable at 243 m (800 ft) for the average motorist. This approximate distance translates to about 5.31 m/cm (44 ft/in) of letter height.

Although these sources did not provide definitive supporting data, they did serve as a basis for comparison. Further, we felt that not only should the average or majority legibility distances be investigated, but that the 85th percentile should also be investigated as it would probably more nearly represent a design value.

STUDY DESIGN

The field study consisted of a determination of the maximum distance at which each of 20 subjects could read a test word. Each subject read three test words, randomized in order between subjects. The test words used were BOAT, BOOK, and ROCK. These words were chosen because they had been shown to be of very nearly equal legibility in a previous Texas Transportation Institute study. The mean legibility distance of the three trials was used as the subject's legibility distance in further computations.

The field study was conducted at the Texas Transportation Institute's proving grounds. A trailer-mounted lamp matrix sign was set up and the study conducted to simulate, as nearly as possible, an actual driving situation (Figure 1). Subjects were tested one at a time while driving a 1976 Chevrolet sedan. Each subject made three test runs at 32 km/h (20 mph). A different legibility test word was used for each run.

Each of the 20 subjects was a licensed driver who had a known corrected static visual acuity. Subjects were chosen from a subject pool to replicate, as closely as practical, a national cross-section of drivers. As these subjects were used in several other field experiments during the testing period, corrected static visual acuity was only one of several selection criteria. However, as shown in Figure 2, their measured visual acuities were fairly close to that of the national driving population (4).

Procedure

Prior to the beginning of each individual study, the experimenter gave instructions to the subject and allowed him or her to become familiar with the vehicle. To be-

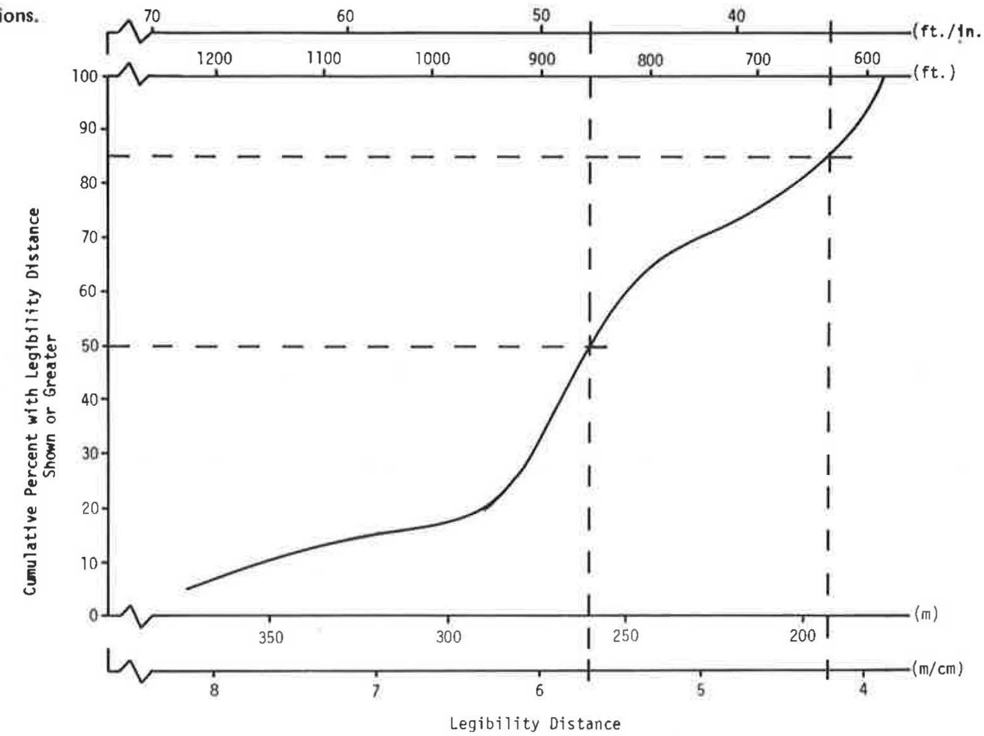


Figure 3. Legibility distance observations.

gin each trial run, the experimenter had the subject drive to a distance well beyond legibility distance of the sign [about 600 m (2000 ft)]. The subject then proceeded toward the sign at about 32 km/h. When the subject was approximately 486 m (1600 ft) from the sign, the second administrator displayed one of the three test words on the sign. As soon as the subject read the word displayed, he or she called out that word to the on-board experimenter, who noted the distance from the sign as indicated by markers alongside the roadway. This procedure was repeated for each of the other two words.

Results

The results of the study indicate that the previous estimates of legibility of lamp matrix signs were fairly accurate with respect to the average driver. However, it appears that a more conservative estimate of legibility distance may be in order for design purposes. As each of the test words had been shown to be fairly equal in legibility, the mean of the three distances was computed for each subject. These means were then plotted on a cumulative distribution (Figure 3).

The mean legibility distance for all subjects was about 255 m (840 ft). This distance translates to 5.58 m/cm (46.7 ft/in) of letter height. From Figure 3, the median legibility distance was 261 m (860 ft), but for the 85th percentile the legibility distance was 194 m (637 ft). These distances translate to 5.72 m/cm (47.8 ft/in) and 4.24 m/cm (35.4 ft/in) respectively.

DISCUSSION OF RESULTS

This analysis showed the 85th percentile legibility distance of a 46-cm matrix sign to be about 4.2 m/cm of letter height. The closeness of the corrected static visual acuities of the subject population and the national population and the general agreement between the study mean and previously reported averages further substantiate the results. The study considered only one size of lamp matrix display, so we cannot generalize the reported legibility distances to other sizes or types of matrix displays. However, these values may be considered as a base from which to conduct further investigations.

Although not addressed in this study, previous field experience has shown that the brightness of the lamps used has a considerable effect on legibility (5). It was found that the size of bulbs necessary to construct a seven-row matrix of less than about 25 cm (10 in) did not produce adequate brightness for effective legibility.

ACKNOWLEDGMENTS

This paper discusses one phase of a research project entitled "Human Factors Requirements for Real-Time Motorist Information Displays," conducted by the Texas Transportation Institute and sponsored by the Federal Highway Administration. The contents of this paper reflect our views and we are responsible for the facts and the accuracy of the data presented. The contents do not reflect the official views or policies of the Federal Highway Administration. The paper does not constitute a standard, specification, or regulation. We wish to express appreciation to Truman M. Mast of the Federal Highway Administration for his guidance throughout the project.

REFERENCES

1. C. J. Messer, W. R. Stockton, J. M. Mounce, D. A. Anderson, and J. M. Turner. Human Factors Requirements for Real-Time Motorist Information Displays, Vol. 8: A Study of Physical Design Requirements for Motorist Information Matrix Signs. Texas Transportation Institute, June 1976.
2. Lighting for Advertising. In IES Lighting Handbook (John E. Kaufman, ed.), Illuminating Engineering Society, New York, 4th Ed., Chap. 16, 1968.
3. M. A. Bogdanoff and R. P. Thompson. Changeable Message Signs. In Evaluation of Warning and Information Systems, Los Angeles Area Freeway Surveillance and Control Project, Pt. 1, Freeway Opera-

tions Branch Rept. 75-5, Sept. 1975.
4. N. J. Rowan and D. L. Woods. Diagnostic Studies of Highway Visual Communication Systems. Texas Transportation Institute, Research Rept. 606-9 F, 1970.
5. W. R. Stockton, C. L. Dudek, D. B. Fambro, and C. J. Messer. Evaluation of a Changeable Message Sign System on the Inbound Gulf Freeway. Texas Transportation Institute, Research Rept. 200-1F, 1975.

Publication of this paper sponsored by Committee on Motorist Information Systems.

Abridgment

Real-Time Diversion of Freeway Traffic During Maintenance Operations

J. Michael Turner and Conrad L. Dudek, Texas Transportation Institute, Texas A&M University, College Station
James D. Carvell,* Pinnell, Anderson, Wilshire and Associates

A changeable message signing system can be used to divert vehicles around an incident and to redistribute traffic to available capacity of an alternate route, such as a service road or parallel arterial street. This diversion will reduce motorists' travel time, improve the level of service on the freeway, and enhance safer operating conditions on the freeway by providing motorists with advance information of unusal traffic conditions.

Messages developed in previous studies were displayed in actual field operation in response to freeway maintenance to determine the relative effectiveness of each message. In addition to routing traffic on the service road around freeway incidents, diversion to alternate arterial routes off the freeway was planned.

The study site was the North Central Expressway, a fully access-controlled freeway, which may be described as a depressed freeway with diamond interchanges in all interchange locations except two. A full cloverleaf interchange is at loop 12 (Northwest Highway) and a directional interchange is at I-635 (LBJ Freeway).

Three study locations were identified for applying management measures, and collection of data was in the northbound (outbound) direction from Mockingbird to loop 12. All service road intersections are under computer control so that real-time operation changes could be made to complement freeway management activities.

STUDY DESIGN

One objective of this research effort is to establish incident management techniques for use in a freeway surveillance and control environment. The three elements to be defined for the incident management studies are (a) incident detection, (b) management measures of alternatives, and (c) measures of effectiveness. Detection of incidents along the study areas on North Central Expressway in Dallas was accomplished by a nine-camera closed-circuit television (CCTV) system; however, for this study information about maintenance operation was known beforehand in most cases.

After the detection and verification of an incident, it is desirable that the driver be given sufficient information to avoid delay and hazardous conditions. Candidate messages for diversion were evaluated by use of two management techniques:

1. The diversion of freeway traffic to the service road around the incident, and
2. The diversion of freeway traffic to arterials around the incident.

Measures of effectiveness for candidate messages were derived from two sources:

1. The change in diversion rates from natural diversion (nonmanagement) to diversion because of informational signing (management), and the varying candidate messages thereof, and
2. Questionnaires, which were distributed to drivers where duration of the incident allowed.

The changes in diversion rates provided a quantitative measure of the effectiveness of various candidate messages. By a comparison of diversion rates as measured at freeway ramps during nonmanagement and management incidents and during the display of various candidate messages, their relative effectiveness could be measured. Questionnaires distributed to drivers who actually passed the sign displays provided a qualitative measure of the adequacy of the information provided. Drivers were asked to evaluate the information displayed as well as to give their opinion about what further information would be helpful.

Hardware Systems

For purposes of this research, it was necessary to design and install sign hardware that would be sufficiently flexible to satisfy the objective of testing a variety of candidate messages.

Three trailer-mounted, computerized, bulb matrix displays (Figure 1) were employed to present diversion information along northbound North Central Expressway in Dallas. The use of these signs provided versatility in message length, display forms, and rate of display, which greatly increased the number and types of messages to be displayed. The ability to display a message is provided to the operator through the use of a digital computer located on the sign trailer in an environmental equipment cabinet.

Procedure

Based on previous studies, a catalogue of candidate