THE CHANGEABLE MESSAGE CONCEPT OF TRAFFIC CONTROL

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THE CHANGEABLE-MESSAGE CONCEPT OF TRAFFIC CONTROL

Report of a conference held July 15-16, 1971

Subject areas

52 road user characteristics
53 traffic control and operations

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FOREWORD

The application of the changeable-message concept to highway-signing technology permits traffic engineers to exercise more flexibility in providing information, warning, and regulatory messages to motorists as conditions change. The capability of static-sign assemblies to provide the needed information is limited.

Recognizing the value of this evolutionary concept and the need for an open discussion of the relative merits of the several current designs for changeable-message signs, the Highway Research Board Committee on Traffic Control Devices sponsored a conference in July 1971 that brought together those involved in the research, development, manufacture, marketing, and operation of the various types of changeable-message signs. The program was structured to permit a comparative evaluation of the various concepts and designs for changeable-message signs commercially available.

One of the objectives of the conference was to publish the proceedings so that the information presented would be available to all highway engineers, administrators, and others concerned with highway signing. This Special Report contains the conference presentations. The application of this information should prove highly beneficial to those concerned with more effectively communicating highway and traffic conditions to motorists on an accurate and timely basis.

INTRODUCTION

Z. A. Nemeth

During the past decade or so we have learned to think about highway transportation as a system that includes the roadway, the traffic control devices, the vehicle, and the driver. The systems engineering approach helped us to understand the functions of the highway transportation system, to identify and characterize the elements and the environment of the system, and to learn more about the operation of the system.

We have become conscious of the existing disorder in the operation of the highway transportation system. Some of the sources of the disorder are easily identified. One source, for example, is the adverse effect of environment changes: snow, ice, rain, or fog. In general, however, the disorder is due to the limited "integration" of the elements of the system. The most striking improvements in traffic operation are associated with the reduction of this constraint by improving communication and coordination among elements of the system.

The communication between the roadway and the driver is provided by traffic signs and pavement markings. The conventional or static sign can do a good job of conveying a message to the driver about a static situation. The solution to some of the problems created every day by variation in the environment or in the system, however, can only be provided by changeable-message signs.

This Special Report contains papers presented at the conference on the design, operation, and use of changeable-message signs.

SOME PRINCIPLES FOR COMMUNICATING WITH DRIVERS THROUGH THE USE OF VARIABLE-MESSAGE DISPLAYS

B. W. Stephens

A sizable number of potential applications of variable- or changeable-message, traffic-control signs have emerged in the past few years. Such signs are envisioned as being a more efficient method for communicating current or imminent roadway or traffic conditions to motorists so that level of service and traffic flow relations will be optimized. Because of the growing number of applications of this kind of communication system, those of us who are concerned specifically with effective communication of highway and traffic conditions must establish bases for rules, tenets, or principles to be applied to the use of changeable-message signs.

MEETING EXPECTATIONS OF MOTORISTS

A statement frequently made by traffic engineers is that motirists generally will be responsive to signs, signals, and other communication devices when the message presented is one that is accurate and timely. For example, a red signal at an intersection is taken seriously, but a fixed sign near a bridge with the message SLIPPERY WHEN WET is given little notice on a bright summer day. A general term for such behavior is is "driver expectancy."

King (1) formulated 5 "basic tenets for the systematic presentation of information needed by the driver." Among those rules is expectancy, which King interprets to mean that traffic and highway designers should avoid surprising motorists. There is a substantial amount of evidence from the literature on human behavior that indicates that King's statement must be qualified and that, in general, the surprise value of a message contributes substantially to its comprehension. A program of studies undertaken by Berlyne indicates that attentiveness to various displays depends to a large extent on their complexity (2). Various simple displays with high predictability generally do not maintain one's attention for very long, whereas a somewhat more complex or novel display generally sustains attention. Studies conducted by Pribram (3) also convey that only so long as inputs provide some elements that are relatively novel does the individual continue to sample or attend to the display.

The other important aspect of the statement by traffic engineers, i.e., the message must be accurate and timely, is related to learning. Motorists must learn relations between the message content and the performance expected of them. For example, the color red has little ambiguity for motorists, at least for American motorists. Although it is assumed that there is a variety of possible interpretations made by different motorists of the same content, there appears to be little evidence for that assumption in the literature. We do find that where there is redundancy of various cues on signs the cues are used selectively. For example, a 1962 study conducted by Gray and Russell (4) revealed that approximately one-third of unfamiliar motorists queried indicated that they used destination names on guide signs, one-third used route numbers, and one-third used both. Such differences reflect different strategies of different motorists in carrying out trips but provide no information on possible ambiguities as associated with low-redundancy signs.

It is difficult to know whether a specific road sign was seen and understood or needed by the motorist. There is some evidence that road signs with messages that are important to drivers simply do not communicate that message. A series of studies reported by Johansson and others (5, 6) indicate that 5 warning signs experimentally placed on Swedish roadways had a likelihood of being noticed 26 to 66 percent of the time, depending on the specific sign. In a recently published study, Johansson and Backlund (6) separated samples of subjects into 2 groups: (a) those who were aware of the experiment and were looking for experimentally positioned warning and speed-limit signs and (b) those who were naive with regard to the experiment. Although under none of the signing conditions did all of the subjects interviewed correctly report the types of signs they had just passed, the enhanced expectancy of prepared motorists contributed to substantial increase in the likelihood of correct responses. Correct reports were given 1.5 to 2.8 times more often by those looking for the signs than by the naive motorists. For a substantial number of the motorists in these experiments, the signed information appears to have merely blended into the background; it is not possible to determine whether the signed information was not conspicuous enough or whether many motorists simply could not believe that an external fixed sign provides timely information.

PROVIDING DIRECTIONS THAT CONFORM WITH BEST INTERESTS OF INDIVIDUAL MOTORISTS

Although the "nut-behind-the-wheel" notion is still a part of our accident causation folklore, many traffic engineers think of the driver as a capable and rational being bent on optimizing his best interests and frequently making even poorly design geometrics and traffic control devices operate reasonably well a great deal of the time. If traffic engineers attempt to optimize traffic flow to the detriment of individual motorists, it is probable that motorists will catch on. Most signal-timing schemes seem to be partially based on such an assumption. Nearly nothing has been published relevant to this point.

Among the traffic control strategies utilized at the National Proving Ground in Detroit was the use of overhead lane-control signs and variable-message speed limit signs. Wattleworth et al. (7) reported that some drivers (we do not know how many, but it is implied that the number is considerable) used the closed lanes "to their advantage because they were nearly vacant of other vehicles and high speeds were possible." Wattleworth reports that variable speed-limit signs appeared to be somewhat effective until motorists detected a staged incident (which presumably they inferred was the reason for a reduced speed limit). After the incident was detected, motorists resumed "a more natural speed" and appeared to ignore the speed-limit signs.

Current research underway at FHWA also seems to indicate that, where regulatory signing prohibiting certain traffic movements is in conflict with perceived time savings by motorists, a substantial number of drivers will disobey the regulatory sign. The number of violations in this situation appears to be directly related to the time savings to be gained by motorists.

MAINTAINING CONTINUITY, RELIABILITY, AND ADVANCE NOTICE IN SIGNING

More than a decade ago, a study on freeway directional signing was reported by Schoppert et al. (8). Based on an analysis of reports of motorists' experiences on freeways, a set of principles for improved directional freeway signing was developed.

Those principles include interpretation, relatability, continuity, advance notice, and prominence. Interpretation and prominence seem bound up with the factors that we considered earlier. All of the principles can be generalized to directional signs as well as to other forms of road signs.

The principal reason that those results are recalled in the context of this discussion on changeable-message signs is simply that they may be easily forgotten or otherwise ignored. Let us consider the importance of continuity in the use of variable-message signs. Continuity, of course, refers to the consistent use of information content within a circumscribed geographical area. For example, if WEST BEACH is used in a guide sign in advance of the interchange, it should also be used in signs at the exit and at subsequent splits within the interchange area and on the road beyond.

Conditional guide signs that attempt to convey alternate courses depending on traffic load must be so constructed that continuity with existing fixed signing is maintained. Converting a fixed sign to a changeable-message guide sign at a single location could lead to greater rather than lesser confusion.

Relatability refers to a signed reference to the actual geometric and traffic conditions as well as to a map representation of such conditions. Corridor and ramp control systems, such as the one on the Gulf Freeway in Houston, are incorporating dynamic displays of the system for motorists. Those dynamic displays obviously must be related to prevailing traffic conditions. The prominence of such signals, of course, could easily overshadow important displays of geometric conditions such as lane drops. In such cases, the lane-positioning directions could easily be brought into conflict, unless optimal spacing schemes or integration of such displays are developed.

Advance notice refers to the positioning of road displays in relation to the location of the condition that is the subject of the display. Some evidence from the National Proving Ground tests conducted by the Texas Transportation Institute suggests that in cases where sight distance is restricted variable-message, speed-control signs were effective in alerting drivers. The data also indicate that those signs were capable of inducing progressive decreases in the standard deviation of vehicle speeds under conditions where a specific incident (presumably associated with the speed sign) was not viewed directly.

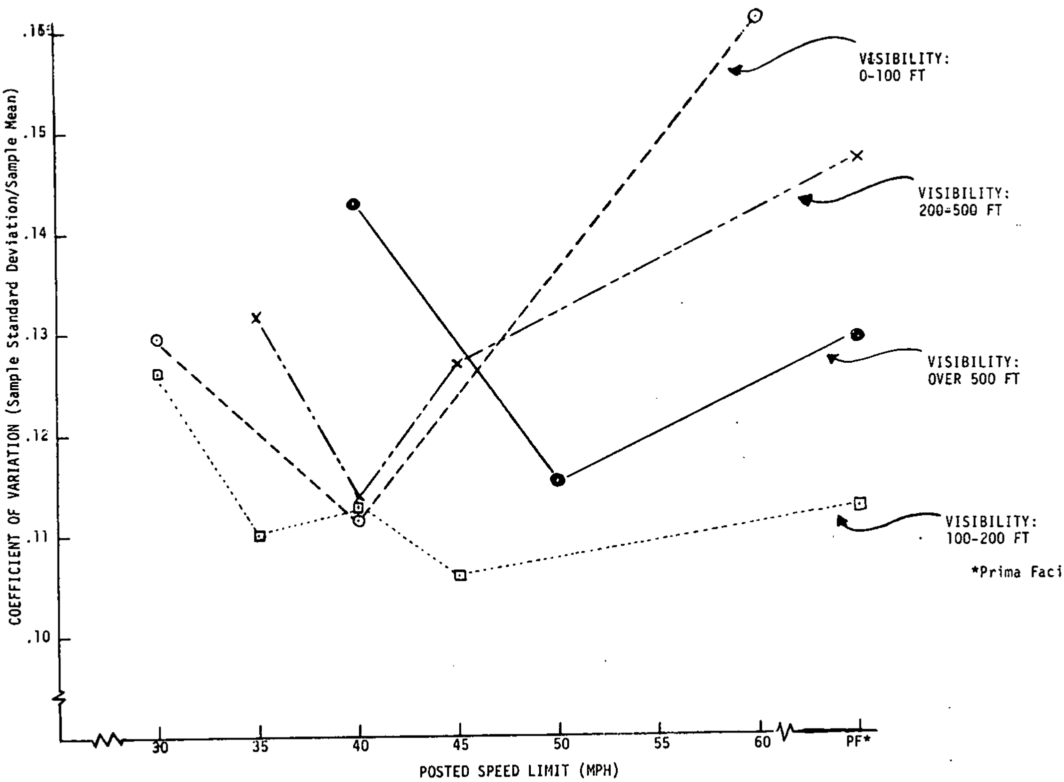
Closely associated with the concept of advance notice is the notion of providing information that helps the motorist overcome sight distance limitations. Nature provides a changeable sight distance problem that appears to be capable of being compensated for by the judicious use of variable-message signs. Recently we had occasion to extend analysis of a 1966 fog study conducted by the California Division of Highways (9). In this study a number of techniques were employed in an attempt to improve traffic movement and reduce accidents on fog-laden roads. The California investigators concluded that "of all the devices and techniques tried on the highway only the posting of speed limits (using changeable message speed signs) had any measurable effect on traffic." As a part of this study, spot speed measurements were taken under various conditions of fog density. Speed limits were systematically varied for various traffic volume conditions.

Our analysis involved making calculations of the coefficient of variation of speeds (an inverse measure of traffic speed stability). Those measures were then related to the posted speed limits as a function of fog-related sight distance. Speed data were used from a 4-lane divided expressway with partial control of access (San Francisco) and Interstate 80 and Calif-160 (Sacramento) for night and day conditions under high and low traffic volumes. Where sufficient data exist, the results are practically unequivocal. There is an advisory speed at which maximum stability exists, and that value differs depending on the visibility conditions. As visibility decreases, the posted speed at which the relative dispersion is minimal is lowered (Fig. 1). In other words, lowering the posted speed a little below the nonsigned "natural speeds" can improve traffic stability; lowering the posted speed too much will reduce stability. Each visibility distance condition has its own optimal value.

OTHER PRINCIPLES

A great deal of effort has been expended to ensure that specific highway and street signs can be detected and the content recognized. Much of the production and painstak-

Figure 1. Speed turbulence as a function of posted speed limit for 4 visibility conditions.



ing efforts have been carried out by Forbes and others at Michigan State University. A great deal of the work completed in applicable both to changeable-message signs and to fixed signs. However, some of the problems of variable-message signs are different and may require further work on visibility, legibility, and attentional demands. Some of these areas are suggested in the following list:

1. Most contemplated changeable-message signs involve luminous sources rather than reflected light, posing specific visibility problems. Contrast between background areas will be much different; compensatory circuits will probably be required for day-night differences and possibly for different gradients of sky brightness.

2. An evaluation of confusion between traffic control devices and commercial displays may be necessary. A proliferation of variable-message signs using matrices and an increased range of spectral characteristics in urban areas would be expected to have detrimental effects on operator detection and discrimination performances.

3. Confusion between similar letters and numbers (such as 5 and S) can be increased with bulb matrix designs or neon or similar light sources. It is not unlikely that other standard numerical-alphabetical series will have to be adopted.

4. Working with the new medium may facilitate the tendency of designers to put too much information on the sign partly because of basic costs for such signs. Masking of "off" portions of the sign must be accomplished cleanly.

5. Initial implementation should employ simple sign arrays. In a 1970 study by Dudek and Jones (10), motorists indicated a preference for "real-time information displays that were simple...over designs containing diagrams that orient them to the freeway and arterial streets."

APPLICATIONS

The direct evidence for establishing the benefits of variable-message signs is meager. Many of the data collected thus far have involved the use of questionnaires and attitude measurement of an abstract nature or laboratory experimentation [for example, Heathington et al. (11) and Dudek and Jones (10)]. Some of the traffic data were discussed earlier.

It seems reasonable to advise motorists of desirable speeds under reduced visibility or restricted sight distance, but optimal speeds to be displayed are dependent on the "natural" speeds of traffic without variable-message signs.

Ramp controls or conditional directional guide signs must be kept simple, and there is some empirical support for their use.

The direct evidence against the use of simple warning displays was not presented in this discussion. It derives primarily from preliminary results of work now being conducted by the Oregon Department of Transportation (12). Specific instructions, such as REDUCE SPEED or CHANGE LANES, that are based on a real system demand may prove effective to improve traffic operations in hazardous areas.

Changeable-message signs have a potential application to traffic operations, but this is an area to which neither operational experience nor research has offered very much. A great deal of both is required before effective principles and standards can be generated.

REFERENCES

1. King, G. F., and Lunenfeld, H. Development of Information Requirements and Transmission Techniques for Highway Users. NCHRP Rept. 123, 1972.
2. Berlyne, D. O. Conflict, Arousal and Curiosity. McGraw-Hill, New York, 1960.
3. Pribram, K. H. The New Biology of Emotion: A Structural Approach. American Psychologist, Vol. 22, 1967, pp. 830-838.
4. Gray, P. G., and Russell, R. Driver's Understanding of Road Traffic Signs. The Social Survey, Vol. 347, Oct. 1962.
5. Johansson, G., and Rumar, K. Drivers and Road Signs: A Preliminary Investigation of the Capacity of Car Drivers to Get Information From Road Signs. Ergonomics, Vol. 9, No. 1, 1966, pp. 57-62.
6. Johansson, G., and Backlund, F. Drivers and Roads Signs. Ergonomics, Vol. 13, No. 6, pp. 749-759.
7. Wattleworth, J. A., Wallace, C. E., Levin, M., and Sample, J. G. Evaluation the Operational Effects of an "On-Freeway" Control System. Texas A&M Univ., Rept. 488-2, 1968.
8. Schoppert, D. W., Moskowitz, K., Hulbert, S. F., and Burg, A. Some Principles of Freeway Directional Signing Based Upon Motorists' Experience. HRB Bull. 244, 1960, pp. 30-87.
9. Tamburri, T. N., and Theobald, D. J. Reduced Visibility (Fog) Study. California Division of Highways, Study B-1-9, March 1, 1967.
10. Dudek, C. L., and Jones, H. B. Real-Time Information Needs for Urban Freeway Drivers. Texas Transportation Institute, Res. Rept. 139-4, Aug. 1970.
11. Heathington, K. W., Worrall, R. D., and Hoff, G. C. An Analysis of Driver Preferences for Alternative Visual Information Displays. Highway Research Record 303, 1970, pp. 1-16.
12. Variable Message Fog Hazard Warning Signs to Control Vehicle Operating Characteristics. Traffic Engineering Section, Oregon Department of Transportation, Int. Rept. of Study HPR-1 (6), 1971.

CHANGEABLE-MESSAGE SIGNS IN OHIO

E. N. Burns

In Ohio we are involved in several active freeway operational projects that present challenging opportunities for the traffic engineer. One such project in Cincinnati is a proposed experimental freeway surveillance and traffic control project.

Downtown Cincinnati is served by the freeways shown in Figure 1: I-75, which is a north-south route; US-50, which is a west (Sixth Street Expressway) and east (Columbia Parkway) route; I-71, which is opened north of the proposed stadium to Broadway and ultimately will be constructed to serve the northeastern area of metropolitan Cincinnati; and I-471, which will serve the eastern and southeastern area after it is entirely completed. I-71 and I-75 now carry or will carry most of the traffic into downtown Cincinnati.

The initial section of freeway designated as an Interstate route in Cincinnati is a portion of I-71 approximately 3/4 mile in length running east and west between the central business district and the Ohio River from Central Avenue to Broadway. It is a 6-lane, depressed freeway and is locally designated as Fort Washington Way. It currently carries US-50 and was designed and built to standards considerably lower than those used for current Interstate routes.

I-75 (Mill Creek Expressway) immediately west of Fort Washington Way is an 8-lane, north-south freeway constructed to Interstate standards and was opened to traffic approximately 6 years ago. This freeway junctions and overlaps I-71 south over the 2-level Brent Spence Bridge across the Ohio River into Kentucky. The bridge carries 3 lanes directional southbound (upper deck) and northbound (lower deck). Although designed to Interstate standards, I-75 temporarily carries I-71 traffic to and through the city as the only north-south freeway. This situation will continue until approximately 1973 when I-71 will have been completed in Hamilton County.

EXISTING TRAFFIC AND OPERATIONAL CONDITIONS

At the present time there are daily afternoon peak-hour breakdowns in traffic flow on I-75 southbound approaching the I-71 junction and downtown Cincinnati (Fig. 2). The congestion can be attributed to

1. Close proximity of exits to Seventh Street, Fifth Street, and I-71 to each other;
2. Left exits to Fifth Street and I-71 connection;

Figure 1. Cincinnati freeway system.

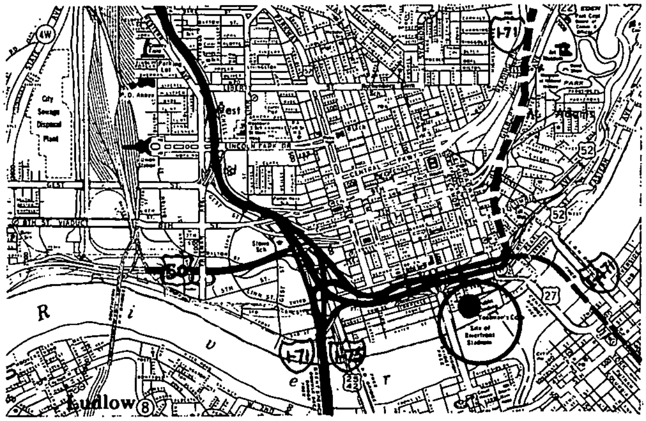


Figure 2. Junction of I-75 southbound with I-71.

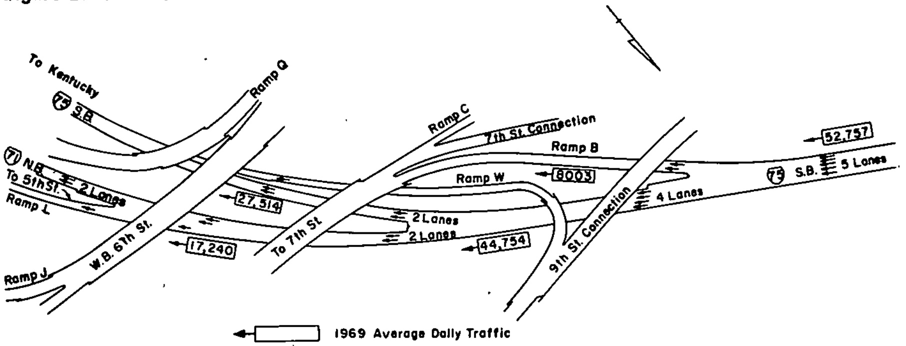
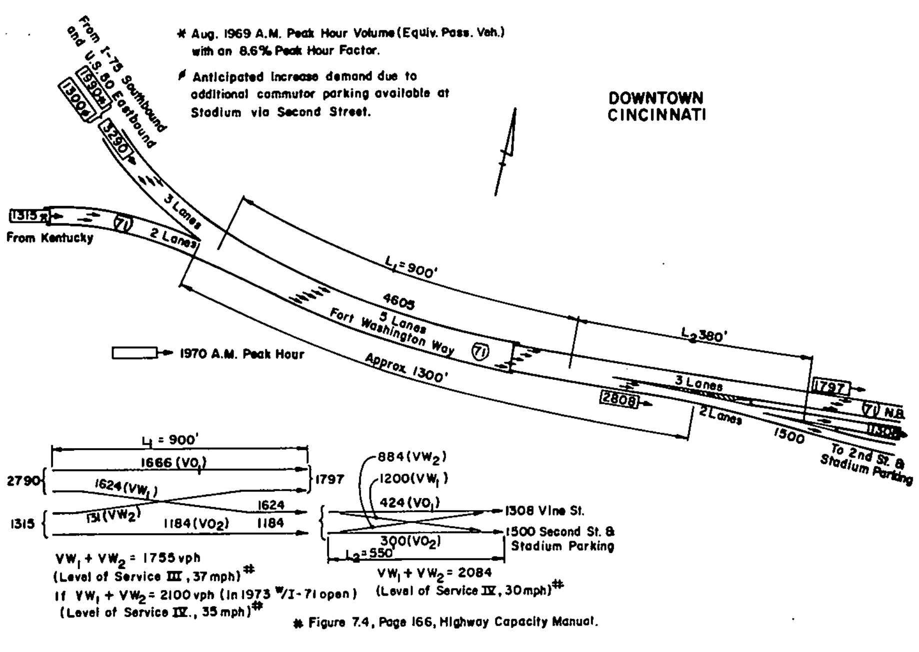


Figure 3. I-71 northbound compound weave section.



3. Lack of route sign continuity at the I-71 junction, which occurs on a horizontal curve to the right (four directional lanes diverge, and the left 2 lanes connect to I-71 northbound and the right 2 lanes carry through traffic on I-75); and
4. Limited capacity on the I-71 and I-75 Brent Spence Bridge over the Ohio River where 3 lanes reduce to 2 immediately south of the bridge.

The alignment of the freeway and the lane reduction at the junction have trapped many motorists who desire to remain on I-75 but, in spite of directional signs, find that left lanes depart to I-71. No degree of traffic control measures can ever completely overcome the unusual geometrics confronting motorists unfamiliar with this situation at that location.

A potential operational problem exists on I-71 northbound (Fort Washington Way) for traffic entering from the left from I-75 southbound and destined to the Second and the Vine Streets exit on the right (Fig. 3). Exiting traffic must execute a compound weave across I-71 northbound traffic in a weaving section where there is a dropped-lane condition because of the local exit. That particular weaving section is operating at approximately 25 mph at the present time during the morning peak periods even though it carries only local traffic from Kentucky traveling north on I-71 into downtown Cincinnati. Through traffic on I-71 is temporarily carried on I-75 as previously mentioned. Because of the lack of route sign continuity on I-71 on Fort Washington Way, this compound weaving section will be severely taxed operationally when through traffic is permanently carried on I-71.

SPORTS STADIUM PARKING FACILITY AND ITS EFFECT ON TRAFFIC

The Sports Stadium seats approximately 55,000 people at capacity and has on-site parking provisions for only about 4,500 vehicles. Additional parking is available in the central business district in public and private garages. The city also operates the on-site parking facility at a very reasonable cost rate for daily commuter parking, and most of the 4,500 parking stalls are in demand for this purpose.

The need for a freeway surveillance and control system is, therefore, based on an analysis of the cumulative effects on freeway operation of normal daily peak-hour and peak-period volumes occurring just prior to and following major stadium events.

Daily Peak-Hour Freeway Operation

Figure 2 shows that the daily volume of traffic carried on southbound I-75 indicates that the freeway is currently experiencing restrictions and resultant congestion due to traffic and the operational factors previously described.

The addition of traffic to the parking facilities is analyzed (Fig. 3) with a "theoretical" compound-weave operating speed of 30 mph, assuming conservatively that there are only 1,500 vehicles during the morning peak hour desiring to travel via I-75 southbound and to make the connection to I-71 northbound and weave across traffic to the Second Street exit. This is the shortest and most direct route to the stadium parking site, and the weaving speed will be drastically reduced if, say, 2,000 to 3,000 vehicles desire to make that maneuver. There is also a likelihood of weaving accidents, and the ramp capacity at the Second Street exit (approximately 1,600 vph) will be exceeded.

Unfortunately, the problem that must be solved if there is any breakdown in traffic flow in the weaving section or the ramp terminal (Second Street) is that motorists on a separate freeway, I-75, must be alerted to the problem and notified sufficiently in advance to permit choice of an alternate route to their destination.

As pointed out previously, the geometrics facing motorists on I-75 southbound approaching I-71 and downtown Cincinnati are not conducive to satisfactory traffic operation and indicate that a surveillance and control system would be of considerable help to traffic engineers, enforcement officials, and motorists when congestion occurs. Similarly, Figure 3 shows that the lack of correlation of the through route (I-71 northbound) with the geometrics forces an unusual maneuver for motorists desiring to remain on the freeway to avoid the exit to Vine and Second Streets. The accident potential on this weaving section will not be fully realized until I-71 is opened to through traffic. At that time, optimum surveillance and control measures will be essential.

Peak Periods Prior to and Following Stadium Events

I-75 southbound is expected to bring 46 percent of the existing traffic to the stadium, and the Second Street exit from I-71 northbound will be severely taxed even for those fortunate few who arrive in time to park in one of the 4,500 spaces available at the stadium site. Parking will also be available in the central business district. However, it will be necessary to keep motorists on all freeway approaches to downtown Cincinnati advised as to which exits may be taken to obtain parking for the stadium event. This dictates a need for surveillance and control of traffic to properly accomplish the objective and to minimize delays and congestion both on the freeway and the city street systems.

Similarly, following stadium events, the routing of traffic and control of freeway entrance ramp traffic will also be necessary to handle traffic as efficiently as possible for freeway-destined vehicles.

Surveillance and Control System Needs

The analyses given above indicate the need for a system of traffic control and surveillance that is flexible enough to handle the following operational needs:

1. Warn and guide motorists to diversion routes during peak and normal hours of the day when an accident or congestion occurs, and
2. Guide motorists to diversional routes for parking when events are held at the Sports Stadium and capacity of the on-site parking or Second Street ramp is exceeded.

PROPOSED FREEWAY SURVEILLANCE AND TRAFFIC CONTROL SYSTEM

The primary objectives of the surveillance and traffic control system are related to the traffic demands or congestion generated by the major events that will occur at the Sports Stadium; integrated features permit normal weekday peak-hour surveillance and traffic control measures to minimize congestion.

The original freeway traffic surveillance and guide sign system proposed by the City of Cincinnati pertained only to needs for controlling traffic for the major stadium events such as football or baseball. Through a series of meetings among city representatives, its consultant, and the Ohio Department of Highways staff, a system was developed and agreed to. The proposed freeway surveillance and traffic control system will consist of the elements listed in the following sections. They incorporate the features discussed above and consider a minimum number of separate sign-support hazards to the motoring public.

Traffic Control System

The traffic control system will utilize a series of changeable-message, matrix sign units located strategically on the freeway system approaching the downtown Cincinnati area. The 2 critical freeway sections involved are located at the southbound I-75 junction with I-71 and the northbound I-71 (Fort Washington Way) compound weave approaching the Second Street exit.

To provide adequate warning to motorists, the proposed changeable-message sign units will be located on I-75 north of the I-71 junction, on US-50 west of I-75, and on I-71 northbound (Fort Washington Way in advance of the Second Street exit). The proposed locations and several typical alternate sign messages are shown in Figure 4.

The proposed system will provide separate advance-warning matrix sign units, as shown in Figure 5, to notify motorists of any adverse freeway conditions ahead and to give exit numbers for parking accommodations for Sports Stadium events, alternate traffic diversion routes, lane closures if the freeway is congested, and commuter parking diversion routes. Matrix signs are proposed in order to permit maximum flexibility in messages that might be required.

Confirmation changeable-message units will be incorporated into the ramp exit gore directional signs as shown in Figure 6 to maintain fluid and current information to motorists if conditions change beyond the previous warning or guidance message observed.

Figure 4. Typical variable-message sign displays.

LOCATION	SIGN NO.	CONGESTION BACKED UP FROM BRIDGE, PAST EXIT 5	FT. WASHINGTON WAY BLOCKED INCL EXIT 1	CONGESTION BACKED UP, PAST EXIT 7	(FOOTBALL) STADIUM PKING PRPD DTWN. PKG FULL TO SEVNTH
OVERHEAD AT VINE-2 ND EXIT — EXIT 2 (VINE-2ND)	1b	DNTOWN	DNTOWN	DNTOWN	DNTOWN PKING
EXIT 1N (VINE SB)	1c	ALT I-75	DNTOWN	ALT I-75	DNTOWN PKING
EXIT 1S (2 ND)	1d	STADIUM	ALT I-71, US-50	STADIUM	STADIUM PKING
OVERHEAD IN ADVANCE OF VINE-2 ND EXIT — (EXIT 2)	3b	DNTOWN	DNTOWN	DNTOWN	DNTOWN PKING
(EXIT 1N)	3c	ALT I-75	DNTOWN	ALT I-75	DNTOWN PKING
	3d	STADIUM	ALT I-71, US-50	STADIUM	STADIUM PKING
E.B. FT. WASHINGTON WAY	12-1	ALT I-75 EXIT 1N DNTOWN EXITS 2, 1N	ALT I-71, US-50 KEEP LEFT DNTOWN EXITS 2, 1N	ALT I-75 EXIT 1N DNTOWN EXITS 2, 1N	STADIUM PKING PREPAID ONLY DNTOWN PKING EXITS 2, 1N
FIFTH ST. GORE (EXIT 3)	21a	DNTOWN	DNTOWN	DNTOWN	DNTOWN PKING
SEVENTH ST. GORE (EXIT 4)	33c	DNTOWN	DNTOWN	DNTOWN	DNTOWN PKING
OVERHEAD IN ADVANCE OF	41b	(blank) (blank) ALT I-75 USE EXIT 1	I-71N, US-50E BLOCKED USE EXIT 3	(blank) (blank) ALT I-75 USE EXIT 1	STADIUM PKING PREPAID ONLY DNTOWN PKING EXIT 4
FREEMAN AVE. GORE (EXIT 5)	45c	ALT I-75	ALT I-71N, US-50E	ALT I-75	STADIUM PKING
LINCOLN PK. DR. GORE (EXIT)	49c	ALT I-75	DNTOWN	ALT I-75	DNTOWN PKING
AT FINDLEY	50a	I-75 CONGESTED ALT I-75 USE EXITS 6,1	I-71N, US-50E BLOCKED USE EXITS 5,3	I-75 CONGESTED ALT I-75 USE EXITS 6,1	STADIUM PKING PREPAID EXITS 5,1 DNTOWN EXITS 6,5,4
WESTERN GORE (EXIT 7)	52b	ALT I-75	(blank)	ALT I-75	(blank)
S. OF MARSHALL	64a	I-75 CONGESTED ALT I-75 USE EXITS 7,1	I-71N, US-50E EXITS 5,3 DNTOWN EXITS 6,4	I-75 CONGESTED ALT I-75. USE EXITS 7,1	STADIUM PKING PREPAID EXITS 5,1 DNTOWN PKING EXITS 6,5,4
AT HOPPLE	71-1	I-75 CONGESTED ALT I-75 USE EXITS 7,1	I-71N, US-50E BLOCKED USE EXITS 5,3	I-75 CONGESTED ALT I-75 USE EXITS 7,1	STADIUM 8 DNTOWN PKING USE EXITS SHOWN
E.B. 6TH ST. EXPWY	201c	I-75 SOUTH CONGESTED USE I-71 EXIT 1N	I-71, US-50E BLOCKED USE MEHRING WAY	I-75 SOUTH CONGESTED USE I-71 EXIT 1N	STADIUM PKING PREPAID ONLY DNTOWN PKING EXIT 5 TH. ST.
E.B. 6 TH. ST. EXPWY at I-71, US-50	209c	ALT I-75	BLOCKED	ALT I-75	(blank)
E.B. 6 TH. ST. EXPWY at 5 TH. ST. EXIT	209c	(blank)	ALT I-71N, US-50E	(blank)	DNTOWN PKING

EXIT NUMBERS
S.B. & E.B. EXIT NO. CODE

1S - SECOND ST.
1N - VINE ST.
2 - MAIN ST.
3 - FIFTH ST.
4 - SEVENTH ST.
5 - FREEMAN AVE.
6 - LINCOLN PARK
7 - WESTERN AVE.

Figure 5. Variable message of full matrix sign unit.

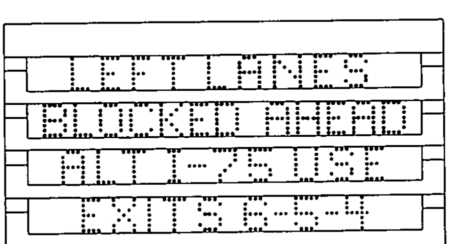
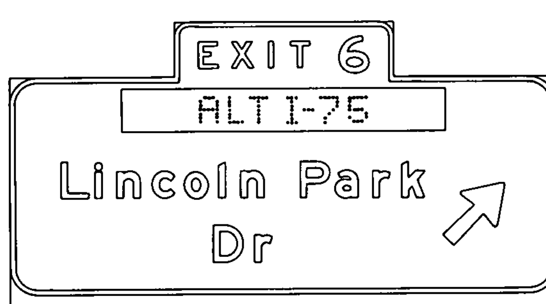


Figure 6. Variable message of one-line matrix sign unit.



Several units will be incorporated into advance directional signs on I-71 (Fort Washington Way) because of inadequate longitudinal placement opportunities on the freeway.

The proposed integrated system has the following advantages:

1. Minimizes the need for additional sign-support hazards to motorists,
2. Has economy in cost of installation by requiring fewer sign supports, and
3. Uses exit numbers to simplify the reference to specific exit names.

Surveillance System

Television cameras are placed at 5 strategic locations to provide visual aid to control system operators in order to provide immediate observation of freeway congestion or accidents and permit expeditious alleviation of cause of delay and dispatch of enforcement or emergency vehicles. The cameras were installed by the City of Cincinnati and are currently operational.

The field detection of real-time conditions will be accomplished by installation of loop detectors at appropriate locations on the freeway system including ramps where volume and speed factors are considered significant. Double-loop installations on the freeway will be utilized to obtain speed data at locations considered to be essential to the operation of the system.

Traffic Control Center

The control center is located in the Sports Stadium and will have facilities for receiving detection data and television pictures and for transmitting appropriate variations to changeable-message sign units for control of traffic by computer. Capabilities will also be available to alert encorcement officials for dispatch of emergency vehicles when required.

MAINTENANCE AND OPERATION

The City of Cincinnati will be responsible for maintaining the operation of the proposed freeway surveillance and traffic control system.

SUMMARY

It is believed that the experimental freeway surveillance and traffic control system will provide meaningful practical benefits to motorists by increasing operational freeway efficiency and minimizing delay through use of variable-message warning and guidance signs for traffic diversion by an automated traffic responsive system.

ACKNOWLEDGMENTS

The author extends his gratitude to Thomas E. Young and staff, City of Cincinnati; T. T. Wiley, consulting engineer; and R. E. Heinz, Federal Highway Administration, for their assistance and for materials included within this presentation.

POTENTIAL USES OF VARIABLE-MESSAGE SIGNS IN NEW YORK CITY

E. Vinson Hoddinott

When the New York City Department of Traffic was organized in 1950, it inherited a signal system that was not only inadequate but outdated. The first department mandate was to improve the traffic signal visibility and coordination. Measures of that kind have been found to be effective in providing relief of vehicular traffic congestion, which in turn decreases the accident potential for both vehicles and pedestrians. Now, 21 years later the effectiveness of the modernization program has been amply demonstrated through the analysis of before-and-after studies.

At the present time, more than 50 percent of the city's traffic signals are modernized to meet or exceed the requirements defined in the Manual of Uniform Traffic Control Devices for Streets and Highways. In May 1969, New York City placed on line the first arterial with 124 signals on its new traffic computerized signal system. That digital system provides traffic engineers with a new tool that may be used to extend their application of professional skills over a broader field of traffic and transportation control.

The planned computerized traffic signal system for New York City will ultimately control 7,000 signalized intersections and use approximately 4,500 system sensors. At the present time the Department of Traffic has one computer controlling 450 intersections on 8 arterials in the Borough of Queens, and the projected expansion is at the rate of approximately 500 or more intersections each year.

We have 200 miles of limited-access highways in the city, and their entrances and exits must be coordinated to the best possible degree with the traffic control system of the local streets. The volume of vehicular traffic is approaching the capacity of the roadway system, and the arterial networks are being further burdened by the built-in barriers and demands of the Borough of Manhattan—the focal point for world trade and commerce and the chief traffic generator for the city. This unique borough, therefore, creates a natural attrition to traffic with its many river crossings consisting of tunnels and bridges. In addition, their disparate entrances and exits to the local street systems cause further conflict.

It may be many years before urban transit improvements, which are now in planning or early construction stages, will become completely operational. In the meantime, we are giving serious consideration to alternatives that will aid in the smoother flow of traffic. One alternative is to make the most of the existing street system with the objective of increasing effective capacity with fewer delays, and another involves new construction of streets or street-widening projects. The preferred alternative is to make the most of the existing street system, for the urban areas have nearly exhausted the possibility for expansion; and new construction is costly, brings about hostility from citizen groups, and creates new traffic generators.

Computers that provide parameters from field sensors give traffic engineers opportunities to convert the data into operational programs that will provide optimum timing patterns for variations on a real-time basis and to recognize and transcend to predetermined modes for emergency operation. The emergencies may consist of extreme weather conditions, water-main breaks, major fires, or other interruptions to the normal traffic flow in an urban area.

Although there are stages in development or planning for freeway and expressway control and information systems, it is not the purpose of this paper to analyze those areas. The Department of Traffic as an operating agency is concerned with the problem of lessening traffic congestion within the city and at the same time reducing vehicular and pedestrian accidents and increasing safety to its citizens.

One of the most effective aids in providing information to the drivers is by signs, generally in areas requiring warning, guide, and regulatory information for the driver. Prior to the use of computer-based control and surveillance systems, most of the signs had messages that either were fixed or could be changed or varied by manual operation.

The development of computerized traffic control systems utilizing on-street sensors with closed-loop feedback makes possible the use of variable-message signing under remote control. These signs, used with computer control, must be capable of conveying the proper message to the driver within the established algorithm.

The traffic engineer must specify conditions under which the variable-message signs may be used to the best advantage for his specific purpose. My primary purpose in this paper is to encourage further research and development in the hardware by manufacturers or vendors of those signs so that the user may have choices depending on his needs as defined by his design parameters and the availability of off-the-shelf equipment within competitive pricing.

Variable-message signing requirements, although highly varied, are technically feasible. The design features should consider the life and operation of the sign in the real world. Attention, within cost limitations, is necessary to provide longevity of the lumination source, vandal-resistant features, and easy maintenance such as self-cleaning or convenient methods of manually cleaning and providing preventive maintenance.

The visibility must be such that direct sunlight during daylight hours or high ambient lighting at night, including headlight glare, will not degrade the informational quality of the message. However, if the cost of implementation is such that it is not economically feasible, then the current practice of increasing lumen output by various means or arrangement should be looked into further. The arrangement for a blank-out sign, where usually a sign is either on or off, must be such that the sign is completely blanked out. The preselected message should be relevant to its location and seasonal condition, commanding the attention of the driver, and there should be no reason for the driver to have a lack of understanding when the sign is on.

The sign may be placed on a sign bridge, pole mounted, or attached to an existing structure. In the selection of mounting sites, maintenance costs must be a factor, for accessibility or traffic obstruction or both will be required during maintenance.

The traffic engineer, in using variable-message signs, must take into consideration the roadway geometrics and the best choice for equipment placement to provide maximum visibility and sufficient response time for message recognition and reaction by the driver. The application of variable-message signs in an urban area may be used in a control and surveillance system for ramp-entrance control to facilitate safer merging, ramp-entrance diversion to frontage roads or local city streets, and ramp blank-out signs indicating ramp closure for proper metering of traffic.

In conjunction with a computer-operated traffic signal system, the variable-message signs may be integrated into the control system to control operational routes on local streets for turning restrictions, truck or bus diversion, and alternate routing due to congestion, particularly in areas adjacent to tunnel or bridge crossings where congestion may occur on city streets. The success of this type of operation depends on adequate traffic capacity on available alternate routes, which should be similarly well signed. Where lane control and, in particular, reversible lanes or reversing direction of the entire street segment is instituted, variable-message signs must be used and coordinated with other traffic control devices and computer monitored and operated equipment.

The prescribed messages used by the traffic engineer and available to him from the sign manufacturer should be adequate for standard conditions. The length of these messages should be governed by letter size, which should be readable and understandable within approach distance related to the maximum legal speed for the area of application. There should be no trade-off of letter reduction below the minimal letter size just to accommodate a long message that may tend to confuse the motorist. Rather, a short, easily understood, highly legible message with maximum-sized lettering will lend itself to the most desirable type of signing. This would include easily read symbols, numbers, and letters as well as the use of standard shapes and colors.

The principal criteria in the use of variable-message signs are economic justification and adaptability to the urban street control system. They should be interfaced where required with expressway control and surveillance systems, including ramp metering and diversion strategies within the corridor.

The central headquarters for the systems must contain a map or maps to indicate sign messages in effect and to monitor sign malfunction or failure. In addition, information must be provided visually, preferably by addition of displays to the map, on volumes at specified or critical locations to permit the traffic engineer to analyze the efficiency of the system. This analysis will permit adjustments for fine tuning the system and will provide a manual interface through either a CRT or a hard-copy device for recording traffic information that may be analyzed as algorithms or parameters are changed. A control console should be provided with a manual override so that, in the event of emergency conditions or malfunctions of system equipment, the judgment of the traffic engineer may be communicated to the system by direct intervention.

The communications from central headquarters to the signs for their variable-message operation should be compatible or capable of being provided with an interface to use the same type of communications system that would be used for the urban computerized traffic signal control system. It is important that the complexity of the control systems communications be essentially of one type so that maintenance is easy and maintenance costs are reduced by a reduced inventory of spare parts and components and also that the degree of skill and depth of training of the service personnel may be minimized. The present control concept in New York City is to place all complex equipment at a central control location where highly skilled technicians and engineers are available to analyze and direct the repair of any malfunctions. The equipment on the street, on the other hand, whether it be variable message signs, telemetering equipment, or other traffic control devices, is of minimum complexity so that it can be maintained and repaired by lower level personnel through the replacement of plug-mounted components rather than through elaborate replacement or repair at the site.

In the past there have been many methods used to provide the variable-message signs. Some have had additions in number of messages and size of message, illumination resistant to incident lighting, and various types of lighting including incandescent lamps, neon tubing, and fluorescent lamps. Here again, standards and specifications by the manufacturers will have to be established to determine the effectiveness of any or all of these methods. The operating temperature range must be considered, including solar effect and icing conditions. Other unfavorable environmental conditions may have to be considered that may affect the mechanical and electrical operation and may tend to degrade the effectiveness of the message intended to be communicated to the motorist.

The New York City Department of Traffic has had practically no experience with vehicular variable-message signing, other than to observe some of the installations that have been installed by the various authorities in the area. However, we have purchased and installed many thousands of variable-message WALK-DON'T WALK pedestrian signals. Although those pedestrian signals have not been considered in the same category as vehicular variable-message signs, I would like to discuss the need and use of this type of signal for the exclusive purpose of controlling pedestrian traffic.

Earlier, the Department of Traffic used neon signs but, in addition to the high installation cost and the high cost of replacing neon grids and large transformers, there was also a large operating cost for energy requirements. Several years ago when the department embarked on a full-scale modernization program to bring up to standard all of its traffic signals, consideration was given to the use of incandescent lamps for the lighting source for several reasons. The signal could be physically lighter in weight, power consumption could be reduced, and ease of maintenance and cleaning of the lenses and reflectors could be achieved. The department has since installed incandescent pedestrian signals at thousands of intersections and has had a high degree of success in pedestrian safety and accident reduction. We are planning to continue this program, and I encourage the manufacturers and vendors to continue to improve the performance of incandescent signs. There are many cities, particularly in the West and Southwest, that require a high degree of internal lighting because of the ambient lighting conditions under which they operate. Traffic engineers in those areas have not expressed a great deal of enthusiasm about signs other than the high-intensity type produced by neon grids. The New York City area ambient lighting is generally lower and is more favorable toward the present incandescent lighting intensities, and economic considerations cause us to look for the maximum number of acceptable signs that we may purchase within our budget.

There are several areas where thought must be given if the signs are to be used for their greatest effectiveness: The illumination of the message must be increased without fringing; the lens must be made of material that is essentially vandal-proof; visors on the signs should be as small as possible so that accidental damage, particularly due to turning vehicles, will be slight when signs are mounted in conformance with standard procedures; and lighting sources should have in addition to the fail-safe provisions a means whereby inspection will readily detect the presence of burned-out lamps when multiple lamps are used. The average cursory inspection of pedestrian signs under high ambient lighting conditions many times will fail to reveal a burned-out lamp that decreases the effectiveness of the message. Experienced manufacturers are well aware that longevity of the illuminating source is far from satisfactory at the present time, and that necessitates a continuous inspection effort and consumes an inordinate amount of time at each intersection to observe and report lamp failure on individual pedestrian signs. I am aware that a great deal of work has been done and am assured by lamp manufacturers that research is in progress to alleviate this limited lamp life, which not only causes economic problems but increases the expense of visual inspection and lamp replacement, and, in many cases, results in total failure of the effectiveness of the signal.

Some of the areas that we are discussing may seem far out. If you should feel this to be the case, I ask you to look at the expressway ramp-control studies and the prototype systems for ramp control and expressway surveillance. We are now using reversible lanes on local streets and exclusive bus lanes, and the future of similar projects may lie in the hands of the traffic engineer and the transportation planner. It is incumbent on all of us to remove any excuse for not advancing a valid project because of lack of suitable equipment. It is my hope that this exchange of ideas will increase the activity at the drawing boards and that the ideal piece of hardware will become a catalog item.

The projected increase of vehicular traffic in the future will further burden street systems including expressways and freeways. It is hoped that a visual real-time information system will be used as one of the tools available to the traffic engineer to assist in alleviating congestion. With the technological knowledge and application of known techniques, manufacturers and vendors will be able to offer sophisticated equipment having features that are fail-safe, flexible, and reliable. In addition to these features, economy must be given prime consideration for the establishment of an effective cost benefit to the community.

USE OF CHANGEABLE-MESSAGE SIGNS BY PORT AUTHORITY

Louis E. Bender

The evolution of changeable signs was caused by the rapid growth of traffic after World War II. Because of lack of materials, roadway construction was limited during the war. After the war, our first project was reversing a short tunnel that carried traffic eastbound from the George Washington Bridge across Manhattan to the Bronx. After a sports event at Yankee Stadium or Polo Ground, several thousand cars would leave New York for New Jersey. Therefore, the tunnel was reversed by a very primitive method of sliding one sign in front of another. For several years, the pattern in the tunnel was 2 lanes eastbound, 1 lane eastbound and 1 lane westbound, and 2 lanes westbound; occasionally, we reversed the tunnel lanes 3 times in 1 hour.

In 1957, we added another 2-lane tunnel to the existing 2 tubes of the Lincoln Tunnel to provide greater capacity between New York and New Jersey. That was the first 3-tube tunnel in the world. It provided the flexibility in the tunnel's traffic-handling capabilities, for traffic lanes in the center tube can be reversed, as demand requires, to provide 2 lanes in 1 direction or 1 lane in either direction.

The problem in New Jersey was simple, for we could just "cone off" 1 tube or lane as required because the entrances to the 3 tunnels were adjacent. In New York, however, we were required to divert traffic on city streets several blocks from the tunnels. To place police at 17 locations appeared to be an impossible undertaking that would cause confusion in that the police officer would have to segregate tunnel-bound traffic from normal street traffic. We worked out a system of blank-out and changeable signs that were erected at key intersections and directed the motorists to use the proper tunnel. In New Jersey, a drum sign is used that tells the motorist that the center tube is operating eastbound toward New York. Revolving the sign gives a DO NOT ENTER message, which indicates that the tube is operating westbound toward New Jersey.

In 1962, the opening of the lower level of the George Washington Bridge required that equipment be installed for diverting traffic. We have used all types of changeable signs to accomplish several traffic patterns. First, we do not allow gas trucks and other hazardous cargo on the lower level. Second, there is currently no direct connection between certain roadways in New Jersey because this would produce an imbalance of traffic between lower and upper levels. Changeable signs divert traffic to the less congested level. Drum diversion signs are installed on the New Jersey side to balance the traffic pattern. We also use what we call a flip sign. Normally this sign, which we make in our sign shop, accommodates a temporary situation during repairs to the roadways or a temporary congested condition.

Blank-out arrows and x's were used recently to establish an exclusive bus lane in New Jersey on the expressway leading to the Lincoln Tunnel. Similar blank-out arrows and x's are used at the Holland Tunnel to indicate open and closed tollbooths. Immediately adjacent to those tollbooths is a signalized intersection. Confusion is eliminated by using the signs to differentiate between a traffic signal and a tollbooth.

An additional use of blank-out signs is to detour traffic from its normal routing when an accident, slippery roadway, or other incident makes it necessary to do so. The detour route is fully signed to bring traffic back to its normal routing.

We are now installing a computer-controlled surveillance and diversion system at John F. Kennedy International Airport and Newark Airport. At Kennedy Airport all the equipment is installed to divert traffic to the least congested roadway automatically by a computer and surveillance system of sensors and blank-out signs. By using a sign to divert traffic within the terminal area, we attempt to direct the traffic past a parking lot as soon as possible to relieve congestion on the terminal roadways.

They say that anything can happen in the New York-New Jersey area, and usually it does. From northern New Jersey to Manhattan, motorists have 3 choices for crossing the river: the Holland Tunnel, the Lincoln Tunnel, or the George Washington Bridge. A stoppage on the arterial system in New Jersey or on one of the river crossings can cause considerable delay. To better serve the public, we installed a matrix sign on the New Jersey Turnpike to inform the motorist of any blockade to or on the crossing. This sign can display 14 different messages and is controlled at the Holland Tunnel. The messages displayed on the sign are also displayed on the console. We surveyed the effectiveness of this sign and found that it diverted more than 400 vehicles per hour to the Holland Tunnel during construction at the Lincoln Tunnel.

New standards state that "variable signs should conform with the same shapes and colors and be of the same dimensions as standard signs provided in the manual." Our experience with variable signs leads us to believe that this requirement will make a variable sign ineffective. Most variable signs are used on highways having high-density traffic composed mostly of commuters. We have found that, to divert traffic of this type, emphasis of some type must be incorporated in the sign. The new Manual of Uniform Traffic Control Devices for Street and Highways prohibits this. There is a difference between a red-orange arrow and a yellow arrow. I suppose both of these arrows now in use will not be in accordance with the new manual. I understand that there will be a period for conversion to the new standards, but what happens if a motorist stops in compliance with a red arrow, which is a prohibitive movement?

There are advantages to each type of changeable-message sign. The major advantage of the matrix sign is the unlimited number of various messages it can convey.

The drum type of sign is limited to 4 messages per drum. The number of drums, of course, is limited by the size of the sign. We have found that on overhead signs 3 or 4 drums are the maximum number that can be used on account of the height restriction. Another disadvantage of the drum sign, in our opinion, is the maintenance factor. The unused faces collect dirt when the drum is revolved, and it has been impossible to keep the unused faces clean unless a very rigid preventive maintenance program can be instituted. One advantage of the drum sign, however, is that one can change colors on the various drums and can comply with the new manual, which states that the message should follow the standard colors for directional signs. As I said before, we have found that the standard-color requirement is an ineffective requirement because a different color should be displayed when one is trying to change the normal traffic pattern. This fact was pointed out recently to the National Joint Committee on Uniform Traffic Conrol Devices but received no consideration whatsoever. I think that we in the Port Authority have enough if not more experience in this area than any other jurisdiction in this country.

About the only advantage of the manual flip sign is that it can be produced very quickly and is inexpensive. In my opinion, it is not the most effective sign because in commuter traffic there is nothing on this sign that draws attention. The biggest disadvantage to those types of signs is that they are not changed promptly. On many occasions I have had to radio to the facility management that a flip sign is not showing the proper message for which it is intended.

The blank-out sign has a disadvantage of not being prominent enough especially when there is direct sunlight on it. The only effective blank-out signs that we have are those that use an orange-red grid and, as previously stated, do not comply with the new manual because a red arrow indicates a prohibited turn.

FOG DETECTORS FOR CONTROLLING CHANGEABLE-MESSAGE SIGNS

Edward D. Spear

By their nature, changeable-message signs require an input. In most existing installations, the input is manual; i.e., at a central location remote from the sign a button or switch is operated, which through a hard wire or radio link changes the sign legend. Again, in most existing installations, the timing of the message is known or can be predicted. For situations such as construction, accident, traffic volume, or lane-turn restrictions, manual control is generally adequate. Fog, however, creates conditions wherein manual control leaves much to be desired. Areas where fog is a problem are usually well known from previous accidents. But the onset and duration of fog cannot be predicted with any accuracy, and any delay between the onset of fog and warning to the motorist can have serious consequence.

There have recently been made available in the United States 3 instruments that will continuously and automatically measure visibility or detect fog or do both. The instruments (manufactured by Impulsphysik, GmbH, Hamburg, West Germany) are the forward-scatter Fumosens, the back-scatter Videograph, and the transmissometer Skopograph. The Videograph and Skopograph were designed for operation at airports to measure RVR and are in operation in Europe, South America, and Canada. They are currently being evaluated by the Federal Aviation Administration for airport use in the United States. The U.S. Coast Guard recently completed an evaluation of the Videograph for use in unmanned aids to navigation (foghorns) (1).

Installations of the equipment are shown in Figures 1, 2, 3, and 4; characteristics are given in Table 1. The Videograph operates by measuring the light from an intense, pulsed-light source backscattered into a calibrated receiver housed with the source. The receiver is designed to reject all signals except those resulting from the very short (1 μsec) pulses and is, therefore, insensitive to ambient light (daylight, signs, or headlights). In addition to the current output proportional to visibility, the Videograph has an alarm circuit that may be set to operate at any level of visibility. Calibration is by means of an internal light guide that, through a solenoid-operated diaphragm, allows a known intensity of light to reach the photodiode of the receiver. The instrument may also be calibrated by using the Vivical. This unit, which is fixed to the receiver sun shield, transmits through a combination of mirrors and an adjustable, calibrated diaphragm the projected light pulse to the receiver.

Figure 1. Fumosens is in operation at Kentucky River Bridge on I-64 south of Frankfort.

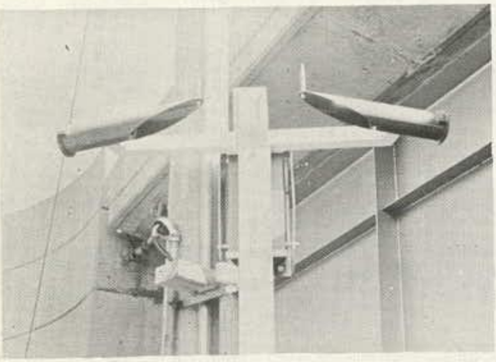


Figure 2. Videograph at Murder Creek interchange on I-5 north of Albany, Oregon, is being evaluated by Oregon State Highway Division for controlling changeable-message sign.

Figure 3. Videograph on Pennsylvania Turnpike, east of Carlisle, controls strobe lights in experimental lighting program.

Figure 5. Changeable-message sign on I-5 in Oregon will be controlled by Videograph.

Figure 4. Skopograph projector and receiver monitors visibility at Commonwealth Edison's Dresden Power Station at Morris, Illinois.

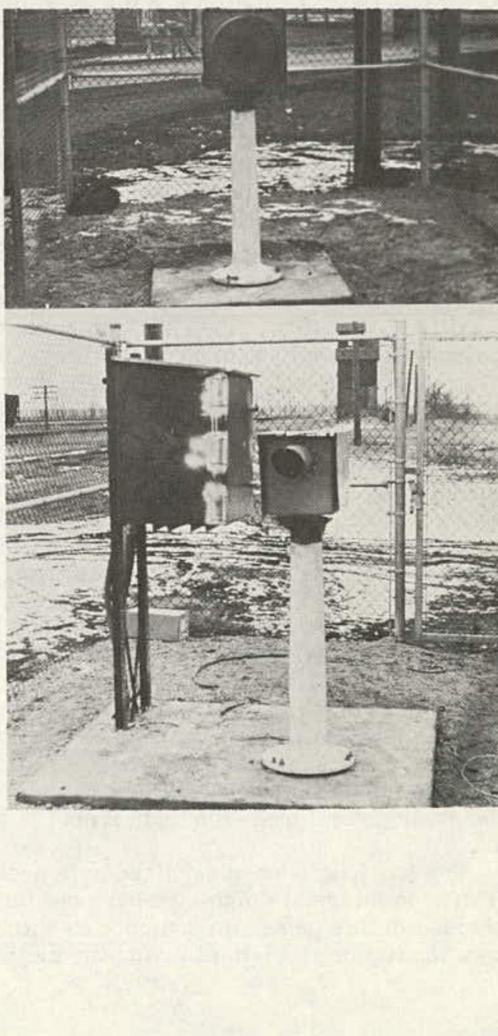


Table 1. Instrument characteristics.

Characteristic	Fumosens	Videograph	Skopograph Projector	Skopograph Receiver
Visibility range, m	50 to 1,000	100 to 10,000 and 30 to 3,000	—[a]	—[a]
Output signal	3 DPDT relay contacts set independently	0 to 1 madc current and panel meter	N. A.	0 to 1 madc current and panel meter
Power at 110/220 V and 60 Hz, W	65	90	90	295
Operating temperature, deg F	0 to 120	-13 to 105	-15 to 120	-15 to 120
Operating humidity, percent RH	100	100	100	100
Weight, lb	46	122	122	111
Base	3 holes on 7⅞-in. diameter	3 holes on $14^{11}/_{64}$-in. diameter	3 holes on 7⅞-in. diameter	3 holes on 7⅞-in. diameter
Calibration	Mark I eyeball	Light guide and Vivical	N. A.	57 and 37 percent neutral-density filters

[a]A function of base line between projector and receiver: maximum of 10 km with 500-m base line and minimum of 20 m with 30-m base line.

In the Oregon installation, the Videograph visibility output is recorded for subsequent correlation with other traffic data and is also fed to an 8-alarm unit that ultimately will control the changeable-message sign (Fig. 5). (Currently, control for the 6 signs is from a panel in the Albany office of the state police. A return telemetry link provides confirmation from the sign to the control panel that the function initiated at the panel is working at the sign. The sign legends may also be controlled from a panel in the equipment cabinet at the base of the sign and read SLOW, FOG, SPEED, 10, 20, 30, 40, 50, and WRECK.)

The Fumosens operates in the ultraviolet portion of the spectrum. It consists essentially of a lamp and a phototube between which is placed a baffle so that no light scattered through an angle of less than 20 deg can reach the phototube from the lamp. However, when visibility is poor, some is scattered toward the phototube by the fog particles. The resulting phototube current activates 3 identical but independent circuits whose output may be used to control external devices or equipment.

The operating threshold of each circuit may be adjusted between minimum and maximum visibility values of 50 to 1,000 m. In order that the Fumosens will not be influenced by daylight or other extraneous lights, the phototube optics include a UV filter operating at the 2,537-nm mercury emission line. Calibration is by means of on-site observation of visibility and manual setting of the 3 threshold circuits.

The Skopograph is a double-ended instrument consisting of a projector and receiver mounted on a base line of 30 to 500 m (depending on the range of visibility to be measured). As in the Videograph, the projector light source is a xenon flash tube pulsed by a solid-state power supply. The light output is constant for a long period (2 years minimum in continuous operation) and is focused into a narrow 4.5-deg beam by a parabolic mirror. The light pulses from the projector are detected by a photodector in the receiver, averaged for a 15-sec period, and converted to an output current proportional to visibility. Using 2 neutral density filters, the Skopograph can be calibrated at 3 values of transmission, corresponding to visibilities of 2.5, 4, and 7 times the base line. The upper limit of the working range is determined by the accuracy with which the very small attenuation along the base line in good visibility can be measured. The lower limit depends on the minimum usable signal/noise ratio of the receiver. For the Skopograph, those limits are 20 and ⅔ times the base line respectively. In those instances where a wider range of visibility must be measured, 2 receivers on the same optical base-line path from the projector but at different distances may be used.

Fog has long been recognized as a problem on highways. The increasing speeds and traffic on Interstate highways have not lessened this problem. The instruments described in this paper, in conjunction with changeable-message signs, can provide a solution to the problem of giving the motorist a real-time warning of fog.

REFERENCES

1. Report 512. U.S. Coast Guard, Proj. 792104/001-003.
2. Twomey and Howell. The Relative Merit of White and Monochromatic Light for the Determination of Visibility by Backscattering Measurements. Applied Optics, Vol. 4, No. 4, April 1965, pp. 501-506.
3. Vogt. Visibility Measurement Using Backscattered Light. Jour. of Atmospheric Sciences, Vol. 25, No. 4, Sept. 1968, pp. 912-918.
4. Oddie. The Transmissometer. Weather, Vol. 23, No. 11, Nov. 1968, pp. 446-455.
5. Frungel. The "Videograph" Backscatter Fog Detector and Visibility Meter. IALA Bull. No. 40, April 1969, pp. 9-16.
6. Oregon Tests Fog Warning System. Better Roads, Vol. 40, No. 3, March 1970, pp. 22-23.
7. Fog Warning. Better Roads, Vol. 41, No. 4, April 1971, p. 20.

RESEARCH DEVELOPMENT OF THE CHANGEABLE-MESSAGE CONCEPT FOR FREEWAY TRAFFIC CONTROL

Slade Hulbert and Jinx Beers

This study afforded the opportunity to utilize the "funnel" approach, which brings together 3 different techniques of traffic safety research to study the same highway signing problem. The UCLA sign tester (a relatively uncomplicated tabletop simulator), the Preview House (an in-theater presentation using motion pictures for large audiences), and the UCLA Driving Simulation Laboratory (a highly sophisticated and instrumented research facility) were all utilized to develop and evaluate various message formats for a proposed advisory system for freeway traffic. Where these 3 research techniques overlapped, driver responses to the same message format were nearly identical, although the sign tester and DSL are individual-oriented and the Preview House is audience-oriented. It is believed that this study has successfully demonstrated the reliability of each research technique.

The focus of the study is on the types of messages that will be appropriate for drivers as they approach congestion. Additional work is needed to investigate those messages that will be appropriate for drivers who are in congestion. The safety implications are, of course, much more serious for the high-speed, freely moving traffic that is rapidly approaching a freeway tie-up. Two aspects of driver reactions and opinions were studied: their feelings about the general concept of changing messages and their reactions to more than 80 specific messages.

The reactions and opinions of drivers to the general concept of an advanced, advisory system for freeway traffic indicated strong approval of such a system despite its obvious cost to taxpayers. The consensus was that any system would be somewhat distracting and confusing to a small proportion of the driving public but that most drivers would find an advisory system advantageous for saving time, making freeway driving safer, and easing some driver frustration.

Although drivers evaluated both the sign and the audio systems more favorably than unfavorably, they repeatedly indicated a preference for a sign-message system over an audio system because of the more "public" nature of signs, the fact that drivers are already used to reading signs, and the 1-step (reading) process of receiving the information rather than a 2-step process (reading a sign and then tuning the radio).

It is one question to ask which of the systems, audio or sign, would the driver prefer to have available to him while driving the freeways, and it is an entirely different question to ask which system would most likely improve driving behavior by actual modification of either his driving techniques or his emotional status. Driver responses in all 3 research techniques demonstrate that either system will favorably modify driving behavior of most drivers. The "authoritative" nature of the sign system exhibited the greatest level of behavior modification for most drivers.

The consensus for all audiences was that the content of the messages should be short and simple and contain specific information for action. Driver preference (in order) for types of information to be given were lane blockage (if any), distance (how far ahead the blockage or problem is), time (length of delay), reason (for delay), and location (by ramp or interchange name).

Considerable confusion was found in discussions of both lane number (lane 1 was identified as either the median or outside lane) and the words "middle lanes" (identified as either median lanes or the center lanes in one direction of travel). It is, therefore, recommended that the words "left" and "right" be used instead of lane numbers or the words center and middle, for example, RIGHT LANES CLOSED AHEAD or LEFT LANES OPEN AHEAD.

When the traffic is moving as usual the motorist expects to know that it is. Out of several ways to indicate that traffic is moving as usual, the drivers in this project chose the message "normal." They rejected a blank sign because of its ambiguity.

It became readily apparent that some difficulty exists in preparing messages that are neither so repetitive as to be boring nor so complex as to be misunderstood. The theater audience data indicate that the perceived advantage of the audio system in providing more detailed information might be negated by the possible loss of clarity of the message. It is recommended that audio messages be limited to 2 or 3 short sentences when used on advanced, advisory signs. Longer messages may be appropriate for stopped or very slowly moving traffic, but this situation has not been studied.

There was some concern that the "authoritative" nature of an advisory system would lead drivers to overreact to messages containing a reference to a specific speed. In all 3 types of research techniques, drivers decelerated as much as an average 30 mph, when a specific speed (15 to 20 mph) was mentioned in conjunction with the words NEXT 2 MILES. When asked what they would do if they saw this speed with the words 2 MILES AHEAD, more than a fourth of the respondents indicated that they would slow promptly. Discussion group participants, however, responded that they would only prepare to slow if the speed reduction was ahead of them and no other vehicles were slowing. The act of only a single driver decelerating immediately because he thought the sign said to go 15 mph creates such a dangerous situation that it is recommended that mph messages be avoided or used only for traffic already stopped or moving very slowly.

Finally, it became quite apparent in all phases of this research that a credibility gap occurs when the congestion or traffic incident does not appear where promised. The key ingredient to the success of either a radio or a sign type of advanced, advisory message system on freeways will be the timeliness and accuracy of the messages it conveys.

CHANGEABLE-MESSAGE SIGNS

Irwin Hart

At the Winko-Matic Signal Company, we believe that changeable-message signs are basically driver-information signs providing either advisory or regulatory information. There are several types of changeable-message signs; 3 types manufactured by our company are the lamp matrix, drum sign, and blank-out sign. Other types on the market are the roller screen and flipping disc.

Changeable-message signs can be used both as part of a system or as individual-message signs not incorporated into a system. The following are examples:

1. Lamp-matrix signs reading either OPEN or CLOSED and used as an insert into a signboard or a truck-weighing station sign;
2. Large, mounted roadside signs reading MERGE RIGHT or MERGE LEFT and utilizing a matrix approach combined with a neon blank-out reading CAUTION SQUEEZE RIGHT or CAUTION SQUEEZE LEFT;
3. Matrix lane-control signals consisting of a single unit showing the red X or green down arrow along with the new yellow arrow for clearance interval;
4. Variable speed signs generally displaying speed limits in 5-mph increments and using an internally illuminated upper portion reading SPEED LIMIT with a lamp-matrix portion showing the variable speeds;
5. A sign with similar construction using lamp matrix reading in mph in 1-mph increments and internal illumination called progression speed indicators advising the driver of the speed that the signals are set for; and
6. Lane-use signals such as a left-turn arrow and the word ONLY that change to a straight up arrow and the word ONLY when the operation of the lane changes.

These typical changeable-message signs can be used on both high-speed and urban-area roadways in a given single situation. However, driver-information, changeable-message signs that give information on roadway conditions probably have the greatest use and those that give additional information on what the driver is to do have the next greatest use. Examples are as follows:

1. ACCIDENT AHEAD followed by REDUCE SPEED 30 MPH;
2. MEN WORKING followed by USE RIGHT LANE or USE LEFT LANE or CENTER LANE CLOSED;

3. ONE LANE AHEAD followed by REDUCE SPEED, MERGE RIGHT, or MERGE LEFT;

4. Road conditions such as HILLS, CURVES, SLIPPERY, ICE, FOG AHEAD, USE CHAINS, HIGH WIND TRAILERS PROHIBITED, BLOCKAGE AHEAD followed by DELAY OF ... MINUTES BECAUSE OF ... and USE ALTERNATE ROUTE ....

I would like to describe the 3 types of signs manufactured by our company. The first one is a changeable-message, blank-out sign that provides 1 message or no message at all on a single sign face with a painted message. When the light is turned off, the painted message is invisible; when the light is turned on, the painted message is visible to the approaching driver. Light sources vary from flourescent tubes to neon tubes and in some cases even a group of incandescent lamps although the latter is not in general use. The advantages of this sign are that it has simple construction, has fairly low current cost, can be manufactured in a fairly small size, complies with U. S. Department of Transportation specifications, and is not entirely limited in color selection.

The second is a drum sign, having the ability to provide a series of either 3 or 4 messages on a single line with as many as 3 lines available before the vertical dimension gets difficult to handle. Legends can be reflectorized, and the background and color of each sign message can vary within the same drum. That is, as the drum revolves, different messages having different colors can be displayed. This sign can also be externally illuminated and is in general passive in nature. Its disadvantages are that it does not stand out any more than any other flat, reflectorized, externally illuminated sign; it is difficult to make this sign small if any message selection at all is required; the number of messages is completely restricted by the number of messages that can be controlled on a given drum or a given group of drums; and the mechanical aspects of the sign, gear-drive motors, and requirements for heaters in winter serve to make this sign in general something that should be used only in a system where maintenance can be performed at regular intervals. The life expectancy of drum signs is not known at this time.

The third is the lamp-matrix sign that utilizes a low-voltage, long-life lamp. It is a very bright spotlight and is encased in its own aluminum heat sink with a lens arrangement. This particular optical arrangement provides a maximum amount of vandalism protection; it is designed so that it carries the heat of the lamp away and allows the lamp to operate at various light levels. For example, the normal daytime light intensity will allow the lamp to operate for a period of about 10,000 hours. Reducing the voltage for nighttime operation to obtain satisfactory legibility increases the life of the lamp to 50,000 hours so that maintenance, from the lamp standpoint, is extremely minimal. Additional advantages are as follows:

1. Light intensity can be adjusted for varying degrees of darkness;
2. Sign is legible at almost 100 ft/in.;
3. Message storage is unlimited by using either a variable-matrix, fixed-type of approach or an infinitely variable matrix-type of approach;
4. Message can be flashed or alternately different messages can be flashed;
5. Sign can be controlled by a teleprinter or pushbutton or computer;
6. Sizes are unlimited;
7. Construction is modular; and
8. Ability to flash from one message to another reduces the number of lines required to present a given number of messages.

Because of these advantages, this sign is more useful than any other basic sign type. For example, the message ACCIDENT AHEAD MERGE RIGHT can be contained on one line no longer than necessary for the message ACCIDENT AHEAD. By flashing alternately from one to the other message at any given adjustable rate, the size of the sign is materially reduced, and additional target value or surprise value is provided to the driver in the form of flashing legends. Several points within the electronic circuit for monitoring are (a) readily available confirmation built into the electronics; (b) no moving parts such as in a drum sign because the entire sign is solid state; and (c) extreme target value because of the high degree of legibility of an internally illumated lighted message.

The two basic systems for controlling matrix signs can be described as a VMF approach and an ICVM approach. The VMF control for matrix signs consists of the self-storing of as many as 12 messages within each sign line. Remote control can actuate any 1 of the 12 circuits or 12 messages and that particular message is displayed. Random selection for alternate flash can be achieved, and any combination of displays of the 12 messages per line per sign can easily be achieved. A 2-line sign, therefore, could easily display 12 different messages on each line for a total of 24 messages or any combination of these. The ICVM approach is an infinitely variable matrix and is a teleprinter or typewriter type of display. Various schemes are available for operating a system of this type; but in general the base station contains prestored messages on either printed circuit cards, tapes, or magnetic cards, and these are sent out via code to the signs as required. In the event that any of the preselected messages are not applicable, it is possible for the operator to type out a different message and send it out to the given sign on an address basis. Additional peripheral equipment is easily installed at the base station so that the teleprinter message is first read before it is displayed on the sign.

Methods of interconnect, therefore, become increasingly important to changeable-message signs. Winko-Matic manufactures Mark I, Mark II, and Mark III systems. The basic differences are as follows.

The Mark I system is a frequency-division multiplex capable of transmitting 80 separate discrete frequencies over a given pair of voice-grade wires. If the tones can be used in a code (and they generally can), a great number of messages can be actuated by using tone code. By the same token, frequency-division multiplexing allows for simultaneous monitoring of signs and their messages because tones can be transmitted in both directions. The Mark IB allows for the use of as many as 80 tones simultaneously on a given pair of voice-grade wires, which means that an almost unlimited combination code can be arranged for controlling and monitoring a given sign system.

The Mark II system is a time-division multiplex capable of being transmitted over voice-grade wires and operating at a rate of 1,000 bits/sec. A standard 4-bit word code is used to both address and provide message function to the sign; the same code system applies to the monitoring ability.

The Mark III system is designed for a large system in which the code is transmitted over coaxial cable. In this case, we use a 10,000-bit rate and 16-bit words. The system can address 256 different field stations with as many as 128 functions per station and update everything every ½ sec. At the same time detector information can be received over the same wire, held in a storage, and updated every 10 msec in serial with the monitor requirements.

Present installations of variable-matrix signs are Woodrow Wilson Bridge in the District of Columbia, Narragansett Bridge in Rhode Island, Pennsylvania Turnpike, New York Port Authority facilities, New Jersey Turnpike, bridge in Connecticut, I-75 in Kentucky, weigh stations in various states, and Verrazano Bridge in New York City.

VARICOM TRAFFIC CONTROL AND COMMUNICATION SYSTEM

Lawrence A. Powers

3M National's activity in changeable-message signs began about 5 years ago as an offshoot of sign-contracting work. One of the products of a formal survey to find out what future information needs of motorists would be was a library search in which we examined accident reports, research reports, trade journals, and speeches by highway policy-makers to determine past and current thinking about changeable-message signs. This has become a continuing effort on our part, and we have bound findings into a booklet entitled "The Motorist Needs to Be Warned. . . . "

A second product of that survey was the evolution of the concepts around which we developed the VARICOM traffic control and communication system. Some of those concepts are discussed in this paper.

A changeable-message sign should be fail-safe against the advent of a power failure. The thinking 3 to 5 years ago was that any traffic condition that required a changeable-message sign was sufficiently critical to demand that it continue to operate normally during a power failure. In fact, it was pointed out to us several times that the occasion of the power failure might well be one of the times when the sign is most needed. This is an area of increasing interest apparently because of the worsening power situation. A statement on this point in the new manual for signing and pavement marking on Interstate highways reads: "This reference concerns overhead signs, but should not changeable-message signs be considered on a par with overhead signs?"

We were told repeatedly that vandalism is a continuing problem and that changeable-message signs especially should be resistant to attack. We were told that changeable-message signs should be able to operate under all ambient conditions including extreme temperatures, ice, and snow. The effect of direct sunlight on message legibility was mentioned, particularly the effect during morning and evening rush hours when the sun is at its 2 low points on the horizon.

A second major category that was mentioned even more frequently than the fail-safe requirements was that of message display. Over and over again we were told that changeable-message signs should be able to display the shapes, sizes, and colors as prescribed in the manual. The comments generally were, "A yellow diamond conveys a warning, regardless of the legend."

We were told that a great deal of effort has gone into the specifications for letter type, width of stroke, and spacing of letters to satisfy the varying levels of motorists' ability to see and to read. We were told in the District of Columbia and in Colorado where initial symbol sign testing was under way that symbols will assume a more important role in traffic signing. We were told that changeable-message signs should be able to accurately reproduce these symbols, especially because most of the motorists' symbol signs will be new and will require an educational process.

Operation and maintenance costs were another major area of interest, especially of those who had some previous experience with changeable-message signs. Cost of operation basically is the cost of electricity. Operational cost was emphasized by some people as being a serious handicap in the use of changeable-message signs. Cost of electricity has risen substantially in the past 3 years. An article 3 months ago in the Los Angeles Times announced a 12 percent rate increase on top of a 5 percent increase 9 months before. That is happening throughout the country, and we are told almost daily that it is going to get worse primarily because of delays in building new capacity.

Greater than the concern about operating costs was the concern about maintenance. Other points we picked up during the survey were a general feeling that the sign is only one part of a system, that the communication link and the control center equipment are important also, and that these should be incorporated into a total system. We were told that traffic engineers sometimes change their minds, and the message format, therefore, should be one that could be easily changed. We were told that it would be important for the sign operator to have positive feedback from the sign to confirm that the proper message is properly displayed.

Let me now explain some of the mechanics of the VARICOM sign.

Consider a fascia that incorporates the static message SPEED LIMIT. First of all it will look exactly like a speed limit sign should look. The shape and format are those of a speed limit sign. The letters are black on a white background. The letters themselves are exact reproductions of the prescribed characters. The letter sizes on the changeable portion of the message are 65, 16 in.; TRUCKS, 6 in.; and 55, 16 in.

Now assume that these are the same 3 lines of copy but that the character size of the bottom 2 lines changes when the speed limit is reduced and made common to all vehicles. We give the motorist the reason for the speed reduction to aid in securing a better compliance and at the same time give him an advance warning of the type of hazard he is about to encounter. The reduced speed limit is still on a white background, which makes it regulatory, but it could be on a yellow background, which makes it advisory or warning.

Now, let us consider the fascia in more detail. There are actually 2 housings behind the fascia. The lower housing contains the thermoelectric generator, the on-site power source. The upper housing is the cabinet for the sign itself. That cabinet is fabricated of 12-gauge steel; the message window is ¾-in. plexiglass. Therefore, the sign now is vandal-proof and will withstand small arms fire, shotgun fire, and a coke bottle thrown at 90 mph. The finish on the cabinet, inside and out, is an inorganic zinc primer with an epoxy top coat, the same finish as specified in California for bridge structures so that they resist corrosion.

The cabinet is sealed and locked, and thus an ideal environment is created and maintained for all of the functional parts of the sign—free from dust and insects and protected from extreme temperatures, ice, snow, and even the effects of pollutants in industrial areas. The temperature within the cabinet is always higher than ambient, so moisture is controlled to less than 50 percent. Cabinet temperature will range from 30 to 150 F for ambient temperatures of -40 to +120 F. For temperature control we utilize the heat produced either by the thermoelectric generator for the self-powered unit or by a strip heater in the line-powered unit. The cabinet is thermally insulated except for the message window. The heat loss that occurs through the window serves to keep the window free of ice and snow and even moisture that might otherwise condense on the message area.

All of the functional elements of the line-powered unit are contained within the sign cabinet: the flashing-light assembly is at the top; the radio or line communications equipment is on the left side; the logic package is suspended from the top; the drive train, with a reversible 12-V dc motor, is on the right side; the cam assembly is on the right side of the top drum; the storage battery is on the bottom right side; and the heat source is at the bottom of the cabinet, beneath the message window.

The messages are printed by the silk-screen process onto a polyester film that is transported and stored on the drum, located at the top and bottom of the message window. The time required to change from 1 message to the next is about 1 sec. Our logic system is designed to display as many as 8 different messages.

Certain signs utilize only a special retroreflective panel for message illumination. Units at the Lincoln Tunnel were internally illuminated, but even in those units we retained the retroreflective panel, which is stationary within the sign. A cross section of the sign would show the plexiglass window as the first layer in the cabinet. Behind that is the message film, which moves, and then the retroreflective panel, which does not move. If the sign is internally illuminated, as the signs at the tunnel are, then that assembly is located behind the reflective panel, which is light transmissive.

Thus, when there is a power failure, the reflective panel and the standard automotive storage battery allow the sign to continue to function normally in all respects. Retroreflection provides message illumination; and the battery operates the drive motor, the flashing lights, the logic system, and the radio or line terminal within the sign. It will do this for at least 24 hours; and when the battery reaches a given level of reduced output, the sign will automatically advise the controller that the end is near.

Our units can operate solely from the storage battery and the reflective panel. The advance-warning lights in the on-cycle are the only incandescent bulbs in the unit. Each is a 12-V, 12-W, sealed-beam spotlight located behind a Fresnel lens. That Fresnel lens gives a narrow beam, which can be seen for more than 1 mile. The brightness level of each light is more than 12,000 ft-L. However, when the motorist is close enough to read the message, he has passed out of the advance-warning light beam so that it does not interfere with his ability to read the message.

The logic system utilizes binary code in conventional teletype format. One VARICOM sign system can accommodate 676 signs, each with its own address code. Within a system, each sign listens to all of the commands from the control center but responds only to its particular address. When a sign is addressed, it is instructed to change its message or it is interrogated for its current status. For feedback, the logic is designed to provide 4 bits of information to the controller. We are currently using this to find out what message is displayed, whether it is properly displayed, whether the handset for the motorist-aid phone is off the hook, and whether the battery level is satisfactory. The logic system is totally solid-state, uses integrated circuits, and is of modular construction for easy field replacement.

The communication link may be radio or hard wire. For radio, we utilize UHF-FM in the 450-MHz range. The FCC has set aside 4 pairs of frequencies in this range for highway safety purposes. In March 1970, we received a temporary 1-year license to test the VARICOM system by using 1 pair of those frequencies. Early in 1971, the FCC issued a rule, in answer to a petition by the states of Rhode Island, Connecticut, and Massachusetts, that now permits the use of those frequencies for point-to-point application.

The test program we conducted under the temporary FCC license ran from March 1970 to March 1971. It included 4 signs using a combination of radio and leased telephone lines. Our interest in the test was to gain data on the use of those frequencies under varying conditions, to detect weaknesses in the system, and to quantify maintenance requirements. During the 1-year test we initiated more than ⅓ million sign station commands and interrogations, which mean more than ⅔ million transmissions. The design goal for unscheduled maintenance requirements for the entire system was a 2-year interval for each sign, on the basis of 50 message changes per day. That translates to 36,500 message changes. By November 1970 we had achieved that goal.

Normally, we utilize AFSK for data transmission for both radio and hard-wire communication, and terminals are at the base station and in each sign station. However, for 1 or 2 signs located only a short distance from the control center, we can use a simple dc loop, and, in fact, that is the technique used at the Lincoln Tunnel.

We have incorporated into the logic and communication links a capability for a motorist-aid phone. We accomplish this as a digital overlay type of transmission to combine command-code data and voice signals. Thus, we can utilize a common power source and communication link for both the sign and the motorist-aid phone. The mechanics of the phone are that when the stranded motorist lifts the handset a light or buzzer or both are activated at the control center. The controller pushes the proper button on the console to activate the phone at the sign and, thus, to begin a 2-way, duplex voice communication.

Control-center equipment may be a simple teletype that could, but probably never will, be used for a very small system. The next step is a hard-wired console that permits pushbutton control and status display of the system. This console automatically scans the entire system, continuously interrogates each sign in turn, and provides a constant updating of the status display.

The human-factors aspect of the console is one of great importance to ensure error-free operation by the controller. From his standpoint, to change a message he merely pushes the proper message button for the sign he wishes to change. The newly depressed button flashes until the scanner interrogates the sign and receives confirmation that the proper message is properly displayed. At that point the button is lighted constantly to provide a status display. As a system approaches 40 units, we suggest the use of a small computer to replace the hard-wired scanner. If space is scarce in the control center, some variation in the pushbutton and status-display board will be desirable. Our signs at the Lincoln Tunnel are activated manually through the existing computer. When that system is totally operational, the computer will activate and interrogate the signs directly.

The cost of the interface between the computer and the VARICOM signs was about $1,000. Initial cost varies substantially depending on the kind of installation; we have submitted proposals starting from $6,000 per sign. Typically, however, the per-sign cost for a limited number of units using line power and line communications, including all communications and control center equipment and the necessary technical field service, is about $10,000. Cost of operation for line power is 12 kW-h/day times the electrical rate, which averages 3 to 5 cents/kW-h, or about 36 to 60 cents per day. Self-powered units consume about 1 gal/day of propane at a cost of 14 cents/gal, so the cost is 14 cents/day.

For maintenance of line-powered and line-communication units, we suggest 1 preventive maintenance call per year. Our results to date show 1 unscheduled maintenance call once every 2 years at 50 message changes per day.

I would like to conclude by discussing some applications that are possible with the VARICOM system.

Using the thermoelectric generator and radio for the communication link now makes it possible to operate a totally free-standing, changeable-message sign. In our survey, 1 New England state and 2 western states indicated a need for changeable-message signs that could not be installed because of the cost of providing power and telephone lines. Since then, several additional traffic engineers have indicated this to be a problem, even in much less remote areas. VARICOM makes it possible to combine changeable-message signs with static signs, such as the speed limit sign discussed earlier.

It is also possible to combine signs when the changeable portion of the sign is a very small part of the total sign. With external illumination, the changeable sign and the static sign both assume the same brightness; thus, the brightness of the one does not interfere with the legibility of the other.

The 12-V electrical system raises the possibility of an economical and portable changeable-message sign. Sequentially flashing amber lights can be used to give advance-directional information. Exact reproduction of the symbols in the new manual is now possible.

DESIGN, OPERATION, AND UTILIZATION OF CHANGEABLE-MESSAGE SIGNS WITH EMPHASIS ON THE ROTATING-DRUM TYPE

Samuel B. Dunne

It is now generally agreed among highway traffic engineers throughout the world that, although static signs are indispensable for routing and controlling traffic, they exhibit a number of limitations in advising, forewarning, and giving regulatory instructions to the motorist.

Table 1 gives 3 essential, though sometimes overlapping, functions of a variable-message sign and the elements of each. Table 2 gives descriptions of current types of variable-message signs now in use. A combination of the types of variable-message signs in one package or incorporated with a static sign may be utilized to take advantage of the best features of each type. Any system of changeable-message signs must incorporate a 100 percent positive, reliable, and independent feedback system capable of indicating the actual message displayed on the sign and not merely the message selected.

At Fosco Fabricators, Inc., we are particularly concerned at this time with the rotary drum type of variable-message sign even though we have the capability of designing and furnishing variable-message signs using other modes of display and operation.

The drum sign in its simplest form consists of a triangular-shaped drum pivoted on each end and mounted in a suitable enclosure. Attached to each face of the rotor is a sign plate bearing the required legend. The rotor is driven at about 6 rpm by means of a gear reducer coupled directly to the rotor spindle, which is supported by flanged ball bearings mounted on ½-in. thick plate bulkheads. Coupled directly to the shaft also are multiple cam-operated microswitches individually adjustable to locate any selected face in the exposed position. An indexing, weighted roller attached to a vertical pull magnet locks into a 3-lobe auxiliary cam also rigidly attached to the shaft. This magnet is electrically connected in parallel with the motor so that, when the microswitch opens the motor control relay, the magnet drops the roller into a curved slot that inhibits any further movement of the drum. To overcome the inertia of the moving drum and driving mechanism, a dynamic brake is incorporated into the motor circuit and effectively prevents overrun and thus contributes to the accuracy of the indexing system and the perpendicularity of the rotor face.

Where the possibility of ice formation would tend to lock or interfere with the rotation of the drum, ice-melting heating coils are incorporated into the periphery of the drum opening. These coils are activated automatically when icing conditions prevail.

Table 1. Functions of variable-message signs.

Motorist Warning	Advisory	Command
Accident ahead	Anticipated delay time	Clear lane for emergency vehicles
Lane closure	Alternate route	Give weigh station instruction
Congestion	Use low gear	Modify permissible speeds as road conditions dictate
Construction	Use chains	Close 1 lane for snowplowing and sanding
Fog	Freeway entrance	Close 1 lane for repair or maintenance
Ice	Other	Reverse center lanes during peak one-direction traffic flow
Snow		Divert traffic to secondary roads
Slippery		Other
Bridge closure		
Other condition		

Table 2. Types of variable-message signs.

Mechanical or Motor-Operated	Mechanical-Matrix Disk[a]	Electrical
Window-shade type such as VARICOM in single or multiple units	Magnetically motivated	Blank-out with incandescent, fluorescent, or neon lights
Single or multiple drums individually or jointly driven having 2 to 8 faces on a drum, vertical or horizontal orientation, and drums in parallel or in-line alignment	Electrostatically motivated	Neon-tube alphanumeric characters superimposed in front of one another or sectional-element configurations individually activated
Flip-over panel type operated either manually or by motor	Pneumatically operated	Matrix multiple-bulb with modular character units or with individual bulb socket configuration 5 by 7 using incandescent or glow discharge bulbs with screw-in or bayonet sockets
		Matrix light-emitting semiconductor diodes (LED)[b]

[a]One surface identical with the sign background, and the alternate surface covered with white or reflective coating. [b]Not yet commercially available.

In areas subject to severe icing or snow conditions, integral heating coils may be embedded in the bottom panel of the cabinet to prevent buildup of such materials, though this represents a most unusual situation.

For areas subject to occasional power failure, provision is made to operate a 12-V dc auxiliary drive unit from the ground by means of an automobile or portable 12-V battery so that the sign may, when necessary, be rotated to a new position. An arrangement for manual rotation of the rotor or rotors is also incorporated into all drum signs.

There is no limit to the sign face size other than practical overall size considerations. We are prepared to design a rotating sign face 6 ft wide by 50 ft long. A sign 3 drums high by 2 drums wide or 6 individual hexagonal drums (each with 6 faces) is now in the process of manufacture. We offer the following options:

1. Multiple faces on each drum with as many as 7 live faces and 1 blank face directly driven by 1 motor;
2. Multiple drums in 1 cabinet as high as 4 rotors and as wide as 2 rotors with individual motors on each drum; and
3. Multiple drums, chain driven by 1 motor.

The advantages of rotary drum signs are as follows:

1. Operation is extremely reliable and simple, and components are not complicated;
2. Sign and system have been proved in operation;
3. Signs are becoming more acceptable and are being specified by more highway agencies and consultants;
4. Total message or legend only can easily be changed or exchanged if messages require modification or substitution in the course of time;
5. Maintenance cost is lowest of all existing changeable-message sign systems;

6. Low maintenance means fewer hazards and correspondingly lower accident probability as a result of maintenance crews working constantly on signs, for instance, replacing bulbs;

7. Operating cost is lowest of all existing systems, and power cost is a fraction of the cost for other systems;

8. Sign looks like a highway sign and not like an advertising or time/temperature sign, is always readable in its entirety because no portions of it are "out" at any given time, and can be seen even if facing the sun;

9. Colored background warns of or indicates different road conditions and situations ahead;

10. Symbols and route markers can be displayed in color;

11. Vandalism damages are less expensive to rectify as compared with those of bulb signs;

12. Motorist will always have a sign available because power failure from underground cable damage, blown fuses, vibrations, or tremors will not affect the sign or make it "disappear";

13. Sign can be hand-operated or, in case of an emergency, can also be operated from ground by car battery;

14. Standard components can be obtained in any city and are easily accessible in sign;

15. Signs can be mounted back to back and still be easily accessible;

16. Maintenance can be by regular maintenance personnel having no electronics background or highly technical knowledge;

17. Remote-control system is much cheaper because of simplicity of design; and

18. System has a 100 percent positive, reliable, and independent feedback system capable of indicating the actual message displayed on the sign and not merely the command or selected message.

We now have rotary drum signs operating in the states of New Jersey, California, and Illinois with units in current production for several other states.

The technical capability required to maintain a rotary drum, changeable-message sign is no more sophisticated than that required to maintain a simple electrical home appliance such as a 110-V washing machine. Experience in simple relays, timers, thermostats, capacitor motors, and microswitches combined in straight-line, hard-wire circuitry and the ability to read and follow a simple circuit drawing are all that are required. Our service experience to date after 2 years of field service on 150 units has been confined chiefly to service calls involving lack of power, low voltage, blown fuses, 4 defective microswitches, and several cases of insects and spiders nesting in the local cabinet push-button switches. For emergency operation during temporary power failure, we provide the option of an overriding 12-V dc motor that can be activated from the ground either by automobile battery jumpers or by a mechanical speed-handle socket wrench that engages an extension of the motor shaft but requires that one climb up on the sign bridge to use it, or the motor can be activated by both jumpers and socket wrench.

We have 2 types of remote control systems. Type 1 involves a buried hard-wire cabling system such as that used by the telephone companies and is entirely adequate for control up to 5 miles. The power supply may be laid in the same trench. A simple, single or chain-coupled double, 4-sided drum sign requires 1 wire for each face, 1 common wire for control, and an equal number of wires for feedback indication making a total control cable bundle of 10 wires. The use of a standard telephone type of 6-pair cable will provide 2 spare wires that may be used for permanent or temporary telephone communication between the sign and the control point for setup, testing, and maintenance purposes. This 19-gauge, multiple-wire cable with its protective casing is about ½ in. in diameter and costs less than $2/100 lin ft. The power supply required for such a sign including de-icing coils and luminaries approximates 2 kW, and a 3-wire 280-V supply with a step-down transformer at the sign to develop 240/120 service is not expensive, depending only on the distance from a source of power.

Type 2 is used either for remote control and status monitoring over long distances or for a large group of separate signs spread over 5 to 50 miles or longer for both of these. We use a coded time division multiplex digital type of 2-wire communication system either with buried cable or through leased telephone circuits. Time sharing a 2-wire communication circuit permits elimination of costly point-to-point wiring. This time division multiplex involves parallel-to-serial conversion. The input information from a set of parallel 2-state inputs such as switch contacts is sequentially examined by an encoder and then transmitted to the decoder. The samples are transmitted repeatedly one after the other over a narrow-band communication channel using an encoder to handle all inputs. In this manner both commands and verifications may be transmitted over the same pair of wires in either direction. Five hundred or more addresses may be controlled and verified by the addition of modular plug-in components. The economy of such a system over a multiplicity of hard-wire cabling circuitry is obvious.

During the next few years, I believe we will see a rapid proliferation in the number and variety of changeable-message sign systems. The use of these signs should result in greater safety, less traffic congestion, and better utilization of highways, tunnels, and bridges.

THE DISTEC SYSTEM: A SIGN OF OUR TIMES

William Ross Aiken

The DISTEC system is an indoor-outdoor display system that is new on the market and is the result of a number of years of development and testing. This new sign system was developed to overcome faults in the old signs; among those faults are high cost, high maintenance, high power consumption, poor visibility under certain conditions, poor resolution, limited display capabilities in terms of types and sizes of characters displayed and their location, and limited control capabilities. The new system is controllable by low-cost, solid-state means without a multitude of expensive current-carrying wires.

The DISTEC is a complete system and includes a display portion, a solid-state control unit, and various readers or input devices and arrangements. The system is supplied on order and as OEM components to sign companies.

The display portion of the system is passive; that is, it does not emit light but instead controls the passage and reflection of light. Thus, it does not "fight" the sun but uses ambient and artificial light to produce displays that are clearly visible under all lighting conditions from the brightest direct sunlight to complete darkness. Displayed characters appear to be made of continuous lines but are really a mosaic of small, very thin vanes that are positioned so as to be unseen or to block the passage of reflection of light (Fig. 1).

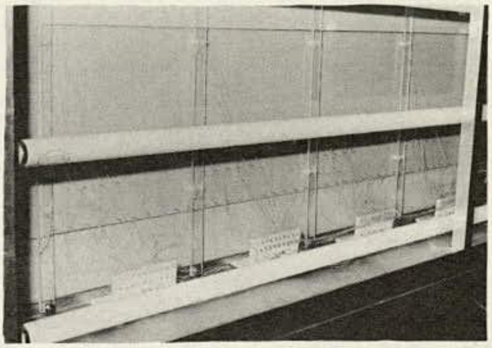
Displays are formed by electrostatically moving the vanes into 1 of 2 positions: erased (hidden from view) or written (in view). There are no magnets, levers, air jets, or other mechanisms. In fact, there is nothing one can see in the sign to indicate how it does work; visible are only a small number of printed-circuit lines to conduct the control signals and set up the unseen fields.

A sign face is made up of modules. Each module has 100 vanes. They fit closely together, horizontally and vertically. This means that signs may be almost any size, single- or double-sided, and characters are not limited to certain locations. A character may cross module boundaries and be any size or shape. Pictures may be shown.

Control wiring is extremely simple. In addition to using printed-circuit technique, the sign is connected in a new way, which we call digital cross-grid. Digital cross-grid is a new method whereby only a few wires are needed to control even a very large sign; the wires are very small in size as well as in number, and they do not have to carry much power. Figure 2 shows the inside, rear of a sign, illustrating the simple wiring.

Figure 1. Displayed characters of DISTEC system.

Figure 2. Inside wiring from rear of sign.



We do something else differently; we use proportional writing. Proportional writing is like proportional typing; the characters do not all occupy the same amount of space. For instance, in proportional writing, an "i" is not as wide as a "w." This allows the use of more characters and makes a better looking display.

Displays may be black on white or white on black (or, in some instances, in color). The device may be illuminated by either ambient or artificial light or both. Light may be from the front or from the back. This has been necessary in the advertising field, for almost all of the commercial outdoor signs in use in the United States today are interior illuminated. From gas station signs to shopping center and theater signs, backlighting is universal. The advertising industry has found that the drawing power of a backlighted sign is many times greater than a frontlighted sign and insists on this arrangement. The DISTEC sign may be lighted either front or back, according to the particular requirements and specific use, or not lighted at all.

The modules are made of molded translucent acrylic plastic with iridized aluminum vanes. A 13-in. square module with 100 vanes weighs only $1\frac{3}{4}$ lb. Signs must have a protective cover, which is very effective to reduce vandalism.

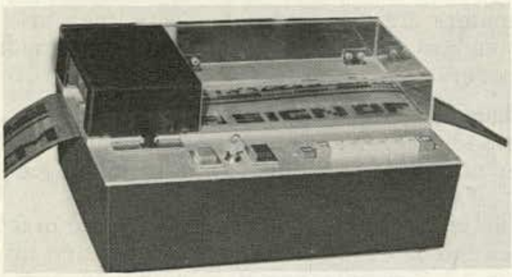
The signs have a very long life and require little or no maintenance. Millions of cycles of operation, temperatures from -40 to +165 F, and zero to saturation humidity seem to have little effect.

The power used in this device is very small, for theoretically there is no power consumption at all, and the voltage is about a fifth of that for a neon sign. It is completely safe; the maximum current available is less than a tenth of that normally specified as safe.

Each sign requires a solid-state control. This may be a simple power supply for a single-message sign or a more complex device for reception of teletype signals. With the exception of a single-message sign, the controls serve to convert low voltage (5- or 12-V) signals from an input reader into a form and voltage usable by the sign. The control uses plug-in, solid-state, printed circuit boards. The number of boards used depends on the size of the sign and whether each side of a double-sided sign is to display separate messages. An interface computer unit is plugged into the control if it is to work from a teletype machine, tape reader, computer, or keyboard. Controls are about 12 by 15 by 17 in. and weigh less than 25 lb. They function from 120 V ac and require less than 30 W even for a large sign of thousands of display elements. A battery-inverter unit is available as a part of the control.

With the exception of single-message signs that function directly from the supply mains, an input must be used to operate the control, that is, to tell the control what to write on the sign. We call these input devices readers. Almost any type of reader may

Figure 3. Tape-card reader with tape.



be used. Combinations of different readers may be used with the same sign. The types of readers are as follows:

1. Marked tape-card readers are produced by Display Technology Corporation. They are optical devices and read marks on 4-in. wide translucent or transparent tapes or cards. Figure 3 shows a tape-card reader with tape. The tapes instruct the control what is to be displayed and where it is to be located on the sign. This is done by means of standard BCD coding for location and direct character representation. For example, one edge of a tape will have the actual "scene" to be displayed marked on it. I say "scene" because one is not limited here to a predetermined number and shape of characters. Any size and shape of symbol—even graphics—may be displayed. (Displays are not limited in location; they may be anywhere on the sign without regard to modules and may be written in a random fashion.) Tapes may be short or many feet long. They may be continuous loops and can be programmed to automatically change messages at predetermined times. Display Technology Corporation supplies premarked tapes on order or will supply coded, unmarked tapes for field use. Premarked cards are also available. These cards are provided in fonts. A font contains several hundred cards including duplicates, each marked with a character, number, or punctuation symbol. An operator simply chooses the cards that spell the message he desires and puts them in the slot in the reader; the display appears on the sign. Four standard-sized characters are currently available: 10.4, 13.0, 15.6, and 20.8 in. high. The width of the lines of characters varies according to the size of the characters. Word cards are also available. They contain commonly used words such as THE, SALE, TODAY, or WELCOME. Other word cards are available on order.

The following readers all use standard ASCII-8 level coding with choice provided for different-sized characters. Special features, such as proportional writing, automatic centering of messages, and continuous choice of character size, are included. Readers may be connected to the control directly by twisted pair line or by telephone line or radio link.

2. A digital magnetic cassette tape reader will work the DISTEC system. We feel that anyone with a car stereo can operate one of these!

3. Standard punched-tape readers may be used. They are available from Display Technology Corporation or may be purchased elsewhere.

4. The keyboard message reader is available on special order. It contains keys marked with complete messages instead of individual characters. Thus, CAUTION, SLOW TO 30 MPH, TAKE NEXT OFF-RAMP, ACCIDENT AHEAD, or WEIGH STATION CLOSED can be displayed without spelling out each word. This reader requires a special interface unit. The messages may also be controlled directly from a computer without having to spell out each word.

5. Teletype machines may be used with the DISTEC system. Two or more sizes of characters are provided as for the punched-tape and magnetic-tape readers. The control will detect operator or technical errors in instructions from the teletype, inform the operator in very polite language what the error is, and tell him how to correct it. Note that it will do this for instructions, not for spelling! Teletype machines in use for other purposes may be utilized, or they may be obtained from Display Technology or directly from Teletype Corporation.

6. The DISTEC reader consists of an electric keyboard with a small TV type of monitor. Messages typed on the keyboard appear on the TV screen and may be edited before they are sent to the control. That is, words or characters may be erased, corrected, moved about, or otherwise altered to the satisfaction of the operator before

they are sent to the control and put up on a sign. Connection may be direct by twisted pair line or by telephone circuit or radio link.

7. The controls may be connected to computers directly by twisted pair lines or by telephone lines or radio link. Coding is standard ASCII-8 level. Writing is proportional unless specified otherwise by special order.

The DISTEC system is a new concept in changeable-message displays; it has complete obliteration and is unique in its low cost, low power consumption, extraordinary contrast, and ability to be backlighted. It has unlimited variability. Its maintenance requirements are close to zero.

The display is passive and is clearly visible under all lighting conditions from direct sunlight to complete darkness. Symbols appear to be continuous lines. There are no magnets, levers, air jets, or other mechanisms. Signs are any size, with no separation between adjacent modules.

Characters may cross module boundaries and be any size or shape; graphics may be shown. Writing may be proportional; displays may be black on white or white on black. There is no radio interference.

Sign wiring is simple, even for thousands of display elements. Remote control is TTL compatible, ASCII coded, low voltage, and direct or by telephone line or radio link.

Operation may be by marked tape, cards, message keyboard, magnetic tape, punched tape, teletype, keyboard-TV monitor, computer, or a combination of these.

All sign circuits may actually be shorted without danger of fire or other hazard. Signs are tested from -40 to +165 F and zero to saturation humidity.

The system may be supplied with modules mounted in a subassembly and prewired and tested to fit within a decorative enclosure made to order or supplied by the purchaser.

The Mark II modules themselves are 13 in. square and have 100 display elements each. Other sign modules with different-sized elements are expected to be in production next year.

CHANGEABLE-MESSAGE DISPLAYS: SOME DESIGN CONSIDERATIONS

William Brooks and David Nelson

Changeable-message displays in the past have been used mainly in outdoor advertising applications. Sign company designers, familiar with advertising requirements, have designed those displays to achieve maximum effect for advertising at the lowest possible cost.

Applications of changeable-message displays in public safety present an entirely new set of requirements that can be considerably more complex than those of advertising. Public-safety displays usually require a systems concept. That is, the display operates in a system of information units, sometimes involving electronic computers. In addition, public-safety displays require high performance because life or property may be endangered if there is faulty operation. Requirements for public-safety display systems are usually first drafted by officials who are concerned about performance. That is, they know what it is they wish to achieve. They usually do not have an electronic background, so they look for some yardstick by which to gauge the requirements to ensure that they are realistic.

The purpose of this paper is to set forth some guidelines based on available technology.

Legibility is the most important consideration in the specification of a display. It is also one of the most difficult to define in a specification. Simple block letters are the most legible. Block letters, width 60 percent of their height, can be read by an average viewer 500 ft away for each foot of letter height. This applies to exposed lamps or other bright copy on a dark background. Lamp spacing is also a legibility factor. Correctly spaced lamps, when viewed at the correct reading distance, will produce a continuous, nearly smooth line of light. For medium-base lamps (household type of base), this distance is 250 to 500 ft.

Viewing angle is important where the person reading the display travels through a large angle. A typical example is a highway display where the driver may have to start reading at a distance and finish reading at close range. If the display is mounted over the roadway, the viewing angle may become severe at close distance.

Because of visual effects, colors have different impacts on viewers. The designer must take account of this in the display design. For instance, for the same visual "impact," 11-W yellow, 15-W orange, 25-W red and green, and 40-W blue would be required. Mixing colors on displays should be avoided if possible.

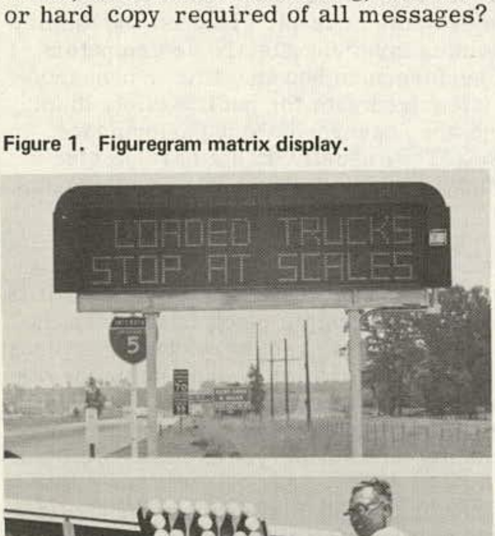
Because of the extreme daylight brightness, the display should use the maximum contrast possible. The readability is based on contrast, not brightness. The background color of the display should be a dark, flat color that reflects little or no incident sunlight. A flat finish also improves unwanted headlight reflection glare at night. Typical highway displays use lamps in the 15-W and over range to produce the required light intensity. Unwanted sunlight reflections from lamps, particularly the reflector type, are greatly reduced by means of sun screens. Sun screens work like miniature blinds, deflecting sunlight at an angle but allowing light to shine out in a down direction.

The required light output from the display at night is greatly reduced. In many applications the light is reduced to 10 percent of the daytime level. Without reduced light output, the display would be difficult to read because of glare.

Dimming is the reduction of light output to maximize the legibility of the display. Dimming should be continuously variable, automatically. This will ensure that the display is legible at all hours of the day. One of the difficulties of step dimming, which is sometimes used, is that at dusk or dawn the display is either too bright or too dim. Stepless dimming also has an added maintenance factor that is highly desirable. With stepless dimming, lamp life up to 15,000 hours is feasible.

There are many ways to control a display. Controls range from manual to full computer control. In selecting modes, one should be mindful of possible future requirements. In the beginning the requirements may be simple, such as a manual selector switch controlling a fixed library of messages. Control system design parameters should answer the following questions: Will initial messages ever be changed, or will more messages be required in the future? Will messages have to be composed as the situation warrants? Will the system be adaptable to both manual and automatic computer control? What are the telephone or cable requirements to display sites? Is it necessary to verify that the display actually displayed the message commanded? Is it sufficient merely to indicate that the display went to position 6 on some selector switch? Must the display read back to the control point data such as power on, lines to display intact, electronics functioning, and message being displayed? Is a permanent record or hard copy required of all messages? Can manual override be employed when local conditions, such as telephone line failure or floods, require local control or manual control at computer location? Is the system modular?

Figure 1. Figuregram matrix display.



Displays composed of banks of lamps are commonly called matrix displays. Some of these displays are very limited in what they can display, and others are completely universal. Simple displays that are hard wired can display a limited number of words such as OPEN and CLOSED. Displays that can show any number of characters are also matrix displays. The point here is that a matrix display has a wide range of capabilities.

There are also several forms of matrix displays. One form is the solid bank of lamps. Typically this type is 7 lamps high by 80 or so lamps long. Space for each character is 5 lamps wide. Space between characters is usually 1 lamp wide. This form requires 42 lamps per character.

Another form of matrix is the "figuregram" type. This type is not a solid bank but consists of strings of lamps to form segments. All letters and numbers can be formed with 15 segments. The advantage of the figuregram over the solid bank is that less control equipment is required. Any letter can be formed with only 15 switches, whereas the solid bank requires 7 times 5 plus 7 or 42 lamps to be switched per character. Also the figuregram type requires 31 lamps instead of 42. A slightly stylized alphabet is used with the figuregram type, but that is not objectionable (Fig. 1). The figuregram type is favored over others because of complete interchangeability and lower cost. Equipment costs are lower because there are fewer parts per character, and operating costs are lower because there are fewer lamps to maintain.

Although changeable-message displays have been used for some time, additional considerations in public safety require new specifications. The system concept must be adopted to allow future expansion of the system. Each level should build on the previous level without extensive revisions or downtime. Flexibility is inexpensive to obtain with modern electronics. Careful examination of present and near-future requirements should be included in drawing all specifications.

NEWEST COST BREAKTHROUGH FOR CHANGEABLE-MESSAGE MATRIX SIGNS

John J. Mauro

Information Concepts, Inc., recently installed in Norfolk, Virginia, an outdoor display system incorporating a new and advanced technology that may offer to traffic engineers a low-cost and highly efficient matrix changeable-message sign for traffic control. Since its inception in 1965, ICI has designed and installed or is currently installing other display systems, as follows:

1. Computer-activated outdoor display system for retail advertising at the Military Circle Shopping Mall in Norfolk, Virginia;
2. Computer-activated major league baseball and football scoreboard display system for the Oakland Athletics and the Oakland Raiders;
3. Computer system to control an existing scoreboard display system for the New York Mets and the New York Jets;
4. IBM Golf Trailer, mobile computer-activated sports scoring and information display system;
5. Computer-activated motorcar scoring and display system for the Ontario Motor Speedway;
6. Computer-activated municipal and U.S. government securities display system for Chase Manhattan Bank; and
7. Computer-activated commodities display system for the Chicago Mercantile Exchange.

Rather than light bulbs with all their inherent problems, we use reflective light that reduces operating and maintenance costs, yet provides a clear and highly visible message. We use Ferranti-Packard reflective disks that are positioned upon command to form alphabetic and numeric characters that are visible under all lighting and weather conditions. Reflecting sunlight in daytime and a light source at night, this display technology has many advantages when used for traffic control.

1. Low initial cost—Light bulbs are not used and, therefore, large transformers and heavy power distribution cables are not required. Displays are lightweight so that simple, attractive structural supports can be used.
2. Low operating cost—Power consumption is negligible. Monthly power costs approximate a tenth of the power costs for a comparable display using light bulbs. The

ICI systems operate either automatically or manually. Messages entered into the system can be displayed automatically for as long as desired. Without the heat and limited life problems of light bulbs, which need periodic replacement, ICI systems require little maintenance expense. The life of each reflective disk is in the order of 20 million operations. Displays are enclosed in a weathertight and vandal-proof plexiglass shield.

3. High operational efficiency—ICI systems operate remotely over telephone lines and can be activated by a computer or a standard teletype, located anywhere convenient for its operation. Solid-state control equipment provides excellent reliability as well as versatility. Complete messages or individual words or lines can be changed in less than 2 sec; attention is ensured by highlighting the messages through a novel range of formats. The display reflects light; therefore, the brighter the light source is, the more brilliant the display is. In direct sunlight, the visibility is so striking that reflective disks exceed the viewability of 100-W lamps and also provide an excellent peripheral viewing angle up to 160 deg.

4. High program flexibility—Configurations for traffic control are quite flexible in size and format. Standard character sizes are available including 4.2, 12, 18, and 42 in. in height. As many lines and characters of information can be displayed as the location requirements dictate. Reflective disks can be obtained in a wide range of colors; thus, standard color codes for traffic applications can be met.

As a demonstration of the effectiveness and reliability of this display technology, Ferranti-Packard installed cross and arrow lane-control signs for the Toronto Highway Traffic Department more than 3 years ago. The signs have operated without fault, and not a single maintenance call has yet been made.

In summary, the ICI display systems, which utilize Ferranti-Packard reflective disks, offer traffic control engineers a changeable-message matrix concept that has the following features: reflective light rather than incandescent light, minimal operating and maintenance expense, high degree of message visibility under all lighting and weather conditions, and long life and high reliability.

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Under the terms of its congressional charter, the Academy is also called upon to act as an official—yet independent—adviser to the federal government in any matter of science and technology. This provision accounts for the close ties that have always existed between the Academy and the government, although the Academy is not a governmental agency and its activities are not limited to those on behalf of the government.

The **National Academy of Engineering** was established on December 5, 1964. On that date the Council of the National Academy of Sciences, under the authority of its act of incorporation, adopted articles of organization bringing the National Academy of Engineering into being, independent and autonomous in its organization and the election of its members, and closely coordinated with the National Academy of Sciences in its advisory activities. The two Academies join in the furtherance of science and engineering and share the responsibility of advising the federal government, upon request, on any subject of science or technology.

The **National Research Council** was organized as an agency of the National Academy of Sciences in 1916, at the request of President Wilson, to provide a broader participation by American scientists and engineers in the work of the Academy in service to science and the nation. Its members, who receive their appointments from the President of the National Academy of Sciences, are drawn from academic, industrial, and government organizations throughout the country. The National Research Council serves both Academies in the discharge of their responsibilities. Supported by private and public contributions, grants, and contracts and by voluntary contributions of time and effort by several thousand of the nation's leading scientists and engineers, the Academies and their Research Council thus work to serve the national interest, to foster the sound development of science and engineering, and to promote their effective application for the benefit of society.

The **Division of Engineering** is one of the eight major divisions into which the National Research Council is organized for the conduct of its work. Its membership includes representatives of the nation's leading technical societies as well as a number of members-at-large. Its Chairman is appointed by the Council of the Academy of Sciences upon nomination by the Council of the Academy of Engineering.

The **Highway Research Board** is an agency of the Division of Engineering. The Board was established November 11, 1920, under the auspices of the National Research Council as a cooperative organization of the highway technologists of America. The purpose of the Board is to advance knowledge of the nature and performance of transportation systems through the stimulation of research and dissemination of information derived therefrom. It is supported in this effort by the state highway departments, the U.S. Department of Transportation, and many other organizations interested in the development of transportation.

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