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FINAL REPORT

INCIDENT MANAGEMENT
Changeable Message Sign Deployment Guidelines

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16. Abstract

The objective of this research was to develop guidelines for the deployment of changeable message signs (CMSs) in support of incident management in the Omaha metropolitan area. The guidelines presented in this report address the location and placement of the CMSs, design and display of CMS messages, alternate routes, and operation of the system. The guidelines promote the deployment of a cost-effective CMS system that provides reliable driver information which will improve the safety and efficiency of freeway operations during incidents. The CMS locations recommended in the guidelines are those which provide greatest benefits to road users per unit cost of the system. The placement and message guidelines foster the readability, understandability, and credibility of the information displayed by the CMSs. The alternate route description discusses the need for trailblazers to guide unfamiliar drivers and the importance of checking conditions on the alternate routes before diverting traffic to them. The operation guidelines emphasize the importance of maintaining the credibility of the system. *Because of their high visibility and the amount of attention they will receive, at least initially, from the drivers and the news media, it would be much better to continue freeway operations without CMSs than to deploy CMSs that display unreliable information.*

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DISCLAIMER

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EXECUTIVE SUMMARY

Incidents are non-recurrent events that reduce roadway capacity or abnormally increase traffic demand. Some incidents are predictable, such as maintenance or construction activities and special events. Other incidents are unpredictable, such as accidents, stalled or disabled vehicles, spilled loads, roadway debris, and inclement weather. Incidents frequently cause traffic congestion and delay, and create the potential for secondary accidents. It has been estimated that over 6,000 unpredictable incidents occur each year on the freeway system in the Omaha metropolitan area, causing approximately 300,000 vehicle-hours of delay and nearly 100 accidents annually *(1)*.

The impact of an incident on traffic congestion and safety depends on: (1) the amount by which it reduces roadway capacity, (2) its duration, and (3) the traffic demand on the roadway when it occurs. The levels of traffic congestion and exposure to secondary accidents are higher when capacity reductions are greater, incident durations are longer, and traffic demands are higher. Incident management can reduce the impacts of incidents by reducing incident duration and traffic demand. Incident management reduces the duration of an incident by enabling earlier detection, quicker response, and faster removal. Incident management reduces traffic demand by providing traffic control and traveler information to divert traffic. An analysis of the potential benefits of freeway incident management in the Omaha metropolitan area *(1)* estimated that the annual road user cost savings would be about $2.5 million, nearly half of which could be attributed to the implementation of a traveler information system.

In April, 1995, the Nebraska Department of Roads (NDOR), the Omaha Metropolitan Area Planning Agency (MAPA), and the Federal Highway Administration (FHWA) formed a focus group to more clearly define the need and opportunity for incident management in the Omaha metropolitan area. The following agencies are represented in the focus group: Omaha Fire Department, Omaha Police Department, Omaha 911, Douglas County Emergency Management Agency, Nebraska State Patrol, Nebraska Department of Roads (NDOR), Metropolitan Area Planning Agency (MAPA), Iowa Department of Transportation (Iowa DOT), and Federal Highway Administration (FHWA).

The primary objective of the focus group was to establish an incident management program in the Omaha metropolitan area. The group evaluated all 45 freeway incident management options included in the FHWA Incident Management Workshop, which was presented in Omaha in April, 1993. Deployment of changeable message signs (CMSs) was selected as one of the options that should be implemented immediately.

The objective of this research was to develop guidelines for the deployment of CMSs in support of freeway incident management in the Omaha metropolitan area. The research consisted of three phases. The first phase involved the assessment of the impacts of incidents occurring on the freeway system in the Omaha metropolitan area and a preliminary evaluation of alternative CMS locations. The second phase comprised a benefit-cost analysis of selected CMS locations and the evaluation of alternative deployment strategies. The third phase entailed the development and documentation of guidelines for the deployment of CMSs in support of freeway incident management in the Omaha metropolitan area based on the preferred deployment strategy. The results of the third phase of the research are documented in this report. The first and second phases are documented elsewhere *(2,3)*.

The guidelines presented in this report address the location and placement of the CMSs, design and display of CMS messages, alternate routes, and operation of the CMS system. The guidelines promote the deployment of a cost-effective CMS system that provides reliable driver information which will improve the safety and efficiency of freeway operations during incidents. The nine CMS locations recommended in the guidelines are those which provide greatest benefits to road users per unit cost of the system. The placement and message guidelines foster the readability, understandability, and credibility of the information displayed by the CMSs. The alternate route description discusses the need for trailblazers to guide unfamiliar drivers and the importance of checking conditions on the alternate routes before diverting traffic to them.

The operation guidelines emphasize the importance of maintaining the credibility of the system. Unless the system is operated in a way to ensure the reliability of the information it provides, drivers will ignore its messages and the resources used to deploy the CMSs will be wasted. NDOR must commit the personnel and secure the interagency cooperation necessary to provide reliable information from the very beginning. Once drivers' confidence in an information system is lost, it is extremely difficult to regain it. *Because of their high visibility and the amount of attention they will receive, at least initially, from the drivers and the news media, it would be much better to continue freeway operations without CMSs than to deploy CMSs that display unreliable information.*

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Chapter 1

INTRODUCTION

1.1 BACKGROUND

Incidents are non-recurrent events that reduce roadway capacity or abnormally increase traffic demand. Some incidents are predictable, such as maintenance or construction activities and special events. Other incidents are unpredictable, such as accidents, stalled or disabled vehicles, spilled loads, roadway debris, and inclement weather. Incidents frequently cause traffic congestion and delay, and create the potential for secondary accidents. It has been estimated that over 6,000 unpredictable incidents occur each year on the freeway system in the Omaha metropolitan area, causing approximately 300,000 vehicle-hours of delay and nearly 100 accidents annually *(1)*.

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The primary objective of the focus group was to establish an incident management program in the Omaha metropolitan area. The group evaluated all 45 freeway incident management options included in the FHWA Incident Management Workshop, which was presented in Omaha in April, 1993. The options were classified into the following implementation categories:

- Options that should be implemented immediately.
- Options that should be implemented in the future.
- Options that have already been implemented.
- Options that are not applicable.

Deployment of changeable message signs (CMSs) was one of 14 options classified as those that should be implemented immediately. The CMSs would be used to improve traveler information about the location and scope of incidents and alternate routes. The information provided by the CMSs would facilitate the diversion of traffic to alternate routes and reduce the traffic demand at the locations of incidents. The lower traffic demand would in turn reduce the impact of the incidents on traffic congestion and safety.

1.2 OBJECTIVE

The objective of this research was to develop guidelines for the deployment of CMSs in support of freeway incident management in the Omaha metropolitan area. The development of the guidelines addressed the following issues relative to the deployment of CMSs: sign locations, messages, CMS type, communications and surveillance requirements, communications technology, alternative routes, operating procedures, staffing and facilities requirements, benefits, costs, and institutional and legal considerations. A benefit-cost analysis of alternative CMS deployment plans for freeway incident management in the Omaha metropolitan area was conducted. The analysis considered the life-cycle costs of system components and the staffing and training needs to support the system. The effects of existing and planned traffic management, traveler information, and communications systems as well as legal and institutional barriers pertinent to the deployment and operation of a CMS system were also considered in the development of the guidelines.

1.3 METHODOLOGY

The research consisted of three phases. The first phase involved the assessment of the impacts of incidents occurring on the freeway system in the Omaha metropolitan area and a preliminary evaluation of alternative CMS locations. The second phase comprised a benefit-cost analysis of selected CMS locations and the evaluation of alternative deployment strategies. The third phase entailed the development and documentation of guidelines for the deployment of CMSs in support of freeway incident management in the Omaha metropolitan area based on the preferred deployment strategy.

1.4 CONTENTS OF REPORT

The results of the third phase of the research are documented in this report. The first and second phases are documented elsewhere *(2,3)*. The results of a benefit-cost analysis of the alternative CMS locations selected by the Project Advisory Committee (PAC) in the second phase of the research are presented in Chapter 2. The effect of CMS placement on target value and legibility and coordination with existing signs are examined in Chapter 3. The design and selection of CMS messages are discussed in Chapter 4. The alternate routes designated by the Omaha Metropolitan Area Incident Management Team are described in Chapter 5. The operation of the CMS system is discussed in Chapter 6.

Chapter 2

CMS LOCATIONS

The potential benefits of CMSs will not be realized unless the CMSs are located properly. Existing guidelines *(4,5)* indicate that CMSs should be located upstream of bottlenecks, high accident locations, and major diversion points in accordance with the minimum distance criteria specified for freeway guide signs in the *Manual on Uniform Traffic Control Devices (6)*. They also suggest that: (1) CMSs should not be located within interchanges and (2) the minimum spacings between CMSs should be at least ¾ mile. However, these guidelines do not include warrants for the installation of CMSs specifying the roadway and traffic conditions which justify their use. Therefore, a benefit-cost analysis of alternative CMS locations was conducted to identify the locations where the costs of CMSs are justified by the potential road user cost savings they provide. The results of the benefit-cost analysis of the alternative CMS locations selected by the PAC in the second phase of the research are presented in this chapter.

2.1 PHASE 1

In Phase 1, all possible diversion points (71 on the mainline and 72 at entrance ramps on cross roads) on the freeway system in the Omaha metropolitan area were evaluated and prioritized based on the potential benefits of traffic diversion provided by CMSs at these locations. The resulting priority ranking of the diversion points was presented in the Phase 1 Interim Report *(2)*, which was submitted to PAC on June 13, 1997. On June 26, 1997, PAC meet to review the Phase 1 Interim Report and select the alternative CMS locations to be studied in the second phase of the research. Factors to be considered in addition to the results of the priority ranking were discussed by the committee. These factors included: (1) special events (*e.g.*, the College World Series); (2) type of alternate routes available at the diversion points (*i.e.*, freeway, major arterial, minor arterial, collector, or local street); (3) capacity of alternate routes; and (4) freeway closure considerations. After considerable discussion, PAC agreed that: (1) only mainline diversion points would be considered and (2) the following 14 mainline diversion points identified in the Phase 1 Interim Report should be included in Phase 2 analysis:

- I-80 EB at Harrison Street
- I-80 EB at 72nd Street
- I-80 EB at 60th Street
- I-80 EB at I-480/Kennedy
- I-80 EB at I-29 NB in Iowa
- I-80 WB at I-29 SB in Iowa
- I-80 WB at 24th Street in Iowa
- I-80 WB at 13th Street
- I-80 WB 60th Street
- I-80 WB at I-680 NB
- I-680 SB at Pacific Street
- I-480 SB at Dodge Street
- I-480 SB at Martha Street
- Kennedy NB at L Street

In addition, PAC recommended that the following three mainline diversion points also be included in Phase 2:

- I-29 NB at Highway 92 in Iowa
- I-29 SB at Nebraska Avenue in Iowa
- I-80 WB at I-680 WB near Minden, Iowa

On July 9, 1997, the study team meet with Iowa members of PAC who were unable to attend the meeting on June 26, 1997. This group agreed with the 17 locations selected by PAC and suggested that the following two mainline diversion points also be included in Phase 2:

- I-29 SB at Avenue G in Iowa
- I-29 SB at I-680 in Iowa

Therefore, a total of 19 mainline diversion points were included as alternative CMS locations in the Phase 2 analysis.

2.2 PHASE 2

In Phase 2, a benefit-cost analysis of CMSs at the 19 mainline diversion points selected by PAC in Phase 1 was conducted. The Phase 2 Interim Report *(3)*, which documents the benefit-cost analysis, was presented to PAC on October 8, 1997. The results of the benefit-cost analysis indicated that deployment of CMSs would be cost effective at 10 locations of the 19 locations selected in Phase 1, but not at the other nine locations. The 10 locations where CMS deployment would be cost effective are:

- I-80 EB at Harrison Street
- I-80 EB at I-480/Kennedy Freeway
- I-80 WB at I-29 SB in Iowa
- I-80 WB at 24th Street in Iowa
- I-80 WB at 60th Street
- I-80 WB at I-680 NB
- I-680 SB at Pacific Street
- I-480 SB at Martha Street
- Kennedy Freeway NB at L Street
- I-29 SB at Nebraska Avenue in Iowa

The members of PAC were asked to review the Phase 2 Interim Report and suggest additional CMS locations and other factors to be considered in Phase 3 by October 17, 1997.

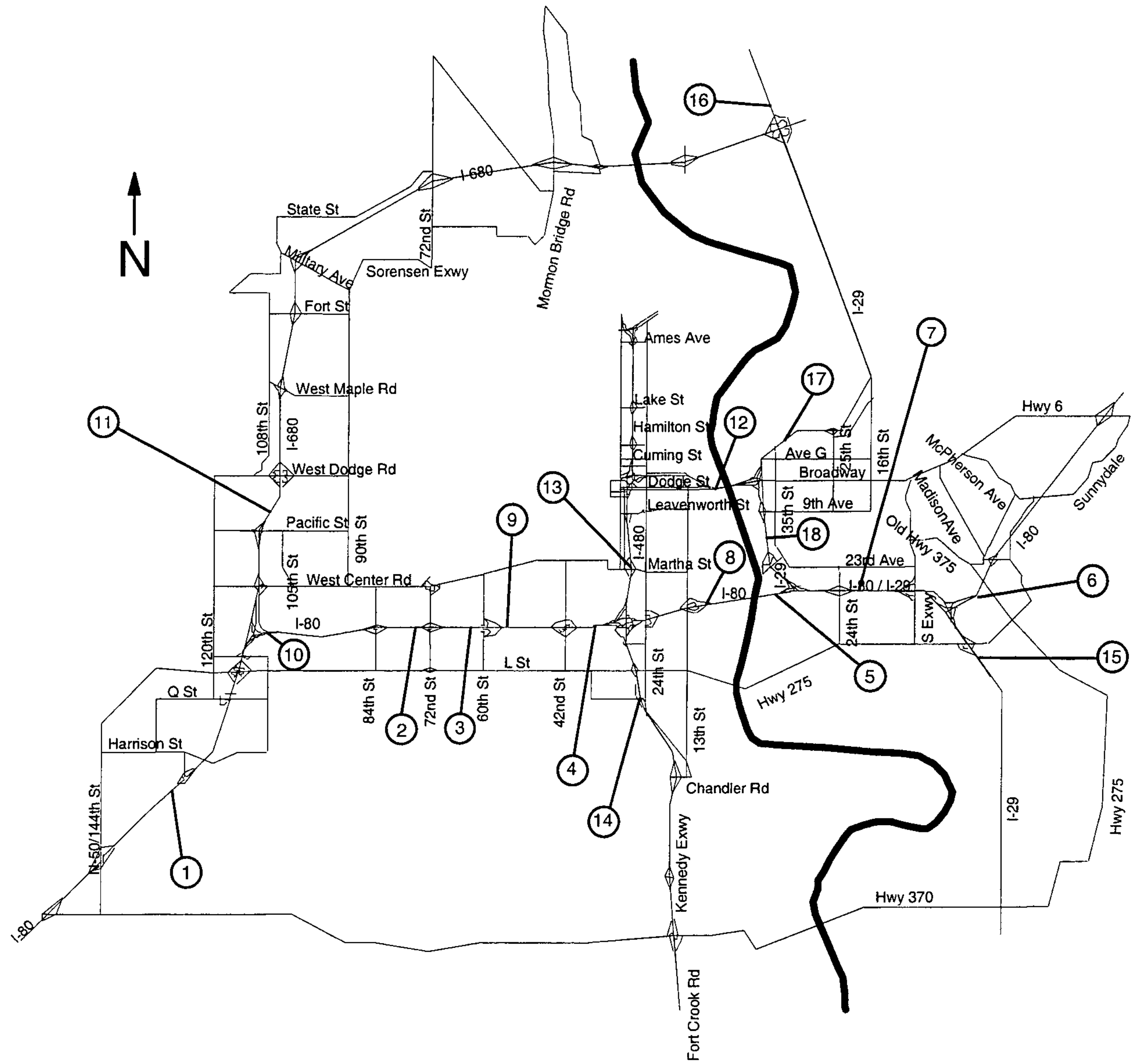
PAC suggested that consideration be given to an additional CMS on eastbound I-80 at either 60th or 72nd Street. PAC also recommended that, as a minimum, CMSs should be installed at the following three locations:

- I-80 EB at Harrison Street
- I-680 SB at Pacific Street
- I-480 SB at Martha Street

Therefore, another benefit-cost analysis of CMSs at the 19 mainline diversion points analyzed in Phase 2 was conducted in Phase 3 beginning with CMSs at these three locations.

2.3 PHASE 3

The locations of the 19 mainline diversion points under consideration in Phase 3 are shown in Figure 2-1. The benefit-cost analysis of CMSs at these locations was conducted given that the first three CMS installations are at the three locations specified by PAC as explained above. The analysis was conducted using the same procedure used in Phase 2, which accounts for the effects of traffic diversion on the alternate routes and the interdependence of the CMSs as described in the Phase 2 Interim Report *(3)*.



1: I-80 EB at Harrison Street
2: I-80 EB at 72nd Street
3: I-80 EB at 60th Street
4: I-80 EB at I-480/Kennedy
5: I-80 EB at I-29 NB in Iowa
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7: I-80 WB at 24th Street in Iowa
8: I-80 WB at 13th Street
9: I-80 WB 60th Street
10: I-80 WB at I-680 NB
11: I-680 SB at Pacific Street
12: I-480 SB at Dodge Street
13: I-480 SB at Martha Street
14: Kennedy NB at L Street
15: I-29 NB at Highway 92 in Iowa
16: I-29 SB at I-680 in Iowa
17: I-29 SB at Avenue G in Iowa
18: I-29 SB at Nebraska Avenue in Iowa
19: I-80 WB at I-680 WB near Minden, Iowa

FIGURE 2-1 CMS Locations Evaluated in Phase 3

The results of the benefit-cost analysis of CMSs at the 19 locations in Figure 2-1 are shown in Table 2-1. Deployment of CMSs at all 19 locations would have an initial cost of $3.3 million and an annual operating and maintenance cost of $96,900 per year. This deployment would provide total annual benefits of $1,173,000 per year and an overall benefit-cost ratio of 2.3. However, the incremental benefit-cost ratios indicate that the installation of only the first 10 CMSs would be cost-effective (*i.e.*, those above the dashed line in Table 2-1). The additional cost of installing more than the first 10 CMSs would be more than the additional benefits they would provide.

TABLE 2-1 Benefit-Cost Analysis

ID of Additional CMS[a]	No. of CMSs	Total Cost		Equivalent Uniform Annual[c]			Incremental		
		Initial ($)	O & M[b] ($/yr)	Benefit ($/yr)	Cost ($/yr)	B/C Ratio	Benefit ($/yr)	Cost ($/yr)	B/C Ratio
1, 11, 13	3	525,840	15,300	347,200	80,100	4.3	347,200	80,100	4.3
10	4	701,120	20,400	744,900	106,800	7.0	397,700	26,700	14.9
7	5	876,400	25,500	842,000	133,500	6.3	97,100	26,700	3.6
14	6	1,051,680	30,600	921,600	160,200	5.8	79,600	26,700	3.0
4	7	1,226,960	35,700	984,500	186,900	5.3	62,900	26,700	2.4
18	8	1,402,240	40,800	1,035,600	213,600	4.8	51,100	26,700	1.9
6	9	1,577,520	45,900	1,075,300	240,300	4.6	39,700	26,700	1.5
2	10	1,752,800	51,000	1,108,100	267,000	4.2	32,800	26,700	1.2
9	11	1,928,080	56,100	1,128,000	293,700	3.8	19,900	26,700	0.7
16	12	2,103,360	61,200	1,139,000	320,400	3.6	11,000	26,700	0.4
15	13	2,278,640	66,300	1,149,700	347,100	3.3	10,700	26,700	0.4
5	14	2,453,920	71,400	1,157,700	373,800	3.1	8,000	26,700	0.3
12	15	2,629,200	76,500	1,163,900	400,500	2.9	6,200	26,700	0.2
3	16	2,804,480	81,600	1,169,700	427,200	2.7	5,800	26,700	0.2
19	17	2,979,760	86,700	1,172,100	453,900	2.6	2,400	26,700	0.1
8	18	3,155,040	91,800	1,173,000	480,600	2.4	900	26,700	0.0
17	19	3,330,320	96,900	1,173,000	507,300	2.3	0	26,700	0.0

a Refer to Figure 2-1.

b Operation and maintenance cost.

c 10-year service life, zero salvage value, 4-percent interest rate.

Three of the 10 cost-effective CMSs (*i.e.*, ID Nos. 6, 7, and 18) are located in Iowa. Their installation would be the responsibility of the Iowa Department of Transportation. Therefore, another benefit-cost analysis, which considered only the CMS locations in Nebraska, was conducted. As in the case of the first benefit-cost analysis, the second analysis was conducted given that the first three CMS installations are at the three locations specified by PAC (*i.e.*, ID Nos. 1, 11, and 13).

The results of the benefit-cost analysis of CMS locations Nebraska are shown in Table 2-2. Deployment of CMSs at all 11 locations in Nebraska would have an initial cost of $1.9 million and an annual operating and maintenance cost of $56,100 per year. This deployment would provide total annual benefits of $977,900 per year and an overall benefit-cost ratio of 3.3. However, the incremental benefit-cost ratios indicate that the installation of only the first eight CMSs would be cost-effective (*i.e.*, those above the dashed line in Table 2-2). The additional cost of installing more than the first eight CMSs would be more than the additional benefits they would provide.

It is interesting to note that the incremental benefits associated with the installation of a CMS on I-80 westbound at 13th Street (ID No. 8) increases substantially when only the CMS locations in Nebraska are considered. These benefits increase from $900 to $24,800 per year, because the effects of CMSs on I-80 westbound in Iowa are ignored. Although the benefit-cost ratio of a CMS at this location is just below 1.0 at 0.9, it seems advisable to place a CMS at this location for two reasons. First, it is the only location on I-80 westbound in Nebraska that is in advance of the major diversion point I-480 and the Kennedy Freeway. Second, even if CMSs are installed on I-80 westbound in Iowa, they would not be under the control of the NDOR.

TABLE 2-2 Benefit-Cost Analysis of CMS Locations in Nebraska

ID of Additional CMS[a]	No. of CMSs	Total Cost		Equivalent Uniform Annual[c]			Incremental		
		Initial ($)	O & M[b] ($/yr)	Benefit ($/yr)	Cost ($/yr)	B/C Ratio	Benefit ($/yr)	Cost ($/yr)	B/C Ratio
1, 11, 13	3	525,840	15,300	347,200	80,100	4.3	347,200	80,100	4.3
10	4	701,120	20,400	744,900	106,800	7.0	397,700	26,700	14.9
14	5	876,400	25,500	824,500	133,500	6.2	79,000	26,700	3.0
4	6	1,051,680	30,600	887,400	160,200	5.5	62,900	26,700	2.4
9	7	1,226,960	35,700	918,000	186,900	4.9	30,600	26,700	1.1
2	8	1,402,240	40,800	945,100	213,600	4.4	27,100	26,700	1.0
8	9	1,577,520	45,900	969,900	240,300	4.0	24,800	26,700	0.9
12	10	1,752,800	51,000	974,100	267,000	3.6	4,200	26,700	0.2
3	11	1,928,080	56,100	977,900	293,700	3.3	3,800	26,700	0.1

[a] Refer to Figure 2-1.

[b] Operation and maintenance cost.

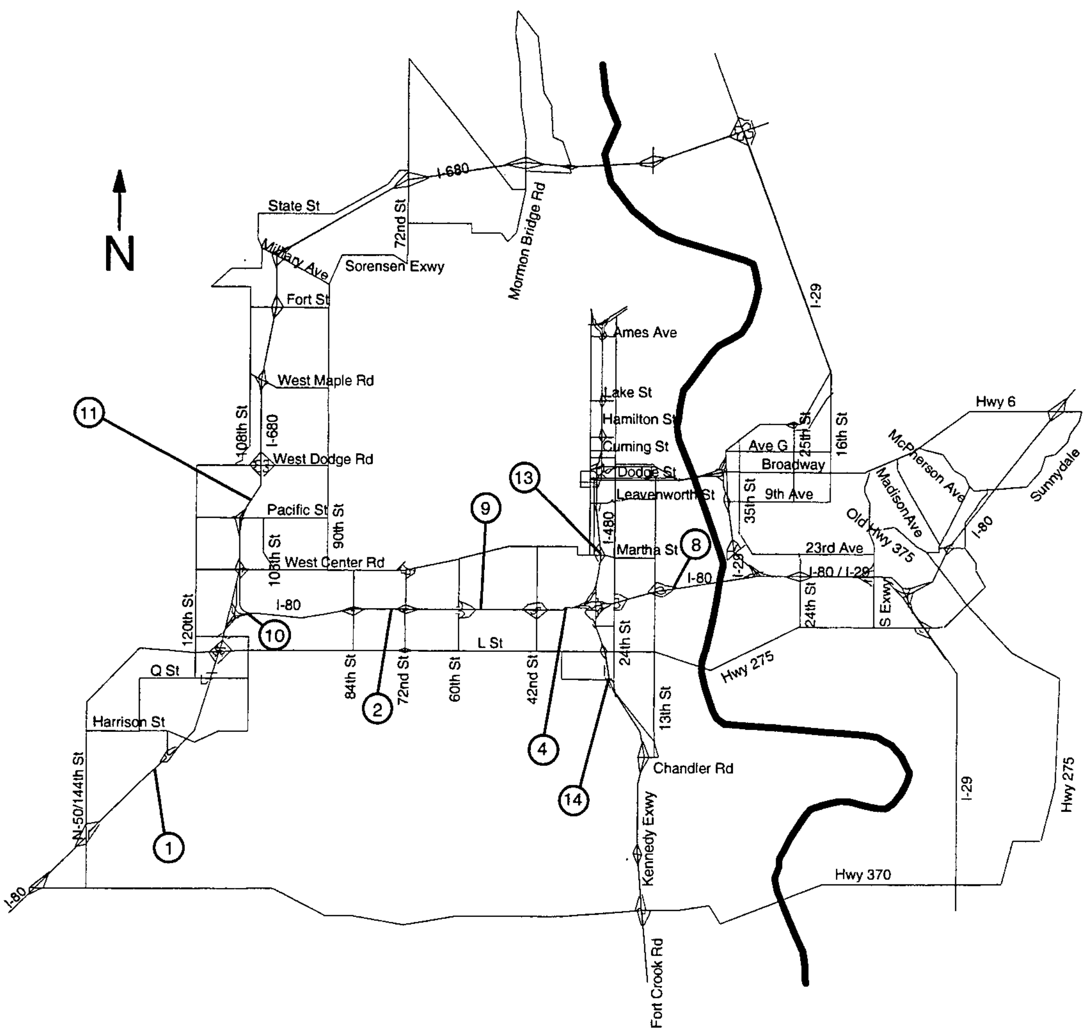
[c] 10-year service life, zero salvage value, 4-percent interest rate.

2.4 CONCLUSION

Based on the results of the benefit-cost analysis and input from the PAC, it is concluded that CMSs should be installed at the following nine locations:

- I-80 EB at Harrison Street
- I-80 EB at 72nd Street
- I-80 EB at I-480/Kennedy Freeway
- I-80 WB at 13th Street
- I-80 WB at 60th Street
- I-80 WB at I-680 NB
- I-680 SB at Pacific Street
- I-480 SB at Martha Street
- Kennedy Freeway NB at L Street

These locations are shown in Figure 2-2.



1: I-80 EB at Harrison Street
2: I-80 EB at 72nd Street
4: I-80 EB at I-480/Kennedy Freeway
8: I-80 WB at 13th Street
9: I-80 WB at 60th Street
10: I-80 WB at I-680 NB
11: I-680 SB at Pacific Street
13: I-480 SB at Martha Street
14: Kennedy Freeway NB at L Street

FIGURE 2-2 CMS Locations

Chapter 3

PLACEMENT OF CMSs

The CMS locations recommended in Chapter 2 are the diversion points upstream of which CMSs should be installed. However, the ability of drivers to read and understand messages displayed by the CMSs will depend on where they are placed in advance of these diversion points. The placement of CMSs affects the distances at which they can be seen and read by drivers. Also, their placement must be coordinated with the locations of other freeway signs to avoid overloading drivers with too many closely spaced signs and to provide drivers with enough distance to change lanes and prepare to exit upstream of the diversion points. The consideration of these factors in the placement of CMSs is presented in this chapter.

3.1 TARGET VALUE

Target value refers to the distance from which the CMS is first noticed by the driver. The CMS can not be read at this distance. But, at this distance, the driver recognizes it to be a CMS and can begin to prepare to read its message. The target value should provide several seconds before the message is readable to enable the driver to become aware of a message being displayed on the CMS. There are no standards for CMS target values. However, previous research *(7)* suggests about 4 seconds of viewing time before the sign can actually be read. At a prevailing speed of 60 mph, this additional distance would be 350 feet. Therefore, the minimum target value should be 350 feet plus the distance at which the sign can be read. Based on the comparison of CMS technologies presented in the Phase 2 Interim Report *(3)*, PAC selected the fiberoptic and LED CMS technologies as the two to be considered further in Phase 3. Thus, the minimum target values for fiberoptic are LED CMSs would be about 1,350 to 1,000 feet, respectively *(8)*.

The CMSs should not be installed in places where their view by drivers on the freeway would be restricted to distances less than the minimum target value for the particular type of CMS. In placing the CMSs, care must be exercised to ensure that the freeway alinement, structures, and roadside appurtenances do not obstruct the drivers' view of the CMSs from any lane in this manner.

On freeway sections with roadway lighting, the CMS should be placed between luminaires so that it is backlit and there is no light from the luminaires shining on its face. In this position, the CMS will appear in negative contrast, which will enhance its target value and legibility.

3.2 LEGIBILITY

The distance from which a driver is able to read the message on a CMS is called the *legibility distance*. The amount of time a driver has to read the message is determined by the legibility distance and the speed at which the driver is traveling as follows:

$$ART = \frac{d_l}{1.47v} \qquad (3\text{-}1)$$

where, ART = available reading time (sec);
d_l = legibility distance (ft);
v = prevailing traffic speed (mph); and
1.47 = conversion constant from mph to fps.

However, the placement of the CMS with respect to the roadway can affect the amount of legibility distance available. The effects of the vertical and lateral placement of CMSs on legibility distance are described below.

3.2.1 Vertical Placement

A driver's view of overhead signs is limited by the roof of the vehicle. As the vehicle approaches an overhead sign, the view of the sign will be lost to the driver when it disappears behind the roof of the vehicle. The distance at which the sign disappears depends on the height of the sign, the height of the driver's eye, and the vertical cutoff angle between the driver's eye and the top of the windshield, as illustrated in Figure 3-1. The distance from the sign at which the driver's line of sight is obstructed by the vehicle's roof is:

$$d = \frac{h_m - h_i}{\sin\phi} \qquad (3\text{-}2)$$

where, d = distance at which view of sign is lost (ft);
h_m = height of center of sign above roadway (ft);
h_i = height of driver's eye above the roadway (ft); and
ϕ = vertical cutoff angle between driver's eye and top of windshield (degrees).

The standard requirement for vertical clearance of signs over interstate highways is 17.5 feet, which would place the center of a CMS with three rows of 18-inch characters about 23 feet above the roadway. Previous research *(9)* indicates that a vertical cutoff angle of 7.5 degrees should be used as a design value. The AASHTO geometric design policy *(10)* specifies a driver eye height of 3.5 feet. Using these values in Equation 3-2, the loss in legibility distance caused by the overhead placement of a CMS is 150 feet. If a CMS is mounted above the minimum vertical clearance of 17.5 feet, the legibility distance lost would be greater than 150 feet. Therefore, in order to minimize the loss in legibility distance, CMSs should be mounted to provide the minimum vertical clearance required (*i.e.*, 17.5 feet).

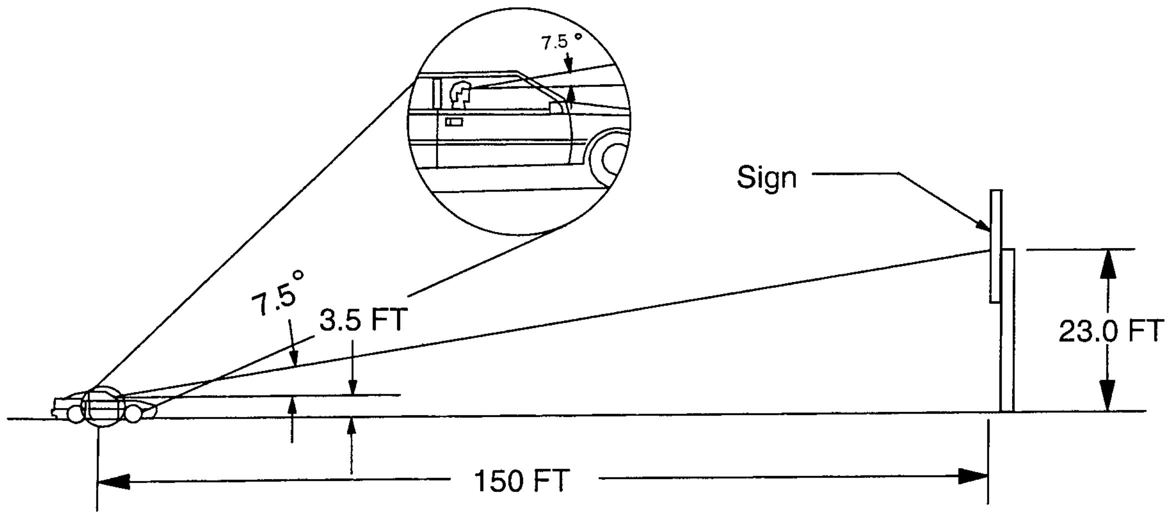


FIGURE 3-1 View of Overhead CMS Obstructed By Vehicle Roof

3.2.2 Lateral Placement

3.2.2.1 Tangent Roadway Sections

The lateral placement of a CMS is controlled by its cone of legibility. The message on a CMS is not legible when it is viewed outside of its cone of legibility. Therefore, the optimum lateral placement of a CMS is centered over the travel lanes of the roadway. Placement on either side of a tangent roadway section reduces the legibility distance of the sign as shown in Figure 3-2.

The point C in Figure 3-2 is the location at which drivers can begin to read the message on the CMS. The angle Θ is the maximum view angle at which the sign is still legible, which is equal to one half of the sign's cone of legibility. When drivers move past point B, they can no longer read the message. Therefore, the distance BC represents the loss in legibility distance caused by the lateral placement of the sign. The relationship between lost legibility distance and the lateral placement of the sign is:

$$BC = \left([(N-1) + 2/3]L + x\right)\cot\Theta \qquad (3\text{-}3)$$

where, BC = lost legibility distance (ft);
N = number of lanes;
L = lane width (ft);
x = lateral distance from edge of travel way to center of CMS (ft); and
Θ = maximum viewing angle (degrees).

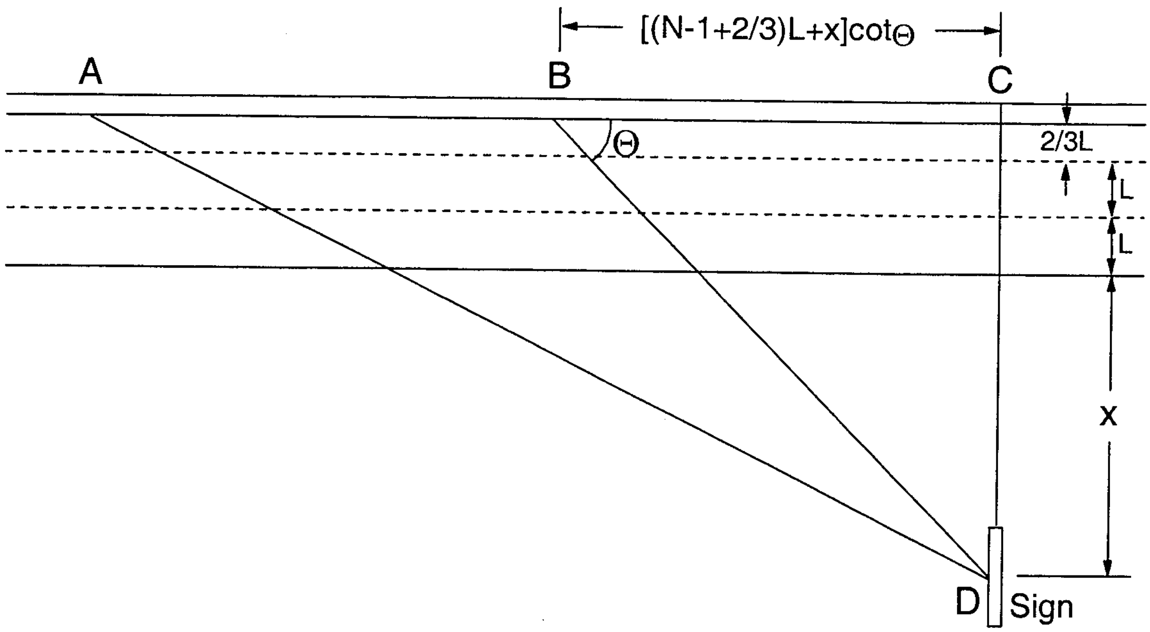


FIGURE 3-2 Lost Legibility Distance on Tangent Roadway Section

The cone of legibility of fiberoptic and LED CMSs are 30 degrees and 20 degrees, respectively *(8)*. The effects of the cone of legibility and roadway width on the loss of visibility distance are illustrated in Table 3-1. These values were computed with Equation 3-3. It was assumed that: (1) the CMS is mounted above the right shoulder of the roadway with its inside edge above the outside edge of the travel way and (2) the lane width is 12 feet. Assuming that the width of the CMS is 30 feet, the value of x used in Equation 3-3 was 15 feet. The values indicate that substantial losses in legibility distance occur when the CMS is mounted at the side of the roadway, especially on roadways with more than two lanes. Also, the lost visibility distance is much greater for the LED CMS, because it has a narrower cone of legibility than the fiberoptic CMS. Except in the case of the fiberoptic CMS on a two-lane roadway, the lost legibility distance is larger than the 150-foot loss in legibility distance caused by the vertical cutoff of the vehicle roof.

TABLE 3-1 Lost Legibility Distance on Tangent Roadway Sections

	Lost Legibility Distance (ft)	
Number of Lanes	Fiberoptic CMS	LED CMS
2	131	198
3	175	267
4	220	335
5	265	403

The lost legibility distances of a CMS placed at the side of the roadway can be reduced by rotating it toward the roadway. In order to keep its cone of legibility from being the limiting factor, the CMS should be rotated so that the lost legibility distance (distance BC in Figure 3-2) does not exceed 150 feet, which is the lost visibility distance caused by the vertical cutoff of the vehicle roof. Thus, the rotation angles required to limit the lost legibility distance to 150 feet were computed by setting BC in Equation 3-3 equal to 150 feet and solving for the maximum viewing angle Θ. As in the case of Table 3-1, it was assumed that the CMS is mounted above the right edge of the travel way, the lane width is 12 feet, and the width of the CMS is 30 feet. The required rotation angles are equal to the maximum viewing angle Θ minus one-half of the cone of legibility, as shown in Table 3-2. It should be noted that the rotation angle must not exceed one-half of the cone of legibility, because this would cause a loss in legibility for drivers in the lane closest to the CMS. Therefore, the maximum rotation angle is 15 degrees for the fiberoptic CMS and 10 degrees for the LED CMS.

As shown in Table 3-2, the required rotation angle of the LED sign exceeds its maximum rotation angle on tangent roadway sections that are wider than three lanes. Therefore, LED signs should not be placed to the side of tangent roadway sections with four or more lanes.

TABLE 3-2 CMS Rotation Angles on Tangent Roadway Sections

Number of Lanes	Viewing Angle [a] (degrees)	Rotation Angle (degrees)	
		Fiberoptic CMS [b]	LED CMS [c]
2	13	0	3
3	17	2	7
4	21	6	11 [d]
5	25	10	15 [d]

[a] Viewing angle for lost legibility distance of 150 feet.

[b] Maximum allowable rotation angle is 15 degrees for fiberoptic sign.

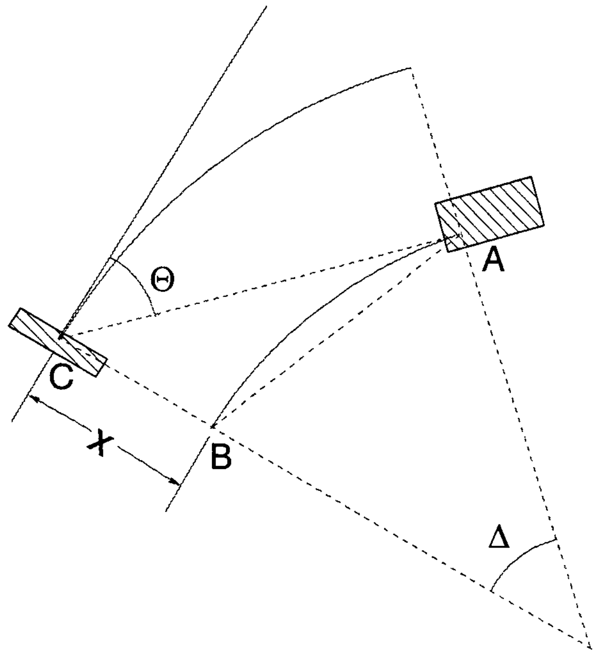
[c] Maximum allowable rotation angle is 10 degrees for LED sign.

[d] Rotation angle exceeds maximum allowable rotation angle of sign.

3.2.2.2 Horizontal Curves

The lost legibility distance is somewhere greater for CMSs placed on the side of roadway within a horizontal curve than it is for CMSs placed on the side of tangent sections of roadway. Also, the magnitude of the lost legibility distance for CMSs placed on horizontal curves depends on the direction of the curve. It is less on curves to the left than it is on curves to the right. The reduction in legibility distance on horizontal curves to the left and to the right is shown in Figure 3-3. In each case, the arc BC represents the lost legibility distance and is computed as follows:

a. Curve To The Left



b. Curve To The Right

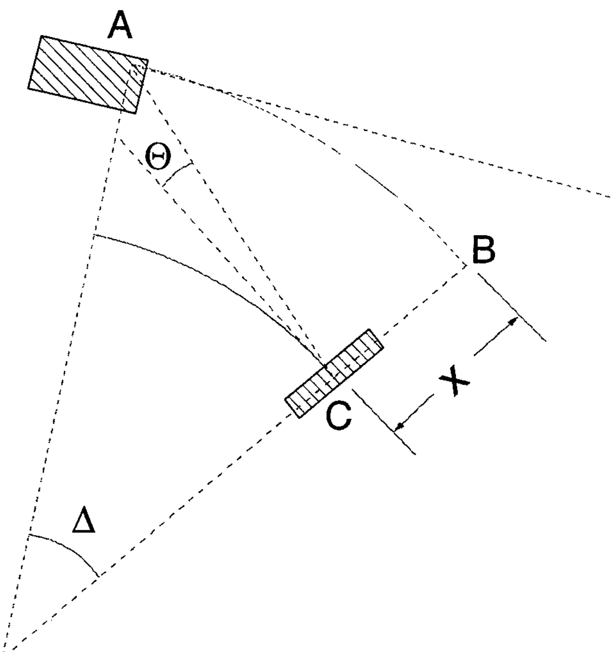


FIGURE 3-3 Lost Legibility Distance on Horizontal Curves

$$\overline{BC} = \frac{\Delta}{D} 100 \tag{3-4}$$

where, $\overline{BC}$ = lost legibility distance (ft);
Δ = central angle (degree); and
D = degree of curvature (degrees).

As in the case of CMSs on tangent sections, the lost legibility distance can be reduced by rotating the CMS toward the roadway. In order to keep its cone of legibility from being the limiting factor, the CMS should be rotated so that the lost legibility distance does not exceed 150 feet, which is the lost visibility distance caused by the vertical cutoff of the vehicle roof. Thus, the rotation angles required to limit the lost legibility distance to 150 feet were computed by setting the length of the arc BC in Equation 3-4 equal to 150 feet and solving for the central angle Δ. The resultant value of Δ was then substituted into the following maximum viewing angle equations.

For curves to the left, the maximum viewing angle is:

$$\Theta = 90 - \arcsin\left(\frac{R\sin\Delta}{\sqrt{R^2 + (R + (N - 1/3)L + x)^2 - 2R(R + (N - 1/3)L + x)\cos\Delta}}\right) \tag{3-5}$$

And, for curves to the right, the maximum viewing angle is:

$$\Theta = 90 - \arcsin\left(\frac{[R - ((N - 1/3)L + x)]\sin\Delta}{\sqrt{R^2 + [R - ((N - 1/3)L + x)]^2 - 2R[R - ((N - 1/3)L + x)]\cos\Delta}}\right) \tag{3-6}$$

where, Θ = maximum viewing angle (degrees);
R = curve radius (ft);
Δ = central angle (degrees);
N = number of lanes;
L = lane width (ft); and
x = lateral distance from edge of travel way to center of CMS (ft).

As in the case of the tangent roadway section, it is assumed in Equations 3-5 and 3-6 that the CMS is mounted above the right edge of the travel way, the lane width is 12 feet, and the width of the CMS is 30 feet.

The required rotation angle is equal to the maximum viewing angle Θ minus one-half of the cone of legibility. It should be noted that the rotation angle must not exceed one-half of the cone of legibility, because this would cause a loss in legibility for drivers in the lane closest to the CMS.

Therefore, the maximum rotation angle is 15 degrees for the fiberoptic CMS and 10 degrees for the LED CMS.

The rotation angles required to limit the lost legibility distance to 150 feet for CMSs placed on the side of horizontal curves are shown in Table 3-3. As expected, these values are higher than those given in Table 3-2 for CMSs placed on the side of tangent roadway sections with the same number of lanes. CMSs placed on the side of horizontal curves to the right must be rotated more than those placed on horizontal curves to the left under similar conditions. Also, as was the case of CMSs on the side of tangent roadways sections, the required rotation angle of the LED sign exceeds its maximum allowable rotation angle on horizontal curves of 3 degrees or less and wider than three lanes. On horizontal curves between 3 and 5 degrees, the LED sign's maximum allowable rotation angle is exceeded on roadways with three lanes as well. Therefore, LED signs should not be placed in these locations.

3.3 EXISTING SIGNS

The placement of CMSs must be integrated with the existing static freeway signs to avoid overloading drivers with too many closely spaced signs and to provide drivers with enough distance to change lanes and prepare to exit upstream of the diversion points. The following are guidelines for the placement of CMSs with respect to existing signs based on previous research *(7)*:

1. CMS must be placed upstream of the exit ramp sign of the nearest ramp used for diversion.

2. CMS should be placed between the two advance guide signs, provided the advance guide sign closest to the ramp is at least ½ mile from the ramp. Otherwise, CMS should be placed upstream of the two advance guide signs.

3. When queuing is expected upstream of the ramp, CMS should be placed upstream of the two advance guide signs.

4. When interchange sequence signs are used, CMS should be placed upstream of at least two advance interchange sequence signs for the ramp.

5. Minimum spacing between CMS and a downstream advance guide sign should be 1,000 feet.

6. Minimum spacing between CMS and upstream advance guide sign should be 350 feet plus the minimum required legibility of the CMS.

TABLE 3-3 CMS Rotation Angles on Horizontal Curves

		Rotation Angle (degrees)			
		Curve to the Left		Curve to the Right	
Degree of Curvature	No. of Lanes	Fiberoptic CMS [a]	LED CMS [b]	Fiberoptic CMS [a]	LED CMS [b]
1	2	0	3.8	0	3.9
	3	3.1	8.1	3.2	8.2
	4	7.1	12.1 [c]	7.3	12.3 [c]
	5	10.9	15.9 [c]	11.2	16.2 [c]
2	2	0	4.6	0	4.7
	3	3.8	8.8	4.0	9.0
	4	7.8	12.8 [c]	8.2	13.2 [c]
	5	11.6	16.6 [c]	12.1	17.1 [c]
3	2	0.3	5.3	0.5	5.5
	3	4.4	9.4	4.8	9.8
	4	8.4	13.4 [c]	9.0	14.0 [c]
	5	12.1	17.1 [c]	13.0	18.0 [c]
4	2	1.0	6.0	1.3	6.3
	3	5.1	10.1 [c]	5.7	10.7 [c]
	4	9.1	14.1 [c]	9.9	14.9 [c]
	5	12.8	17.8 [c]	13.9	18.9 [c]
5	2	1.7	6.7	2.1	7.1
	3	5.8	10.8 [c]	6.5	11.5 [c]
	4	9.7	14.7 [c]	10.7	15.7 [c]
	5	13.4	18.4 [c]	14.8	19.8 [c]

[a] Maximum allowable rotation angle is 15 degrees for fiberoptic sign.

[b] Maximum allowable rotation angle is 10 degrees for LED sign.

[c] Rotation angle exceeds maximum allowable rotation angle of sign.

3.4 CONCLUSION

The placement of CMSs at the locations recommended in Chapter 2 must consider the factors of target value, legibility, and coordination with existing static freeway sign. The installation of CMSs where sight obstructions would restrict their target values to distances less than 350 feet plus their minimum required legibility distances must be avoided. In addition, on lighted freeway sections, they should be placed so they appear in negative contrast to enhance their nighttime target values and legibility.

The effects of the placement on CMS legibility must also be considered. The placement of a CMS overhead at the minimum vertical clearance results in a 150-foot loss in the sign's legibility distance, because the driver's view of the sign is obstructed by the vehicle's roof when the vehicle is within 150 feet of the sign. Higher mounting heights would increase the lost legibility distance. Therefore, in order to minimize the loss in legibility distance, CMSs should be mounted to provide the minimum vertical clearance required. Determination of the minimum required vertical clearance should account for potential future pavement overlays.

The optimum lateral placement of CMSs is over the center of the travel lanes in order to minimize the portion of the roadway that is outside of the sign's cone of legibility. One of the disadvantages of the CMS technologies selected by PAC is their relatively narrow cones of legibility. The fiberoptic CMS has a 30-degree cone of legibility, whereas the LED CMS has only a 20-degree cone of legibility. When these types of CMSs are placed on the side of the roadway, they must be rotated toward the roadway in order to keep the lost legibility distance comparable to the 150-foot lost legibility distance caused by the vertical cutoff of the vehicle roof. The angle of the rotation necessary is larger on wider roadways. Fiberoptic CMSs placed on the side of the roadway can be rotated as much as needed in order to limit the loss in legibility distance to 150 feet on tangent sections and horizontal curves of 5 degrees or less. However, LED CMSs placed on the side of the roadway can not be rotated enough without exceeding their maximum allowable rotation angle of 10 degrees on roadways wider than three lanes on tangent sections and horizontal curves of 3 degrees or less. Therefore, LED CMSs should not be placed on the side of the roadway at locations with four or more lanes.

Finally, CMS placement must be integrated with the existing static freeway signs to ensure their effectiveness. In addition, whenever possible the CMSs should be erected on existing bridges over the freeway to reduce the number of lateral obstacles on the roadside.

Chapter 4

CMS MESSAGES

The primary purpose of the CMSs is to support freeway incident management in the Omaha metropolitan area. The CMSs will inform drivers of the occurrence and location of incidents on the freeway, thereby increasing their awareness of conditions ahead and their propensity to divert to alternate routes. The heightened awareness of drivers and their diversion to alternate routes will reduce the accidents and congestion caused by incidents on the freeway system. However, the effectiveness of CMSs in improving the safety and efficiency of traffic operations during incidents depends on the extent to which the information they convey is read, understood, and believed by the drivers. The readability, understandability, and credibility of this information is determined by the messages displayed on the CMSs. Guidelines for the design of CMS messages are presented in this chapter.

4.1 GENERAL CONSIDERATIONS

Like any other traffic control device, CMSs must satisfy the following basic requirements to be effective *(6)*:

1. Fulfill a need.
2. Command attention.
3. Convey a clear, simple message.
4. Command respect of road users.
5. Give adequate time for proper response.

These requirements not only pertain to the design, placement, operation, and maintenance of CMSs, but they also apply to the design of the messages displayed on them.

The credibility of CMSs is dependent on their messages satisfying the first and fourth requirements. CMS messages must provide timely information consistent with current conditions. CMS messages will not be able to elicit proper responses from drivers if they provide information that is contrary to existing conditions or recommend a course of action that is viewed as unnecessary by drivers. It would be better for CMSs to display minimal or no information, if conditions can not be monitored to ensure that the proper message is being displayed at the proper time. Messages that provide reliable, accurate, and current information fulfill a need and command the respect of drivers.

The construction of CMS messages is determined by the remaining requirements. The elements of a message affect its ability to command the attention of drivers. The text of a message influences the degree to which it conveys a clear, simple meaning. The legibility, length, and format of a message establish its reading time which, combined with CMS placement, determines the available response time.

4.2 MESSAGE CONTENT

The objective of incident management messages is to advise drivers of unusual conditions on the freeway and recommend a course of action. These messages consist of the following elements:

- Problem Statement, which conveys the type and location of the incident.
- Effect Statement, which conveys the consequences of the incident.
- Attention Statement, which conveys the group of drivers for whom the message is intended.
- Action Statement, which conveys the course of action to be taken by drivers addressed by the message.

The statements included in a message and their order of inclusion depend on: (1) the nature of the incident, (2) the drivers affected, (3) the type of action desired from drivers, (4) the amount of time drivers have to read the message, (5) the size of the CMS, and (6) the surveillance capabilities of the system. The minimum information that must be included in a message is the problem and action statements. Drivers need to know what to do and the reason for doing it.

4.2.1 Problem Statement

The problem statement conveys the type and location of the incident. Examples of the types of incidents are:

- Accident
- Road Maintenance
- Road Construction
- Pavement Damage
- Spilled Load
- Stalled Vehicle
- Debris on Road
- Icy Bridge
- Water Over Road
- Fog
- Ice
- Snow

The specific types of incidents for which CMS messages would be displayed depends on the magnitude of their effects. CMS messages should not be displayed for minor off-roadway incidents that can be easily seen and avoided by lane changing *(7)*. However, if an incident does block a portion of the roadway or slows traffic substantially, a CMS message providing advance warning should be displayed.

General classification of incident types is preferred. For example, VEHICLE OVERTURNED, VEHICLE COLLISION, and VEHICLE FIRE should all be described by the word ACCIDENT. Likewise, ROAD MAINTENANCE, PAINT STRIPING, and ROAD CONSTRUCTION should all be termed ROAD WORK. General classification of incident types reduces the need for a library of messages for every type of incident. More importantly, it also avoids the loss of credibility caused by messages with overly precise descriptions which are not exactly consistent with actual conditions *(7)*.

The location component of the problem statement aids drivers in knowing where and when they should slow down, change lanes, and/or divert to an alternate route. When the majority of drivers are commuters or familiar drivers, incident locations should be referenced to the nearest cross street. These drivers can relate to cross streets better than to distances *(7)*. Distances are more difficult for commuters to use in determining if an incident location is upstream or downstream of their exit ramp. However, if the majority of drivers are travelers who are unfamiliar with the names of the cross streets, distances to the nearest ½ mile should be used.

4.2.2 Effect Statement

The effect statement conveys the consequences or impacts of the incident. These impacts may be expressed in terms of congestion, delay, and lane blockage.

4.2.2.1 Congestion

The levels of congestion expressed in effect statements are usually limited to two, CONGESTION and HEAVY CONGESTION. When drivers are approaching congestion, they want to know where it begins. But, when they are already in the congestion, they want to know where it will end *(7)*. The credibility of the CMSs is reduced when messages state the obvious. Therefore, CMSs located within a congested freeway section should not display messages with effect statements in terms of congestion. Messages stating where traffic clears would be preferred.

4.2.2.2 Delay

Delay information is used by drivers as a basis for making the decision to divert to an alternate route. Research *(7,11)* has found that the amount of delay that would cause the average driver to divert is about 20 minutes. Only 8 percent of drivers would divert if the delay is less than 5 minutes, whereas 95 percent of the drivers would divert if the delay is one hour. About 5 percent of drivers would not divert regardless of the delay time. The type of incident did not affect the diversion percentage given equal delay times. Based on these findings, it has been recommended that delay times of less than five minutes, or more than one hour, should not be displayed *(7)*.

Delays are interpreted by drivers as being relative to their normal travel times *(7)*. In other words, they interpret delay to be the additional time it will take them to reach their destinations. They do not necessarily believe that delays represent the length of time they will be delayed at one point along their route or the length of time it will take to clear an incident. Also, drivers can easily check delay times. Therefore, the credibility of the CMS messages will be diminished if the delay times displayed are inaccurate, or misrepresent those experienced by drivers.

4.2.2.3 Lane Blockage

Drivers interpret the statement LANE BLOCKED to mean that the lane is temporarily blocked by an accident or other incident; whereas, they interpret the statement LANE CLOSED to mean that the lane is closed for a prolonged period *(7)*. Therefore, LANE BLOCKED may be displayed when the blockage is due to an incident. Otherwise, LANE CLOSED should be displayed.

On 2- or 3-lane freeway sections, the lane blockages can be specified by the descriptors LEFT, RIGHT, and CENTER. However, on sections with four lanes or more, these terms are less clear in specifying which lanes are closed. Therefore, anchoring messages with X's and arrows as shown in Figure 4-1 are preferred on sections with more than three lanes.

The statements FREEWAY BLOCKED or FREEWAY CLOSED should not be displayed unless all lanes of the freeway are blocked or closed. As long as at least one lane of the freeway is open, LANE CLOSED statements should be used.

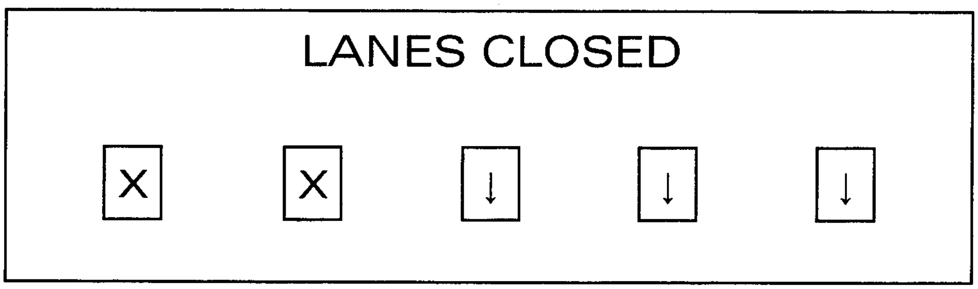


FIGURE 4-1 Anchored Lane Closure Display

4.2.3 Attention Statement

The attention statement conveys the group of drivers for whom the message is intended. It is required only when the action statement does not apply to all drivers. When an attention statement is used, it must always be accompanied by an action statement. Driver groups may be distinguished by vehicle type (*e.g.*, CARS, TRUCKS, or BUSES), trip (*e.g.*, LOCAL or THRU), route (*e.g.*, I-80, I-480, I-680, or WEST DODGE ROAD), destination (*e.g.*, EPPLEY AIRFIELD, COUNCIL BLUFFS, or LINCOLN), or event (*e.g.*, COLLEGE WORLD SERIES, STATE TRACK MEET, or FIREWORKS). In the case of messages addressing drivers going to a special activity, the selection between a destination or event designation depends on the driver group's familiarity with the destination name. Event designations would be preferred for messages pertaining to events attracting large numbers of non-local, unfamiliar drivers. For example, messages intended for driver going to the college world series should display COLLEGE WORLD SERIES rather than ROSENBLATT STADIUM.

The word TRAFFIC should be used with the trip designation (*i.e.*, LOCAL TRAFFIC or THRU TRAFFIC). It is usually unnecessary to use the word TRAFFIC with the other driver group designations, because it is understood unless the location of the incident is not displayed. When the location is not displayed the word TRAFFIC may need to be used to avoid confusion. For example, the message ACCIDENT AT 24th STREET/COUNCIL BLUFFS/USE I-480 is generally understood that traffic going to Council Bluffs should use I-480. However, if the message did not include the location of the accident (*i.e.*, AT 24th STREET), it could be interpreted to mean that the accident is in Council Bluffs. Addition of the word TRAFFIC after the destination COUNCIL BLUFFS would eliminate this confusion.

4.2.4 Action Statement

The action statement conveys the course of action to be taken by drivers addressed by the message. Therefore, it must be understood and remembered by drivers in order for the CMS message to be effective. There are two major categories of action statements, those used in diversion situations and those used in non-diversion situations.

4.2.4.1 Diversion Situations

Action statements in diversion situations direct, or at least encourage, drivers to use an alternate route. Verbs used in these statements include: USE, TAKE, FOLLOW, EXIT and CONSIDER. The first three verbs are used in diversion messages that direct drivers to a specific alternate route. The verb USE should be selected for messages that include a specific alternate route (*e.g.*, USE TEMPORARY BYPASS). The verb TAKE should be selected for messages that direct drivers to a specific exit or leg of an alternate route (*e.g.*, TAKE NEXT EXIT or TAKE 72nd STREET). The verb FOLLOW should be selected for messages that specify an alternate route marked by guide signs or trailblazers (*e.g.*, FOLLOW MARKED DETOUR).

The verb EXIT may be used in messages that direct drivers to a specific exit (*e.g.*, EXIT AT 72nd STREET). When EXIT is used as a verb, it should be followed by the name of a cross street.

The verb CONSIDER is used in general diversion messages that do not include a specific alternate route (*e.g.*, CONSIDER ALTERNATE ROUTE). These messages are intended to encourage drivers to divert voluntarily and find their own alternate routes.

4.2.4.2 Non-Diversion Situations

Action statements in non-diversion situations direct drivers to control their vehicles in a certain manner or to increase their attentiveness with respect to prevailing roadway and traffic conditions. Some of these statements refer to the lane control of the driver's vehicle and use verbs such as: MERGE, KEEP, STAY, and USE. Examples of these statements are: MERGE LEFT, KEEP RIGHT, STAY IN YOUR LANE, and USE RIGHT LANE.

Some action statements in non-diversion situations refer to speed of the driver's vehicle. Verbs used in these statements include: SLOW and REDUCE. Examples of these statements are: SLOW TO XX MPH and REDUCE SPEED.

Action statements designed to heighten the attentiveness of drivers use verbs such as: PREPARE, WATCH, PROCEED, and USE. Examples of these statements are: PREPARE TO STOP, WATCH FOR _______, PROCEED WITH CAUTION, and USE CAUTION.

4.3 MESSAGE LENGTH

Message length is the number of words, excluding prepositions, in the message. It is limited by the time drivers have to read the message. Research *(5)* has found that the reading time that should be used to design CMS message for unfamiliar drivers is one second per short word, up to eight characters per word, excluding prepositions. Studies *(5)* also suggest that an eight-word message, excluding prepositions and having about four to eight characters per word, is approaching the information processing limits of drivers traveling at high speeds. Thus, in order for a CMS message to be readable, its length must be: (1) short enough to be read within the reading time available to drivers, and (2) not more than eight words, excluding prepositions.

The time required to read a CMS message is:

$$RRT = N \tag{4-1}$$

where, RRT = required reading time (sec); and
N = number of words in message, excluding prepositions.

The time available to read a message is a function of the CMS's legibility and the prevailing speed of traffic, as expressed in Equation 3-1. However, as explained in Chapter 3, the overhead placement of a CMS reduces the distance over which the CMS can be read because of the vertical cutoff angle between the driver's eye and the top of the windshield. The distance at which the CMS is lost from view is calculated using Equation 3-2. Thus, the available reading time in Equation 3-1 must be adjusted to account for this effect by subtracting the distance at which the CMS is lost from view in Equation 3-2 from the legibility distance in Equation 3-1 as follows:

$$ART' = \frac{d_l - d}{1.47v} \tag{4-2}$$

where, ART' = adjusted available reading time (sec);
d_l = legibility distance (ft);
d = distance at which CMS is lost from view (ft);
v = prevailing traffic speed (mph); and
1.47 = conversion constant from mph to fps.

Setting Equations 4-1 and 4-2 equal to each other yields the maximum number of words that can be used in a message:

$$N_{max} = \frac{d_l - d}{1.47v} \tag{4-3}$$

where, N_{max} = maximum number of words, excluding prepositions.

The maximum message lengths for CMS legibility distances of 650 and 900 feet are shown in Figure 4-2. The maximum message lengths decrease as the prevailing traffic speed increases. At speeds up to 60 mph, eight-word messages could be displayed on a CMS with a 900-foot legibility distance. At speeds above 60 mph, the message lengths would have to be shorten to six or seven words in order to be readable. However, eight-word messages could only be displayed at speeds up to 40 mph on a CMS with a 650-foot legibility distance. At speeds above 60 mph, the messages would have to be shortened to four or five words. Therefore, in designing CMS messages, both the sign legibility and prevailing speed of traffic must be considered. For example, during periods of high-speed uncongested flow, the messages must be kept shorter than during periods of lower-speed, congested flow. Also, it must be noted that the message lengths in Figure 4-2 are maximum lengths. Every effort should be made to keep messages as short as possible in order to minimize the demands on the driver.

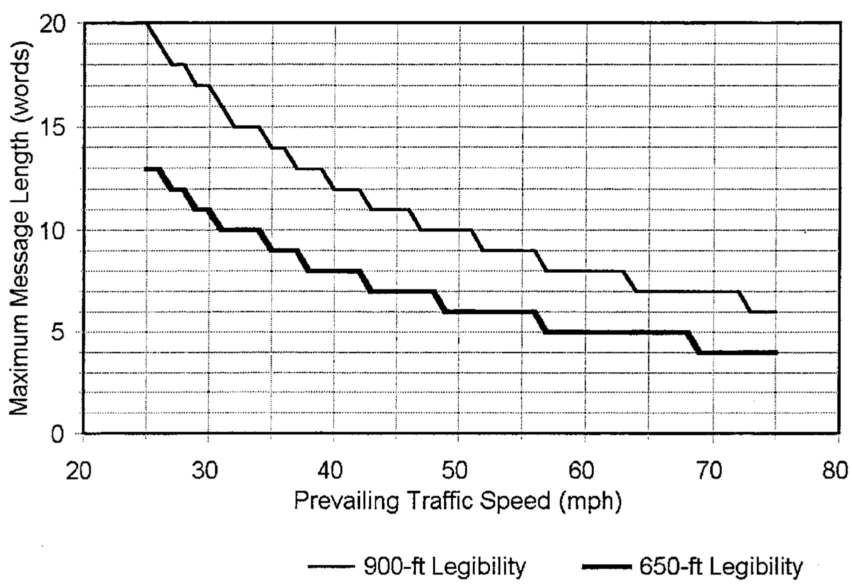


FIGURE 4-2 Maximum Message Length

The legibility distance required to provide enough time for drivers to read an eight-word message is shown in Figure 4-3. A CMS with a legibility distance of approximately 1,000 feet would be able to satisfactorily display 8-word messages for traffic traveling at speeds up to 70 mph. Sign legibility data are somewhat limited. Dudek *(5)* recommends the use of a CMS legibility distance of 36 feet per inch of character height for CMS design in the absence of more definitive data. This would indicate that a CMS with 18-inch characters would have a legibility distance of about 650 feet. Legibility studies *(8)* conducted in Arizona suggest that LED and fiberoptic CMSs have longer legibility distances under some conditions as shown in Table 4-1. These data suggest that longer messages may be displayed during the mid-day, and shorter messages should be displayed during other periods.

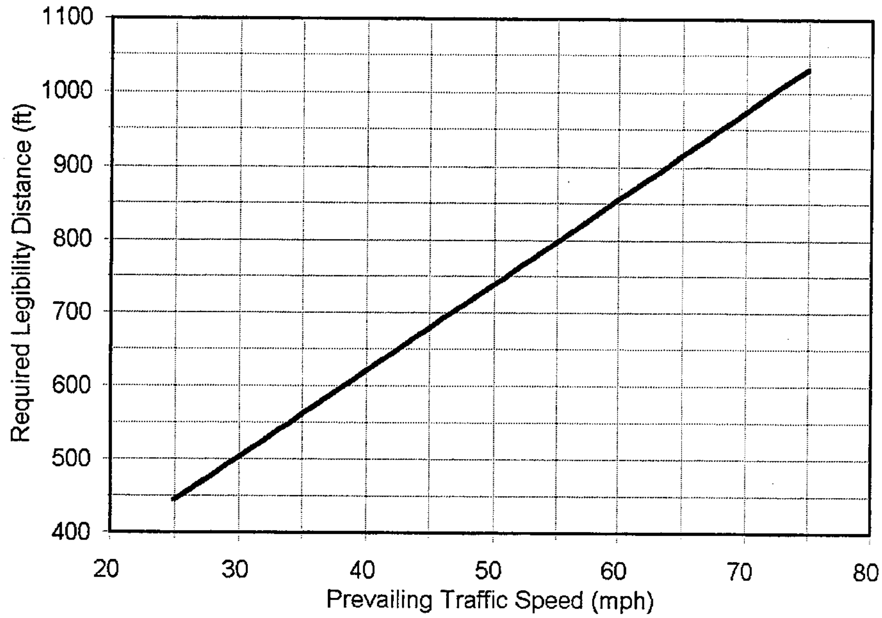


FIGURE 4-3 Required Legibility Distance

TABLE 4-1 Mean Legibility Distances *(8)*

Condition	Legibility Distance	
	LED CMS	Fiberoptic CMS
Mid-Day	740	980
Night	690	680
Wash-Out [a]	490	850
Backlight [b]	500	660

[a] Sun shines brightly on the face of the CMS.
[b] Sun shine brightly from behind the CMS.

4.4 DISPLAY FORMAT

Display format refers to the manner in which a message is presented on the CMS. There are three basic display formats:

1. Discrete Format, entire message is displayed at once.
2. Sequential Format, message is divided into parts and displayed one part at a time.
3. Run-on Format, message is displayed by running it continuously across the sign from right to left.

The run-on format is not recommended because it takes longer for drivers to read *(7)*. However, the decision to use the discrete or sequential format depends on the number of units of information in the message.

A unit of information is a portion of a message that answers a question about the incident and provides a basis for a driver to decide on a course of action in response to the information. The questions answered by units of information are related to the message elements:

1. What is the problem?
2. Where is the problem?
3. What is the impact or effect on traffic?
4. For whom is the message intended?
5. What action is advised?

A unit of information typically consists of two words, but may contain from one to four words.

The preferred format is the discrete format. The need to use a sequential format depends on the length of the message, the length of the words in the message, and the size of the CMS. However, the need is also determined by the information processing limits of the driver. As mentioned earlier in the discussion of message length, studies *(5)* suggest that an eight-word message, excluding prepositions and having about four to eight characters per word, is approaching the information processing limits of drivers traveling at high speeds. In addition, research *(7)* indicates that no more than three units of information should be displayed at once if it is expected that the driver must recall all three units of information. If not, four units of information may be displayed at once when at least one of the units is minor and does not have to be remembered by the driver in order to take appropriate action in response to the message. Thus, even if a CMS is large enough to display a message with four units of information in a discrete format, it would be better to display it in a sequential format if all four units of information must be recalled by the driver.

If a sequential format is necessary, it should be limited to two sequences, or phases. Usually, three-phase sequential displays are too longer to be read within the available reading time by drivers traveling a high speed. Research *(7)* has found that two-phase messages, up to four words per phase, can be displayed at rates as fast as 0.5 seconds per word without loss of recall. However, longer messages should be displayed at a rate of only 1 second per word or slower. Desirably, drivers should be exposed to the message twice while within the range of the CMS's legibility.

Also, messages displayed in more than two sequences may not be understood by drivers who are not exposed to the message in logical sequence (*i.e.*, from beginning to end). Driver understanding of the message is enhanced when a sequential format is limited to two phases. A message should be shortened if more than two phases would be needed to display it.

4.5 MESSAGE FORMAT

Message format is the arrangement of the units of information in the message. The units of information in a message relate to the message elements discussed above under the heading of message content. They convey information about of the problem, its location, its effect, the drivers affected, and the desired action by the drivers. The units of information included in a message and their order of inclusion depend on: (1) the nature of the incident, (2) the drivers affected, (3) the type of action desired from them, (4) the amount of time they have to read the message, (5) the size of the CMS, and (6) the surveillance capabilities of the system.

4.5.1 CMS Size

As was done in the second phase of this project *(3)*, it is assumed that the CMSs installed on the Omaha freeway system will have three lines, each with 20, 18-inch characters. Although one unit of information may be displayed on more than one line of a CMS, no more than one unit of information should be displayed on a single line *(5)*. Therefore, a three-line CMS can display a maximum of three units of information in one phase, or six units of information in two phases. When a message must be displayed in two phases, it is desirable to repeat key words in the second phases which appeared in the first phase. This will improve the driver's understanding and recall of the message. However, the time required to read the message must be within the available reading time determined by the CMS's legibility. Therefore, every effort should be made to keep messages as short as possible in order to minimize the demands on the driver.

As noted above in the discussion of message length, studies *(5)* suggest that an eight-word message, excluding prepositions, is approaching the information processing limits of drivers traveling a high speeds. Since a unit of information typically consists of two words, this limitation indicates that messages should be limited to no more than four units of information.

4.5.2 Surveillance Capabilities

The surveillance capabilities of the system determine the extent to which messages should describe incident effects and specify alternate routes. It is assumed that the CMS system to be installed in Omaha, at least initially, will not have TV or electronic surveillance on the freeway or on the alternate routes. Detection of incidents will rely on reports received by Omaha/Douglas County 911, and incident verification will consist of on-site observation by law enforcement or NDOR District 2 maintenance personnel. Therefore, messages should not include overly-precise descriptions of incident effects nor specific diversion instructions. Without real-time surveillance capabilities, this information would be unreliable and diminish the credibility of the messages.

4.5.3 Drivers Affected

If the action required in response to the message is the same for all drivers, then the drivers-affected unit of information is not included in the message. Otherwise, this information must be included. This information typically consists of one unit of information. But, if different actions are desired from two different groups of drivers, then two units of information would be required. For example, cars could be asked to take one course of action and trucks another.

4.5.4 Non-Diversion Messages

The recommended format for non-diversion messages about accidents, road work, or environmental warnings is one phase with the following units of information:

Line 1: problem (accident, road work, ice, *etc.*)
Line 2: location of problem
Line 3: effect of incident or desired action by driver

The unit of information included in Line 3 depends on implications of the effect statement. For example, in the message below, the desired action (*i.e.*, merge to the right) is implied by the effect. Therefore, the effect is included in Line 3 instead of the desired action.

ACCIDENT AT 72nd STREET LEFT LANE CLOSED

The inclusion of additional units of information would depend on the intent of the message and the need to consider more than one group of drivers. For example, if the intent of the message is to have drivers merge immediately, then both the effect and desired action should be included. To do this, the message must be divided into two phases, with the first two lines being repeated in each phase to provide repetition.

Phase 1	Phase 2
ACCIDENT AT 72nd STREET LEFT LANE CLOSED	ACCIDENT AT 72nd STREET MERGE RIGHT

If the intent of the message is to accommodate both familiar and unfamiliar drivers, two units of information must be used to describe the location as follows.

Phase 1	Phase 2
ACCIDENT AT 72nd STREET 7 MILES AHEAD	ACCIDENT AT 72nd STREET LEFT LANE CLOSED

However, it should be noted in each case the additional units of information resulted in messages containing six units of information in 12 words, which would require about 12 seconds for drivers to read. According to the earlier discussion of message length and the information shown in Figure 4-2, the reading time required by this message probably exceeds the available reading time and the number of words in the message is greater than the eight-word maximum length based on the information processing limits of drivers traveling at high speeds *(5)*. Therefore, the messages should be shortened to four units of information presented in two phases as follows:

Phase 1	Phase 2
ACCIDENT AT 72nd STREET	LEFT LANE CLOSED MERGE RIGHT

Phase 1	Phase 2
ACCIDENT AT 72nd STREET	LEFT LANE CLOSED 7 MILES AHEAD

In the case of environmental warnings, the word CAUTION may be used on Line 1, with the problem on Line 2, and the action statement on Line 3, as follows.

CAUTION ICY ROAD REDUCE SPEED

However, CAUTION should only be used in this format if its use does not require the addition of a second phase to the message display.

4.5.5 Diversion Messages

Because of the limited surveillance capabilities of the system, the diversion messages should not give specific diversion instructions. Instead, they should be limited to the following units of information in order to maintain the credibility of the CMS messages:

Line 1: problem (accident, road work, ice, *etc.*)
Line 2: location of problem
Line 3: effect of incident

The information in these messages is intended to encourage drivers to divert voluntarily from the freeway and find their own alternate route.

The effect statement may be expressed in terms of delay or lane blockage depending on the nature of the problem. Delay should be expressed in general terms, such as DELAY or MAJOR DELAY. MAJOR DELAY should be used when the delay exceeds 20 minutes. Otherwise, the term DELAY should be used.

The terms DELAY and MAJOR DELAY are preferred to the words CONGESTION and HEAVY CONGESTION, respectively. Delay is a shorter word, which makes it more effective from the standpoint of reading time.

When lanes are blocked temporarily due to an incident or closed for a prolonged period for road work, the effect statement should provide information about which lanes are closed. It is recommended that the word CLOSED be used for both cases, because the action required by drivers is the same regardless of the reason for the closure. The consistent use of the word CLOSED should facilitate the reading and understanding of the message by drivers.

On two- or three-lane freeway sections, the lane blockages can be specified by the descriptors LEFT, RIGHT, and CENTER. However, on sections with four lanes or more, these terms are less clear in specifying which lanes are closed. Therefore, anchoring messages with X's and arrows as shown in Figure 4-1 are preferred on sections with more than three lanes.

The statement FREEWAY CLOSED should not be displayed unless all lanes of the freeway are blocked or closed. As long as at least one lane of the freeway is open, LANE CLOSED statements should be used. However, when all lanes are closed and FREEWAY CLOSED is displayed, the diversion message must include additional units of information which describe the detour route that drivers must follow. The message may have to be divided into two phases in order to provide this additional information.

For example, suppose that a fatal accident has occurred on eastbound I-80 east of 60th Street and the interstate must be closed. A CMS on eastbound I-80 at Harrison Street might display the following message:

Phase 1	Phase 2
ACCIDENT 7 MILES AHEAD I-80 CLOSED	I-80 CLOSED THRU TRAFFIC USE I-680

Attention and action statements are added to the basic three-line diversion message, which requires the message to be displayed in two phases. The message contains six units of information contained in 12 words, which would require about 12 seconds for drivers to read. According to the earlier discussion of message length and the information shown in Figure 4-2, the reading time required by this message probably exceeds the available reading time and the number of words in the message is greater than the eight-word maximum length based on the processing limits of drivers traveling at high speeds *(5)*. Therefore, the message should be shortened to four units of information presented in two phases as follows:

Phase 1	Phase 2
I-80 CLOSED	THRU TRAFFIC
7 MILES AHEAD	USE I-680

In response to this same incident, a CMS on eastbound I-80 at 72nd Street might display the following message:

Phase 1	Phase 2
ACCIDENT	I-80 CLOSED
AT 42nd STREET	EXIT AT 60th STREET
I-80 CLOSED	FOLLOW DETOUR

In this case, two units of information containing diversion instructions are added to the basic three-line diversion message. However, the message is also too long and must be shorten to four units of information as follows:

Phase 1	Phase 2
I-80 CLOSED	EXIT AT 60th STREET
AT 42nd STREET	FOLLOW DETOUR

4.6 MESSAGE TEXT

The text of the messages refers to the specific words that are used to express the message elements displayed on the CMSs. The effectiveness of the messages can be enhanced by selecting appropriate words for these messages. Recommended text for problem, effect, attention, and action statements are presented in Tables 4-2, 4-3, 4-4, and 4-5, respectively. The text used in these statements is based on the findings of studies *(5,7,8,11)* previously discussed in this chapter, which involved drivers from other parts of the country. However, experience with CMSs on the Omaha freeway system in the future may determine that other words are equally, or perhaps more, effective for the purposes for incident management. Also, because there are so many variables involved in incident management situations, it is impractical to develop statements to cover every conceivable CMS application. Therefore, the statements in these tables are intended to provide samples to be used by CMS operators to design appropriate text for specific situations.

TABLE 4-2 Text for Problem Statements

Problem Type		Problem Location
ACCIDENT	ICE	AHEAD
ROAD WORK	SNOW	_____ MILES AHEAD
PAVEMENT DAMAGE	FOG	AT _____ STREET
WATER OVER ROAD	ICY BRIDGE (RAMP)	

TABLE 4-3 Text for Effect Statements

DELAY	_____ LEFT LANES CLOSED
MAJOR DELAY	_____ RIGHT LANES CLOSED
LEFT LANE CLOSED	OFF RAMP CLOSED
RIGHT LANE CLOSED	FREEWAY CLOSED
CENTER LANE CLOSED	

TABLE 4-4 Text for Attention Statements

ALL TRAFFIC	WIDE LOADS
CARS	COLLEGE WORLD SERIES
TRUCKS	(ROUTE NO.) TRAFFIC
THRU TRAFFIC	(DESTINATION) TRAFFIC
LOCAL TRAFFIC	

TABLE 4-5 Text for Action Statements

Non-Diversion Situations	Diversion Situations
MERGE LEFT	TAKE NEXT EXIT
MERGE RIGHT	AVOID DELAY
STAY IN YOUR LANE	CONSIDER ALTERNATE ROUTE
PREPARE TO STOP	FOLLOW DETOUR
REDUCE SPEED	USE _____ TO _____
DO NOT PASS	
USE RIGHT LANE	
USE LEFT LANE	
CAUTION	
WATCH FOR _____	

4.7 ABBREVIATIONS

It may be necessary to use abbreviations in some situations in order to fit the desired message on the CMS. It is important for drivers to understand the abbreviations used. Research *(7)* has found that the abbreviations in Table 4-6 are understood by at least 85 percent of the driving public if they appeared on a road sign. These abbreviations would be understood by drivers regardless of the specific context of their usage.

TABLE 4-6 Abbreviations Understood by Drivers Without Prompt Word

Word	Abbreviation	Word	Abbreviation
Boulevard	BLVD	Normal	NORM
Center	CNTR	Parking	PKING
Emergency	EMER	Road	RD
Entrance, Enter	ENT	Service	SERV
Expressway	EXPRWY	Shoulder	SHLDR
Freeway	FRWY, FWY	Slippery	SLIP
Highway	HWY	Speed	SPD
Information	INFO	Traffic	TRAF
Left	LFT	Travelers	TRVLRS
Maintenance	MAINT	Warning	WARN

Other abbreviations were found to be understood by at least 85 percent of the driving public whenever they appear in conjunction with a particular word (prompt word) commonly associated it *(7)*. These abbreviations are shown in Table 4-7. Care should be used in using them with other prompt words, because the high understanding of these abbreviations was determined only with the prompt word given in the table.

The abbreviations shown in Table 4-8 were understood with a prompt word by about 75 percent of the drivers *(7)*. Public education would be required before these abbreviations are used.

Certain abbreviations were prone to misunderstanding and confusion because another word is, or could be, abbreviated in the same way *(7)*. These abbreviations are shown in Table 4-9 along with the words with which they were confused. They should not be used.

TABLE 4-7 Abbreviations Understood by Drivers With Prompt Word

Word	Abbreviation	Prompt Word	Word	Abbreviation	Prompt Word
Ahead	AHD	Fog*	Mile	MI	(Number)*
Blocked	BLKD	Lane*	Minute(s)	MIN	(Number)*
Access	ACCS	Road	Oversized	OVRSZ	Load
Bridge	BRDG	(Name)*	Prepare	PREP	To Stop
Chemical	CHEM	Spill	Pavement	PVMT	Wet *
Construction	CONST	Ahead	Quality	QLTY	Air*
Exit	EX, EXT	Next*	Route	RT	Best*
Express	EXP	Lane	Turnpike	TRNPK	(Name)*
Hazardous	HAZ	Driving	Vehicle	VEH	Stalled*
Interstate	I	(Number)	Cardinal	N, S, E, W	(Name)
Major	MAJ	Accident	Directions		
Minor	MNR	Accident	Upper	UPR	Level
			Lower	LWR	Level

* Prompt word given first.

TABLE 4-8 Abbreviations Understood by Drivers With Prompt Word and Public Education

Word	Abbreviation	Prompt Word	Word	Abbreviation	Prompt Word
Downtown	DWNTN	Traffic	Roadwork	RDWK	Ahead
Northbound	N-BND	Traffic			(Distance)
Congested	CONG	Traffic	Township	TWNSHP	Limits
Temporary	TEMP	Route	Frontage	FRNTG	Road
Condition	COND	Traffic*	Local	LOC	Traffic

* Prompt word given first.

TABLE 4-9 Abbreviations To Be Avoided

Abbreviation	Intended Word	Understood Word	Abbreviation	Intended Word	Understood Word
WRNG	Warning	Wrong	PARK	Parking	Park
ACC	Accident	Access	RED	Reduce	Red
		(Road)	POLL	Pollution	Poll
DLY	Delay	Daily		(Index)	
LT	Light	Left	FDR	Feeder	Federal
	(Traffic)		TEMP	Temporary	Temperature
STAD	Stadium	Standard	CLRS	Clears	Colors
L	Left	Lane (Merge)			

4.8 CONCLUSION

The effectiveness of CMS messages depends on the extent to which they are read, understood, and believed by the drivers. The objective of incident management messages is to advise drivers of unusual conditions on the freeway and recommend a course of action. This chapter presents guidelines for the design of the content, length, display, format, text, and abbreviations of these messages. The guidelines are based on previous research *(5,7,8,11)* involving drivers from other parts of the country. Experience with CMSs on the Omaha freeway system in the future may find some messages, which do not fit within these guidelines, are equally, or perhaps even more, effective for the purposes of incident management in Omaha. Therefore, NDOR should pre-test CMS messages to ensure that they will be understood correctly by drivers, especially messages with abbreviations.

The information processing capabilities of the drivers determine the limits on display format and message length. The discrete format, which presents the entire message at once, is the preferred format for CMS messages *(7)*. But, if the message is too long to be displayed in a discrete format, it may be divided into two parts and displayed in a two-phase sequential format, which displays one part at a time. Two is the maximum number of phases that should be used in a sequential format. Messages displayed in three or more phases are usually too long to be read by drivers within the time available and prone to driver misunderstanding. If more than two phases are required to display the message, it should be shortened.

An eight-word message, excluding prepositions, or about four units of information, is approaching the information processing limits of drivers traveling at high speed *(5)*. In addition, no more than three units of information should be displayed at once if the driver must recall all three units of information *(7)*. Otherwise, four units of information may be displayed at once when at least one of the units is minor and does not have to be remembered by the driver in order to take appropriate action in response to the message. Thus, even if a CMS is large enough to display a message with four units of information in a discrete format, it would be better to display it in a sequential format if all four units of information must be recalled by the driver.

In order for drivers to be able to read a CMS message, the time required to read the message must not be longer than the time available. Research *(5)* has determined that the reading time used to design CMS messages should be 1 second per short word (*i.e.*, words no more than eight characters long), excluding prepositions. The time available to read a message is a function of the CMS's legibility and the prevailing traffic speed. According to the information presented in this chapter, a legibility distance of nearly 1,000 feet would be needed to adequately display an eight-word message to drivers traveling at 70 mph. However, the recommended design legibility distance of 650 feet for a CMS with 18-inch characters *(5)* indicates that eight-word messages can only be displayed to drivers traveling at 40 mph or slower. Messages would have to be shortened to four or five words to accommodate drivers traveling above 60 mph. Therefore, in designing CMS messages, both the sign legibility and prevailing traffic speed must be considered. Longer messages could be displayed during periods of low-speed congested flow than during periods of high-speed uncongested flow. But, in any case, messages should be kept as short as possible in order to minimize the demands on the driver.

For purposes of preparing the guidelines in this chapter, it was assumed that the CMSs installed on the Omaha freeway system will have three lines, each with 20, 18-inch characters. Although one unit of information may be displayed on more than one line of a CMS, no more than one unit of information should be displayed on a single line *(5)*. Therefore, a three-line CMS can display a maximum of three units of information in one phase, or six units of information in two phases. When a message must be displayed in two phases, it is desirable to repeat key words in the second phase which appeared in the first phase. This will improve the driver's understanding and recall of the message. However, the time required to read the message must be within the available reading time determined by the CMS's legibility. Also, it must be remembered that an eight-word message, excluding prepositions, is approaching the information processing limits of drivers traveling at high speeds. Since a unit of information typically consists of two words, this limitation indicates that messages should be limited to no more than four units of information for high-speed traffic flow conditions.

Finally, the limitations of the surveillance capabilities of the system must be considered in the design of CMS messages. The surveillance capabilities of the system determine the extent to which messages should describe incident effects and specify alternate routes. It is assumed that the CMS system to be installed in Omaha, at least initially, will not have TV or electronic surveillance on the freeway or on the alternate routes. Detection of incidents will rely on reports received by Omaha/Douglas County 911, and incident verification will consist of on-site observation by law enforcement or NDOR District 2 personnel. Therefore, messages should not include overly-precise descriptions of incident effects nor specific diversion instructions. Without real-time surveillance capabilities, this information would be unreliable and diminish the credibility of the messages. Thus, except in the case of freeway closures, CMS should not give messages instructing drivers to follow specific alternate routes.

Chapter 5

ALTERNATE ROUTES

The Omaha Metropolitan Area Incident Management Team has prepared a preliminary list of alternate routes to be used to divert traffic from the freeway when it is closed. These routes are shown in Table 5-1. Primary and secondary alternate routes were designated between each pair of mainline diversion points on the freeway system. These routes are intended to accommodate the traffic that would be diverted from the freeway when it is closed in either direction between the diversion points. The primary route would be used unless it is unavailable for some reason, such as road work or occurrence of an incident, in which case the secondary route would be used.

The Omaha Metropolitan Area Incident Management Team is currently checking the preliminary set of alternate routes to ensure that the roadway geometrics, bridges, and pavements are able to handle the traffic that would be diverted from the freeway. Ultimately, capacities of these routes will be analyzed to determine the need for signal timing plan changes, turning movement restrictions, and other traffic control measures to improve the safety and efficiency of traffic operations during diversion. Diversion plans will be developed to coordinate the implementation of the traffic control measures when the freeway traffic is diverted to the alternate routes.

The alternate routes should be marked with trailblazers to aid unfamiliar drivers. The trailblazers could be permanently installed, or placed in position just before the freeway is closed, as other traffic control measures are being implemented. In either case, the design and placement of the trailblazers should not conflict with the existing signs on the route and confuse drivers not destined for the freeway. Trailblazers should be located at every point along the route where drivers may become confused. They should be placed at every major intersections where the alternate route traffic is controlled by a traffic signal or stop sign, and at forks in the road. Supplementary trailblazers should be installed between major intersections that are separated by one mile or more, and where they are needed to pull drivers through busy intersections.

Immediately before diverting traffic from the freeway, conditions on the primary alternate route should be checked to ensure that it is operating normally and can accommodate the traffic diversion. If there is road work, an accident, or some other condition on the primary alternate route preventing it from being able to handle the diverted traffic, then the secondary route should be checked. If conditions on the secondary alternate route are also unsuitable for traffic diversion, then modifications to these routes must be made, or another route must be found for the diverted traffic. In any case, traffic should not be diverted to an alternate route that has not been checked prior to the diversion.

TABLE 5-1 Alternate Routes

		Alternate Route	
Freeway	Closure	Primary	Secondary
I-80	Hwy 50 - 126th	144th / Harrison	144th / L
	126th - L	Harrison / 108th / L	Harrison /123rd / Q / L
	I-680 - 84th	84th / L	Center / 84th
	84th - 72nd	84th / Center / 72nd	84th / L / 72nd
	72nd - 60th	72nd / Center / 60th	72nd / L / 60th
	60th - 42nd	60th / Center / 42nd	60th / L / 42nd
	42nd - I-480	42nd / L / Kennedy	42nd / Center / I-480
	24th - 13th	Kennedy / L / 13th	I-480 / Martha / 13th
	13th - I-29	13th / Hwy 92 / 24th	13th / I-480 / I-29
	I-29 - 24th	I-29 / River / 23rd / 24th	13th / Hwy 92 / 24th
	24th - S. Expwy	24th / Hwy 92 / S. Expwy	24th / 23rd / S. Expwy
	S. Expwy - I-29	S. Expwy / Hwy 92 / Valley View	S. Expwy / H / Hwy 75 / Madison
	I-29 - Madison	S. Expwy / Hwy 92 / Valley View	S. Expwy /H / Hwy 75 / Madison
	Madison - Hwy 6	Valley View / Sunnydale / Hwy 6	Bennett / McPherson / Hwy 6
I-680	I-80 - Center	I / 120th / Center	Center / 84th
	Center - Pacific	Center / 120th / Pacific	Center / 105th / Pacific
	Pacific - Dodge	Pacific / 120th / Dodge	Pacific / Regency / Dodge
	Dodge - Maple	Dodge / 90th / Maple	Dodge / 108th / Maple
	Maple - Fort	Maple / 90th / Fort	Maple / 108th / Fort
	Fort - Hwy 133	Fort / Hwy 133	Fort / 108th / Ida
	Hwy 133 - 72nd	Hwy 133 / Crownpoint / 72nd	Hwy 133 / State / 72nd
	72nd - Hwy 75	72nd / McKinley	72nd / Hwy 75
	Hwy 75 - 30th	Hwy 75 / Hwy 36 / 30th	Hwy 75 / Calhoun
I - 480	I-80 - Martha	Martha / 24th / I-80	Martha / 42nd / I-80
	Martha - Leavenworth	Martha / 24th / Leavenworth	Martha / 42nd / Leavenworth
	Leavenworth - Dodge	Leavenworth / 24th /Dodge	Leavenworth / 13th / I-480
	Dodge - 13th	Dodge / 13th / I-480	Dodge / 30th / Cuming / I-480
I-29	I-80 - Nebraska	24th / 23rd / River	S. Expwy / Broadway
	Nebraska - 9th	River / 35th / 9th	S. Expwy / Broadway
	9th - I-480	9th / 35th / G	S. Expwy / Broadway
Kennedy	Chandler - Q	Chandler / Railroad / Q	Chandler / 13th / L
	Q - L	Q / 24th / L	Chandler / 13th / L
	L -F	L / 24th / F	L / 13th / I-80
North	Hamilton - Lake	Hamilton / 30th / Lake	Hamilton / 24th / Lake
	Lake - Ames	Lake / 30th / Sorensen	Lake / 20th Sorensen

Chapter 6

OPERATION

The purpose of the deployment of the CMSs is to provide traveler information in support of freeway incident management in the Omaha metropolitan area. The CMSs will inform drivers of the occurrence and location of incidents on the freeway, which will prepare them for the conditions ahead and encourage some to avoid the problem by diverting to alternate routes. In order to be effective, the information provided by the CMSs must be reliable. Otherwise, drivers will ignore the CMS messages and the resources used to deploy the CMSs will be wasted. Because of their high visibility and the amount of attention they will receive, at least initially, from the drivers and the news media, it would be much better to continue freeway operations without CMSs than to deploy CMSs that display unreliable information. The operation of the CMS system will be the key to the reliability of the information it presents to drivers. The operation of the CMS system and issues that need to be addressed by NDOR before the deployment of the system are discussed in this chapter.

6.1 INCIDENTS

A freeway incident is any non-recurrent event that reduces the capacity of the freeway or abnormally increases the demand on the freeway. Some incidents are predictable, such as maintenance or construction activities and special events. Others are unpredictable, such as accidents, stalled vehicles, spilled loads, roadway debris, and inclement weather. Some incidents caused traffic congestion and increase the potential for secondary accidents. Others merely present hazards to drivers, especially those involved. In any case, incident response is necessary in order to provide assistance to the drivers involved and minimize the effects on other drivers.

The phases of an incident are: detection, response, and removal. Thus, the duration of an incident is determined by the amount of time it takes to detect it, respond to the scene, and clear it from the freeway. However, its effect can persists long after the incident itself has been removed because of the congestion it creates. Studies *(12)* have shown that delay to drivers increases geometrically with the time it takes to clear an incident. For example, the California Department of Transportation has estimated that for each minute that the duration of an incident is reduced, the delay to drivers is reduced by 4 or 5 minutes.

6.2 INCIDENT MANAGEMENT

Various agencies already respond to the incidents which occur on the Omaha freeway system. Therefore, the goal of incident management is not to create a response, but rather to create a more effective response from all of the responding agencies. A response that will reduce the duration of incidents and the magnitude of their effects.

Incident management is the coordinated preplanned use of agencies' resources to restore freeway operations to normal after an incident has occurred and to provide drivers with information and direction until the effects of the incident have dissipated. It consists of the following tasks:

- Detection
- Verification
- Response
- Removal
- Traffic Management
- Driver Information

Successful completion of these tasks in a timely manner requires the cooperation of the responding agencies and the state and local jurisdictions they represent.

6.2.1 Detection

Detection is the determination that an incident of some type has occurred. At the present time, the primary means of detecting the occurrence of incidents on the Omaha freeway system is calls to 911 via cellular telephone. Some incidents are detected by local law enforcement, Nebraska State Patrol, and Motorist Assist personnel on patrol. Inclement weather and hazardous road surface conditions are detected by NDOR Road Weather Information System (RWIS) stations and maintenance personnel. Incidents, such as road work and special events, are scheduled activities known in advance by NDOR and the local jurisdictions.

TV and electronic freeway surveillance does not exist on the Omaha freeway system. It is in the early planning stages and not scheduled for implementation before the installation of the CMSs *(13)*. Although local TV stations have cameras along the freeway system to show traffic conditions during their newscasts, video feeds are received by NDOR from only two of these cameras and none of the cameras can be operated by NDOR. Therefore, at least in the short term, the operation of the CMS system must rely on the current sources for detection of incidents. Effective detection of incidents for the purpose of displaying credible CMS messages will require communication links between the NDOR and the sources of incident detection information.

6.2.2 Verification

Verification is the determination of the precise location and nature of the incident. Currently, verification relies on information provided by 911 callers and reports from emergency responders at the scene. Inclement weather and hazardous road surface condition reports from the NDOR RWIS stations are verified by maintenance personnel. Incidents, such as road work and special events, are verified by NDOR maintenance personnel and the local jurisdictions where the special events are held, respectively. TV surveillance will not be available during the initial operation of the CMS system. Therefore, NDOR must continue to rely on the existing methods of verification to provide the information necessary for the display of credible CMS messages.

6.2.3 Response

Response is the mobilization of resources to the scene of the incident once its location and nature have been determined. These resources may include several emergency responders, such as fire, medical, police, towing, hazardous materials clean-up, and highway maintenance. At the present time, the response to incidents is usually initiated by 911. The 911 dispatcher selects the emergency responders (*i.e.*, fire, medical, police, *etc.*) initially sent to the scene based on the description of the incident provided by the caller(s). After reaching the scene, the emergency responders may request additional resources as needed to remove the incident and control traffic until freeway operations are returned to normal. In the case of weather-related incidents detected by NDOR RWIS and maintenance personnel, the response is initiated directly by NDOR. The response to road work is initiated by NDOR, and the response to special events is prearranged by the local jurisdictions where the events are held. At the present time, there is not a formal plan defining the roles of responding agencies, interagency communication links, and detailed policies and procedures for responding to incidents on the Omaha freeway system.

6.2.4 Removal

Removal is the clearing the roadway of wreckage and debris resulting from the incident. It includes first-aid treatment and transportation of injured parties and accident scene investigation. Snow and ice removal are also involved in the case of winter weather-related incidents. Road work and special events do not involve this task.

Removal may involve several agencies depending on the nature of the incident. At the present time, there is not a formal plan defining the roles of responding agencies, interagency communication links, policies and procedures for removing incidents on the Omaha freeway system.

6.2.5 Traffic Management

Traffic management is the application of traffic control measures to mitigate the impacts of the incident and ensure the safety of incident victims, other drivers, and emergency response personnel. These measures include the use of freeway shoulders, merging controls, lane and entrance ramp closures, emergency vehicle parking policies, traffic diversion, and signal timing changes on alternate routes.

Traffic control is typically provided by law enforcement officers and NDOR maintenance personnel. At the present time, there is not a formal traffic management plan describing policies and procedures for traffic control and implementation of alternate routes for incidents on the Omaha freeway system. The effectiveness of the designated alternate routes in the event of freeway closures will depend on the interagency cooperation to check conditions on the alternate routes immediately prior to diversion and implement signal timing adjustments and temporary traffic control measures as needed on the alternate routes to accommodate the diverted traffic.

6.2.6 Driver Information

Driver information is the activation of various means of communicating incident site traffic conditions to drivers. Based on reports from emergency responders at the scene, 911 personnel fax information about major incidents to the news media, especially about incidents which close the freeway. Portable CMSs are deployed by NDOR at strategic points along the freeway to advise drivers of conditions ahead. NDOR faxes information to the news media regarding road work and weather-related hazardous road surface conditions. Also, in the case of road work and special events, NDOR utilizes portable CMSs to advise drivers in these cases. Local jurisdictions also issue news bulletins regarding special events in their jurisdictions.

The permanent CMSs will provide another means of communicating with drivers. The initial CMS deployment recommended in Chapter 2 will not eliminate the need for portable CMSs in some cases, depending on the location of the incident. The effectiveness of the CMSs will depend on the timeliness and the accuracy of the information they provide.

6.3 SYSTEM ARCHITECTURE

The CMS system will be implemented within the context of the incident management tasks described above. It will be a key component of the driver information task. However, its effectiveness will be limited primarily by the methods used to detect and verify incidents and monitor traffic conditions at the incident scene and on the alternate routes.

The CMS system architecture is illustrated in Figure 6-1. The traffic management center (TMC) is the focal point of the system where the incident information from several sources is used to select and implement the CMS messages. The TMC will be operated and maintained by NDOR District 2. As a minimum, it should be a space at NDOR District 2 with a desk, telephone, NDOR radio, desk top computer for CMS central controller software, interagency call list, and alternate route maps.

In order to ensure the credibility of the CMS system, messages must not be displayed until the precise location and nature of an incident has been verified by a responsible authority at the scene. Unpredictable incidents requiring emergency response are most often detected by calls to 911 via cellular telephone. These calls are usually from drivers who are not able to give precise incident locations and descriptions; and, in some cases, these calls are false alarms. CMS messages should not be displayed based solely on the information from these calls. CMS messages should only be displayed after the incidents have been verified by local emergency responders, Nebraska State Patrol, or NDOR maintenance personnel at the scene. Consequently, there will be some delay between the detection of these incidents and the display of CMS messages. On the other hand, road work and special events are predictable incidents for which CMS messages can be displayed immediately once their occurrence as scheduled has been verified with the appropriate authority (*e.g.*, NDOR maintenance personnel in the case of road work and appropriate local jurisdictions in the case of special events). On occasion, Iowa DOT may report the occurrence of a major incident on I-80 or I-29 outside of the metropolitan area and request the display to CMS messages advising Iowa bound traffic. Therefore, the architecture only shows communications links between the TMC and responsible agencies.

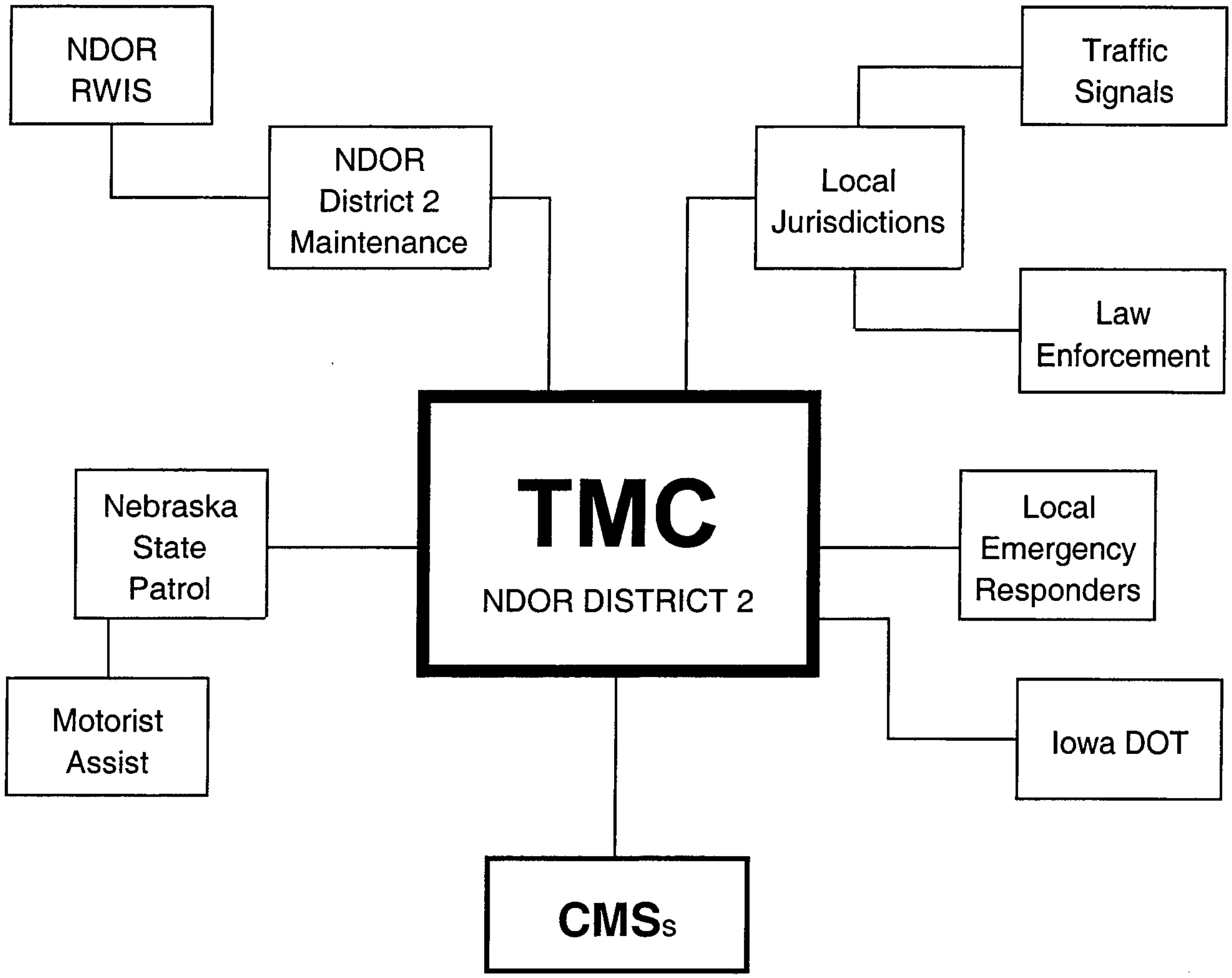


FIGURE 6-1 CMS System Architecture

The credibility of the CMS system also depends on the display of messages that are consistent with existing conditions. It is very important that the current relevance of the messages displayed be monitored. When the incident has been cleared and conditions return to normal, the display of the CMS messages must be discontinued immediately. Therefore, a responsible agency must monitor traffic conditions at the scene and report the return to normal conditions to the TMC in a timely manner. Without TV surveillance, this could be done most reliably by NDOR maintenance personnel at the scene.

As indicated in Chapter 4, because of the limited surveillance capabilities of the current system, the diversion messages should not give specific diversion instructions, except in the case of freeway closures when traffic will be diverted to alternate routes. In these cases, it will be necessary to check conditions on the alternate routes immediately prior to diversion and implement signal timing adjustments and temporary traffic control measures as needed on the alternate routes to accommodate the diverted traffic. This will require communication between the TMC and local jurisdictions to ensure the alternate routes have been checked, traffic signal timing adjustments have been made, and law enforcement has been dispatched to provide traffic control as needed.

As discussed in the Phase 2 Report *(3)*, several types of communications media can be used for transmitting data to and from CMS locations. Applicable media include wire and wireless communications ranging from copper wire to fiber optics and from radio wave to microwave. Agency-owned wire communications are usually copper wire, coaxial, or fiber optics depending on the data transmission rate requirements of their information system. These systems require right-of-way and conduit throughout the network. However, at this point, the installation of a communications infrastructure to support the deployment of CMS and other intelligent transportation systems (ITS) elements in the Omaha metropolitan area is in the early planning stage, and is not expected before the deployment of the CMSs. Therefore, until the ITS communications infrastructure is installed, dial-up communications service should be leased to provide the CMS communications in the short term.

6.4 MESSAGES

6.4.1 Selection

The CMS message displayed will be selected by NDOR District 2 personnel based on information received at the TMC from a responsible authority at the scene of the incident. Depending on the nature of the incident, the message will be selected from a message library to be developed by NDOR, or composed by the operator, based on the guidelines presented in Chapter 4. The limited surveillance capabilities of the system will require that the message not include overly-precise descriptions of incident effects nor specific diversion instructions, which would diminish the credibility of the system. The messages must be discontinued as soon as freeway conditions return to normal.

Depending on the impact of the incident, messages may be displayed on more than one CMS upstream of the incident. Generally, messages displayed on CMSs farther upstream would be less specific than those displayed on CMSs closer to the incident. For example, as mentioned in Chapter 4, suppose that a fatal accident has occurred on eastbound I-80 east of 60^{th} Street and the interstate must be closed. A CMS on eastbound I-80 at Harrison Street might display the following message:

Phase 1	Phase 2
I-80 CLOSED 7 MILES AHEAD	THRU TRAFFIC USE I-680

In response to this same incident, a CMS on eastbound I-80 at 72nd Street might display the following message:

Phase 1	Phase 2
I-80 CLOSED AT 42nd STREET	EXIT AT 60th STREET FOLLOW DETOUR

6.4.2 Non-Incident Situations

According to a recent survey of transportation agencies that operate CMSs *(4)*, 20 of the 26 agencies responding have a policy of displaying messages only when unusual conditions exist on the freeway and leave the CMS blank during other times. The remaining agencies display messages during non-incident situations, such as safety messages, day and time, or name of next exit. All of the agencies prohibit the display of commercial advertising as required by the Manual on Uniform Traffic Control Devices *(6)*.

Agencies that do not display messages during non-incident situations believe the non-incident messages detract from the importance of incident messages, because drivers may become accustomed to messages always on the CMSs and tend not to notice incident messages which may be important to their safety and convenience. There is also concern that non-incident messages are more apt to be misinterpreted or cause controversy, which could raise a liability issue. Also, allowing non-incident messages may generate a flood of requests to display messages from various agencies and civic organizations.

On the other hand, agencies that do display messages during non-incident situations believe that it is important for drivers to know that the CMS is functioning. Drivers may not believe the CMS is working if it is blank for long periods of time. There is also concern that blank CMSs are more likely to generate complaints about wasteful expenditures of public funds for CMSs that do nothing.

It will be necessary for NDOR to establish a policy on the display of non-incident messages. This policy should be developed in concurrence with appropriate public officials. An information program must be conducted to communicate the policy to the public, especially if the CMSs are blank during non-incident situations.

6.5 STAFFING

NDOR District 2 will be responsible for the operation and maintenance of the CMS system. Experience of other transportation agencies indicates that maintenance problems encountered vary considerably among different installation *(5)*. However, unforeseen hardware problems usually do not occur until the system has been operational for several months. It is highly recommended that agencies stipulate that the contractor furnish one or two years of maintenance during which time the agency can decide on whether or not to eventually do its own maintenance.

Previous studies *(4,5)* also indicate that the fiberoptic and LED CMS technologies selected by PAC in Phase 2 of this project *(3)*, have lower maintenance costs than the other technologies. The Ontario Ministry of Transportation *(5)* found the average number of maintenance calls per CMS per year was five for fiberoptic CMSs and three for LED CMSs.

NDOR District 2 personnel at the TMC will select and display the CMS messages. According to the analysis of incidents presented in the Phase 1 Report *(2)*, about 4,200 incidents are expected to occur on the Omaha freeway system in the year 2000. About one half, or 2,100, of these incidents would be expected to block one or more lanes of the freeway and perhaps justify the display of a CMS message. This would equate to an average of about six messages per day on one or more CMSs. Typically, about two of these messages would be displayed during the morning and evening peak periods (*i.e.*, 7:00-9:00 am and 4:00-6:00 pm). This level of activity suggests that an operator would not need to be stationed at the TMC throughout the entire day, but perhaps only during the peak periods. At other times, the operator could be paged when an incident demanded attention at the TMC. Also, during non-working hours (*i.e.*, nighttime and weekends), operators could be on-call and implement CMS messages remotely via telephone.

It would seem that the TMC operator duties could be handled with the existing NDOR District 2 personnel, at least in the short-term. The need for additional staff can be determined based on experience with the system and its expansion in the future. However, it is extremely important that NDOR provide whatever staff is needed to ensure that the messages displayed are reliable. Otherwise, without credibility, the CMS system will not be effective and the investment in it will be wasted.

6.6 INTERAGENCY COOPERATION

A key to the successful operation of the CMS system is interagency cooperation. It is essential that NDOR secure the cooperation of local jurisdictions, emergency responders, law enforcement, Nebraska State Patrol, and Iowa DOT to ensure that the messages displayed by the system are reliable. Their cooperation will be needed in the detection, verification, and monitoring of incidents. In addition, their assistance will be needed to check the status of alternate routes and implement signal timing changes and other traffic control measures necessary to accommodate traffic diverted to them in the case of freeway closures.

Chapter 7

CONCLUSION

The objective of this research was to develop guidelines for the deployment of CMSs in support of freeway incident management in the Omaha metropolitan area. The research consisted of three phases. The first phase involved the assessment of the impacts of incidents occurring on the freeway system in the Omaha metropolitan area and a preliminary evaluation of alternative CMS locations. The second phase comprised a benefit-cost analysis of selected CMS locations and the evaluation of alternative deployment strategies. The third phase entailed the development and documentation of guidelines for the deployment of CMSs in support of freeway incident management in the Omaha metropolitan area based the preferred deployment strategy. The results of the third phase of the research are documented in this report. The first and second phases are documented elsewhere *(2,3)*.

The guidelines presented in this report address the location and placement of the CMSs, design and display of CMS messages, alternate routes, and operation of the CMS system. The guidelines promote the deployment of a cost-effective CMS system that provides reliable driver information which will improve the safety and efficiency of freeway operations during incidents. The CMS locations recommended in the guidelines are those which provide greatest benefits to road users per unit cost of the system. The placement and message guidelines foster the readability, understandability, and credibility of the information displayed by the CMSs. The alternate route description discusses the need for trailblazers to guide unfamiliar drivers and the importance of checking conditions on the alternate routes before diverting traffic to them.

The operation guidelines emphasize the importance of maintaining the credibility of the system. Unless the system is operated in a way to ensure the reliability of the information it provides, drivers will ignore its messages and the resources used to deploy the CMSs will be wasted. NDOR must commit the personnel and secure the interagency cooperation necessary to provide reliable information from the very beginning. Once drivers' confidence in an information system is lost, it is extremely difficult to regain it. *Because of their high visibility and the amount of attention they will receive, at least initially, from the drivers and the news media, it would be much better to continue freeway operations without CMSs than to deploy CMSs that display unreliable information.*

Chapter 8

RECOMMENDATIONS

Based on the results of this study, the following recommendations are made concerning the deployment of CMSs in support of freeway incident management in the Omaha metropolitan area:

1. Based on the results of the benefit-cost analysis and input from PAC presented in Chapter 2, CMSs should be installed at the following nine locations:
   - I-80 EB at Harrison Street
   - I-80 EB at 72nd Street
   - I-80 EB at I-480/Kennedy Freeway
   - I-80 WB at 13th Street
   - I-80 WB at 60th Street
   - I-80 WB at I-680 NB
   - I-680 SB at Pacific Street
   - I-480 SB at Martha Street
   - Kennedy Freeway NB at L Street

2. The placement of CMSs at the locations recommended in Chapter 2 should consider the factors of target value, legibility, and coordination with existing static freeway sign.

3. The installation of CMSs where sight obstructions would restrict their target values to distances less than 350 feet plus their minimum required legibility distances should be avoided. In addition, on lighted freeway sections, they should be placed so they appear in negative contrast to enhance their nighttime target values and legibility.

4. The effects of the placement on CMS legibility should also be considered. The placement of a CMS overhead at the minimum vertical clearance results in a 150-foot loss in the sign's legibility distance, because the driver's view of the sign is obstructed by the vehicle's roof when the vehicle is within 150 feet of the sign. Higher mounting heights increase the lost legibility distance. Therefore, in order to minimize the loss in legibility distance, CMSs should be mounted to provide the minimum vertical clearance required. Determination of the minimum required vertical clearance should account for potential future pavement overlays.

5. The optimum lateral placement of CMSs is over the center of the travel lanes in order to minimize the portion of the roadway that is outside of the sign's cone of legibility. One of the disadvantages of the CMS technologies selected by PAC is their relatively narrow cones of legibility. The fiberoptic CMS has a 30-degree cone of legibility, whereas the LED CMS has only a 20-degree cone of legibility. When these types of CMSs are placed on the side of the roadway, they should be rotated toward the roadway in order to keep the lost legibility distance comparable to the 150-foot lost legibility distance caused by the vertical cutoff of the vehicle roof. The angle of the rotation necessary is larger on wider roadways. Fiberoptic CMSs placed on the side of the roadway can be rotated as much as needed in order to limit the loss in legibility distance to 150 feet on tangent sections and horizontal curves of 5 degrees or less. However, LED CMSs placed on the side of the roadway can not be rotated enough without exceeding their

maximum allowable rotation angle of 10 degrees on roadways wider than three lanes on tangent sections and horizontal curves of 3 degrees or less. Therefore, LED CMSs should not be placed on the side of the roadway at locations with four or more lanes.

6. CMS placement should be integrated with the existing static freeway signs to ensure their effectiveness. In addition, whenever possible the CMSs should be erected on existing bridges over the freeway to reduce the number of lateral obstacles on the roadside.

7. The effectiveness of CMS messages depends on the extent to which they are read, understood, and believed by the drivers. The objective of incident management messages is to advise drivers of unusual conditions on the freeway and recommend a course of action. Chapter 4 presents guidelines for the design of the content, length, display, format, text, and abbreviations of these messages. The guidelines are based on previous research *(5,7,8,11)* involving drivers from other parts of the country. Experience with CMSs on the Omaha freeway system in the future may find some messages, which do not fit within these guidelines, are equally, or perhaps even more, effective for the purposes of incident management in Omaha. Therefore, NDOR should pre-test CMS messages to ensure that they will be understood correctly by drivers, especially messages with abbreviations.

8. The information processing capabilities of the drivers determine the limits on display format and message length. The discrete format, which presents the entire message at once, is the preferred format for CMS messages *(7)*. But, if the message is too long to be displayed in a discrete format, it may be divided into two parts and displayed in a two-phase sequential format, which displays one part at a time. Two is the maximum number of phases that should be used in a sequential format. Messages displayed in three or more phases are usually too long to be read by drivers within the time available and prone to driver misunderstanding. If more than two phases are required to display the message, it should be shortened.

9. An eight-word message, excluding prepositions, or about four units of information, is approaching the information processing limits of drivers traveling at high speed *(5)*. In addition, no more than three units of information should be displayed at once if the driver must recall all three units of information *(7)*. Otherwise, four units of information may be displayed at once when at least one of the units is minor and does not have to be remembered by the driver in order to take appropriate action in response to the message. Thus, even if a CMS is large enough to display a message with four units of information in a discrete format, it should be displayed in a sequential format if all four units of information must be recalled by the driver.

10. In order for drivers to be able to read a CMS message, the time required to read the message must not be longer than the time available. Research *(5)* has determined that the reading time used to design CMS messages should be 1 second per short word (*i.e.*, words no more than eight characters long), excluding prepositions. The time available to read a message is a function of the CMS's legibility and the prevailing traffic speed. According to the information presented

in Chapter 4, a legibility distance of nearly 1,000 feet would be needed to adequately display an eight-word message to drivers traveling at 70 mph. However, the recommended design legibility distance of 650 feet for a CMS with 18-inch characters *(5)* indicates that eight-word messages can only be displayed to drivers traveling at 40 mph or slower. Messages must be shortened to four or five words to accommodate drivers traveling above 60 mph. Therefore, in designing CMS messages, both the sign legibility and prevailing traffic speed should be considered. Longer messages could be displayed during periods of low-speed congested flow than during periods of high-speed uncongested flow. But, in any case, messages should be kept as short as possible in order to minimize the demands on the driver.

11. For purposes of preparing the message design guidelines in Chapter 4, it was assumed that the CMSs installed on the Omaha freeway system will have three lines, each with 20, 18-inch characters. Although one unit of information may be displayed on more than one line of a CMS, no more than one unit of information should be displayed on a single line *(5)*. Therefore, a three-line CMS can display a maximum of three units of information in one phase, or six units of information in two phases. When a message must be displayed in two phases, it is desirable to repeat key words in the second phase which appeared in the first phase. This will improve the driver's understanding and recall of the message. However, the time required to read the message must be within the available reading time determined by the CMS's legibility. Also, it must be remembered that an eight-word message, excluding prepositions, is approaching the information processing limits of drivers traveling at high speeds. Since a unit of information typically consists of two words, this limitation indicates that messages should be limited to no more than four units of information for high-speed traffic flow conditions.

12. The primary and secondary routes identified by the Omaha Metropolitan Area Incident Management Team, which are listed in Chapter 5 should be checked to ensure that the roadway geometrics, bridges, and pavements are able to handle the traffic that would be diverted from the freeway. In addition, capacities of these routes should be analyzed to determine the need for signal timing plan changes, turning movement restrictions, and other traffic control measures to improve the safety and efficiency of traffic operations during diversion. Diversion plans should be developed to coordinate the implementation of the traffic control measures when the freeway traffic is diverted to the alternate routes.

13. The alternate routes should be marked with trailblazers to aid unfamiliar drivers. The trailblazers could be permanently installed, or placed in position just before the freeway is closed, as other traffic control measures are being implemented. In either case, the design and placement of the trailblazers should not conflict with the existing signs on the route and confuse drivers not destined for the freeway. Trailblazers should be located at every point along the route where drivers may become confused. They should be placed at every major intersections where the alternate route traffic is controlled by a traffic signal or stop sign, and at forks in the road. Supplementary trailblazers should be installed between major intersections that are separated by one mile or more, and where they are needed to pull drivers through busy intersections.

14. Immediately before diverting traffic from the freeway, conditions on the primary alternate route should be checked to ensure that it is operating normally and can accommodate the traffic diversion. If there is road work, an accident, or some other condition on the primary alternate route preventing it from being able to handle the diverted traffic, then the secondary route should be checked. If conditions on the secondary alternate route are also unsuitable for traffic diversion, then modifications to these routes must be made, or another route must be found for the diverted traffic. In any case, traffic should not be diverted to an alternate route that has not been checked prior to the diversion.

15. In order to be effective, the information provided by the CMSs must be reliable. Otherwise, drivers will ignore the CMS messages and the resources used to deploy the CMSs will be wasted. Because of their high visibility and the amount of attention they will receive, at least initially, from the drivers and the news media, it would be much better to continue freeway operations without CMSs than to deploy CMSs that display unreliable information. Every effort should be made by NDOR to ensure the reliability of the information the CMSs present to drivers.

16. NDOR should establish communication links with the sources of incident detection and verification information identified in Chapter6 in order to ensure effective detection of incidents for the purpose of displaying credible CMS messages.

17. NDOR in cooperation with the Omaha Metropolitan Area Incident Management Team should develop and adopt a formal operations agreement that defines the roles, responsibilities, interagency communication links, and detailed policies and procedures for incident management. The agreement should include the incident management activities of detection, verification, response, removal, traffic management, and driver information described in Chapter 6.

18. The CMS system should be operated and maintained by NDOR District 2. As a minimum, it should be a space at NDOR District 2 with a desk, telephone, NDOR radio, desk top computer for CMS central controller software, interagency call list, and alternate route maps.

19. In order to ensure the credibility of the CMS system, messages should not be displayed until the precise location and nature of an incident has been verified by a responsible authority at the scene. Unpredictable incidents requiring emergency response are most often detected by calls to 911 via cellular telephone. These calls are usually from drivers who are not able to give precise incident locations and descriptions; and, in some cases, these calls are false alarms. CMS messages should not be displayed based solely on the information from these calls. CMS messages should only be displayed after the incidents have been verified by local emergency responders, Nebraska State Patrol, or NDOR maintenance personnel at the scene. Consequently, there will be some delay between the detection of these incidents and the display of CMS messages. On the other hand, road work and special events are predictable incidents for which CMS messages can be displayed immediately once their occurrence as scheduled has been verified with the appropriate authority.

20. The credibility of the CMS system depends on the display of messages that are consistent with existing conditions. It is very important that the current relevance of the messages displayed be monitored. When the incident has been cleared and conditions return to normal, the display of the CMS messages should be discontinued immediately. Therefore, NDOR maintenance personnel at the incident scene should monitor traffic conditions at the scene and report the return to normal conditions to the CMSs control center in a timely manner.

21. Dial-up communications service should be leased to provide the CMS communications in the short term until the ITS communications infrastructure planned for the Omaha metropolitan area is installed.

22. The CMS message displayed should be selected by NDOR District 2 personnel based on information received from a responsible authority at the scene of the incident. Depending on the nature of the incident, the message should be selected from a message library to be developed by NDOR, or composed by the operator, based on the guidelines presented in Chapter 4. The limited surveillance capabilities of the system will require that the message not include overly-precise descriptions of incident effects nor specific diversion instructions, which would diminish the credibility of the system. The messages should be discontinued as soon as freeway conditions return to normal.

23. The CMSs should not be used to display non-incident messages. These messages may unnecessarily distract drivers and degrade the credibility of the CMSs when incident messages are displayed.

24. Experience of other transportation agencies indicates that maintenance problems encountered vary considerably among different installation *(5)*. However, unforeseen hardware problems usually do not occur until the system has been operational for several months. It is highly recommended that NDOR stipulates that the contractor furnish one or two years of maintenance during which time the NDOR can decide on whether or not to eventually do its own maintenance.

25. Based on the current number of incidents occurring on the Omaha freeway, it seems that the operation of the CMS system could be handled with the existing NDOR District 2 personnel in the short-term. The need for additional staff should be determined based on experience with the system and its expansion in the future. *However, it is extremely important that NDOR provide whatever staff is needed to ensure that the messages displayed are reliable. Otherwise, without credibility, the CMS system will not be effective and the investment in it will be wasted.*

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