USING CHANGEABLE MESSAGE SIGNS ON ARTERIAL STREETS FOR INCIDENT MANAGEMENT

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ABSTRACT

For over 30 years, changeable message signs (CMSs) have been used in urban environments as a means of relating real time information about the driving environment to individual motorists. The flexibility of the CMSs allows the display of a variety information about the nature of the downstream incident and possible diversion routes that can be taken to avoid the problems associated with the incident. Arterial CMSs can be used not only to provide information about freeway incidents and impacts, but also to indicate any problems detected on the arterial street system. With background knowledge of the street-freeway network or information provided on the CMS, the informed driver can make alternative route choices and avoid the hazard and congestion caused by the incident.

The fold-out, scroll, vane matrix, and bulb matrix signs of the past have given way to the fiber optic, fiber optic/reflective disk, and LED signs of today. New technologies are continually being developed, and the latest innovation is super bright LEDs, which have a rated life of 100,000 hours (or 12 years).

When designing an arterial CMS installation, the engineer must consider driver information needs and sign placement, message type, environment, size, visibility, and operations. To fulfill an incident management function, information as to the type of incident, the incident location, and suggestions for alternative routes should be provided.

Applications of CMSs to arterial streets can be found in Santa Anna and Anaheim, California and in Minneapolis, Minnesota. Irvine, California is planning a small CMS installation for congestion management and Dallas, Texas used CMSs on Skillman Avenue as early as 1973 to display information about the nearby North Central Expressway.

The further use of CMSs on arterials is anticipated as a "second phase" of real time displays to augment freeway CMS installations or, in the absence of freeway CMSs, as a means of addressing a specific incident management problem that can be solved, at least in part, by providing real time information prior to freeway access. Increasing realization by cities that traffic must now be managed, rather than constructed for, will also lead to more frequent applications of real time traffic control and information systems. With the commitment of the operating agency and conscientious design, selection, maintenance, and operation of an arterial CMS system, motorists will benefit from more efficient and safer street networks.

SUMMARY

With ever increasing demand on transportation facilities during a time of limited enhancement and reduced new construction, the proper and thorough management of existing roadways is becoming essential. Programs for congestion management and incident management are being developed to meet this need. New technology is also continually being developed that will enable road users to realize the full utility of urban infrastructure.

Any device or procedure that lessens or simplifies driver information gathering and processing would certainly decrease driver work load and may have ancillary benefits of increased safety and improved driver response to the driving environment. CMSs are one such proven device. The signs are used to provide motorists with real-time information about the condition of the downstream primary freeway or the surrounding arterial street network. The flexibility of the CMSs allows the display of a variety information about the nature of the downstream incident and possible diversion routes that can be taken to avoid the problems associated with the incident. Arterial CMSs can be used not only to provide information about freeway incidents and impacts, but also to indicate any problems detected on the arterial street system. With background knowledge of the street-freeway network or information provided on the CMS, the informed driver can make alternative route choices and avoid the hazard and congestion caused by the incident.

When designing an arterial CMS installation, the engineer must consider driver information needs and sign placement, message type, environment, size, visibility, and operations. To fulfill an incident management function, information as to the type of incident, the incident location, and suggestions for alternative routes should be provided. The CMS should be located upstream of alternative route decision points so that the message is effective. The letters used in the CMS message must be sufficiently visible so that time is available for the sign to be read at arterial speeds and in complex arterial environments. Average legibilities for light reflecting and light-emitting CMSs are 28 to 30 feet and 36 to 40 feet per inch of letter height, respectively.

Applications of CMSs to arterial streets can be found in Santa Anna and Anaheim, California and in Minneapolis, Minnesota. The Santa Anna system is flexible and will be used for incident management, congestion management, or motorist information, depending on the status of the roadway network. The Anaheim and Minneapolis CMS systems were developed for traffic and congestion management around special events centers. Irvine, California is planning a small CMS installation for congestion management and Dallas, Texas used CMSs on Skillman Avenue as early as 1973 to display information about the nearby North Central Expressway.

The first steps in developing an incident management arterial CMS system are identification of the objectives of the overall incident management program and the objectives of the CMS role in the system. Analysis must be performed to determine available, least congested alternative routes for use under incident conditions. Messages must be designed for all foreseeable incident types and locations, and the messages must be designed around the incident management objectives and the information needs of drivers.

It is recommended that CMSs be placed a minimum 1000 feet and a maximum 2500 feet upstream of alternative route decision points. The latest technology light-emitting signs are recommended for their high visibility, and the most promising are super bright LED signs. In complex arterial environments, three or four line CMSs are recommended; in less complex environments, a two-line CMS can be used with sequencing message "chunks." Once installed, adequate maintenance must be performed to ensure CMS effectiveness. Motorist feedback should be used as a means of improving the system.

With the commitment of the operating agency and conscientious design, selection, maintenance, and operation of an arterial CMS system, motorists will benefit from more efficient and safer street networks. Increasing realization that traffic must be managed, rather than constructed for, will emphasize real time traffic control and information systems.

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INTRODUCTION

With ever increasing demand on transportation facilities during a time of limited enhancement and reduced new construction, the proper and thorough management of existing roadways is becoming essential. Programs for congestion management and incident management are being developed to meet this need. New technology is also continually being developed that will enable road users to realize the full utility of urban infrastructure. Recent attention to intelligent vehicle highway systems (IVHS) emphasizes this point.

One vital and important aspect of this emerging management approach to handling transportation demand is obtaining information about the system at the time the demand occurs. Such "real time" information can now be reliably collected, communicated, and processed with modern detectors, fiber optic lines, and digital computers. Once assembled, the traffic information is used to make decisions whose focus is the most efficient and expedient use of the urban street network. Unfortunately, this "big picture" of the network is not available to the individual motorists using the system. Drivers must rely on previous knowledge of alternate routes and the street system, traffic information on television before departure, or en route radio broadcasts of traffic conditions to decide on and take the best route to reach their destination.

A driver in a large city is loaded with information concerning regulations on the roadway on which he/she is driving, the route names and numbers of surrounding roadways, traffic control devices, influences of other vehicles, businesses and advertisements, and special information concerning maintenance or special events. This visual information competes for the driver's attention amidst such concerns as vehicle control and navigation, environmental audio noise, and, often, a car radio. Additionally, background information is necessary about alternate routes that can be taken in times of congestion, construction, and incidents. Any device or procedure that lessens or simplifies driver information gathering and processing would certainly decrease driver work load and may have ancillary benefits of increased safety and improved driver response to the driving environment.

One such tool that is finding increased use in the United States is changeable message signs (CMSs). CMSs are roadway signs that can display different messages. CMSs furnish drivers with real time information that advises them of a problem and the best course of action. To be effective, the CMS must provide timely, accurate, and reliable information (1). Potential applications of CMSs and other real time displays can be found in Table 1. These devices provide the motorist with a vast variety of real time information about traffic conditions, downstream congestion, incidents, construction, lane closures and alternate routing. Perhaps more importantly, the information is displayed only when necessary and the messages displayed can be changed as the conditions change. With this flexibility, these signs can be integral parts of municipal incident management programs. When combined with detection, validation and incident confirmation through surveillance, and an active control system, the role of CMSs can contribute to the efficient operation and safety of the roadway network, especially during incident conditions. They can be combined in operation with other roadway information systems, such as Highway Advisory Radio (HAR). CMSs can also be used for congestion management, but this application may be hampered by the fact that only some drivers are willing to divert (2). To date, CMSs have had a large majority of their applications on freeways. The present study will address the application of CMSs to urban arterial roadways.

Table 1. Applications of Changeable Message Signs and Other Types of Real-Time Displays (1).

Function	Application
Traffic Management and Diversion	• Freeway Traffic Advisory & Incident Management • Freeway-to-Freeway Diversion • Special Events • Adverse Road and Weather Conditions • Speed Control
Warning of Adverse Conditions	• Adverse Weather & Environmental Conditions • Adverse Road Conditions • High Truck Loads
Control at Crossings	• Bridge Control • Tunnel Control • Mountain Pass Control • Weigh Station Control • Toll Station Control
Control During Construction & Maintenance	• Warnings • Speed Control • Path Control
Special-Use Lane and Roadway Control	• Reversible Lanes • Exclusive Lanes • Contraflow Lanes • Restricted Roadways

Objectives

The objectives of this study are to:

1. Perform a literature review and phone survey to summarize issues surrounding CMS applications, such as: the reason the sign was used, the desired response from motorists, the messages the sign portrayed, the sign and letter sizing, and whether or not the sign fulfilled its intended function.

2. Develop recommendations for the effective use of CMSs on arterial streets for incident management.

Scope

The literature review will be limited to those articles that can be obtained within the limited time available to perform the investigation. Articles that will receive the most attention will be those most current and related to state-of-the-practice. All CMS information and signing standards will be researched from known applications of CMSs to arterial roadways. No effort will be made to produce a universal application guide.

Initial investigation and discussion with the project mentor and coordinator has identified two implementable uses for CMSs in arterial environments: incident management and traffic information/direction near a special events center or large trip generator. In incident management, the sign would be used to identify the presence of incidents and redirect traffic to open routes. At a special events center, the signs would be used to facilitate parking and local circulation. This investigation will focus on the incident management function of arterial street CMSs due to the project time constraints.

Organization

This report will open with a discussion of types of CMSs and an overview of signing effectiveness criteria. From the limited sample of cities that have applied CMS technology to arterials, information will be obtained as to the type of signing, problem/problems addressed by the sign, ability of the sign to perform the desired function, and any problems encountered in the application. The research effort will then summarize this information and set forth recommendations for the use of CMSs on arterial streets.

BACKGROUND

Categories of CMSs

For over 30 years, CMSs have been used as motorist information devices. Early static signs that were posted when needed have evolved into the fiber optic and light-emitting diode (LED) signs of today. Despite the variety of signs that have been developed over the years, CMSs can generally be classified into one of three categories (2):

1. Light-reflecting;
2. Light-emitting; and
3. Hybrid.

By definition, light reflecting signs convey their message by reflecting back light from some external source, such as the sun, headlights, or sign mounted lights specifically designed for this purpose. Light emitting signs use internally generated light from or behind the sign surface. Hybrid signs are some combination of light-reflecting and light-emitting signs that attempt to capture the advantages of both. Displays and related technologies that have been or are being used today (1,3) are shown in Table 2.

In addition to the stationary CMSs that can be found along roadways in the United States, portable CMSs have also found utility for a variety of uses. These signs are most familiar in the form of manual CMSs (i.e. slide-in message panels and cloth signs), signs that are displayed only when needed, bulb-type, and flip disk CMSs (4). The signs can be truck or trailer mounted, "pick-up" signs, or signs with removable panels (1). These signs can be applied for parking and circulation around special events centers, traffic management during major incidents, bridge crossing control, construction and work zones, and any other situations where temporary information must or should be conveyed to the driver.

History of CMS Use in the United States (5)

CMSs have been used to portray real-time motorist information since 1960. The early stages of CMS technology included inserts with desired messages that could be slid into roadside frames. Other displays came about soon after that included fold-out, blank-out, rotating drum, and scroll signs. The need for more flexible signs arose and provided the impetus for the development of vane, flap, bulb and disk matrix signs. The availability of computer equipment for sign control in the early 1970s led to the predominance of bulb-type displays. However, the mid-70s energy crisis heightened concern for "non-essential" consumption, and disk matrix CMSs were preferred for their lower energy needs and lower maintenance requirements.

Table 2. CMS Display Types and Related Technologies (1,3)

Display Types	Technology Used
Static with beacons	• Static sign with flashing beacons
Background light source	• Blank-out
Electromechanical	• Fold-out (type I) • Scroll (belt) • Rotating drum (prism) • Disk matrix • Flap matrix • Rotating cylinder/triangle • Vane matrix
Light source	• Bulb matrix (incandescent) • Fiber optics matrix (fixed grid) • Light-emitting diode (board) • Light-emitting diode (cluster)
Light source/electromechanical	• Fiber optics matrix with shutters • Disk matrix with fiber optics
Manual	• Cloth • Fold-out (type II) • Removable panels

Renewed attention to safety and driver information needs in the 1980s resulted in new technology being applied to CMSs. Fiber optic, light-emitting diode (LED), liquid crystal display (LCD), fiber optic/reflective disk (FO/RD), cathode tube, and laser scan technologies were examined more thoroughly than in the past (5). The light-emitting sign types with the most potential for implementation at present are super bright LEDs, FO/RD, and shuttered fiber optic. The fact that super bright LEDs have a life expectancy of 100,000 hours (12 years) and no mechanical parts (low maintenance) may lead to their future preference.

Selecting the Appropriate CMS

Dudek (6) enumerates a procedure to be followed for selection of the appropriate CMS. Myriad concerns are present including display capability, cost, operating requirements, and maintenance. Experience indicates that trade-offs are always present and that an objective approach to the selection process is essential in determining the CMS that best fulfills an agency's needs. The following is a procedure for CMS selection:

1. Clearly establish the objectives of the CMS. Identify the:
    - Specific problem to be addressed;
    - Audience to be communicated with;
    - Desired response from audience;

- Location where the response is to take place;
- Degree of audience response required; and
- Operations of the system.

2. Prepare the messages necessary to accomplish the objectives;

3. Determine required legibility distance;

4. Determine location of the CMS;

5. Identify type and extent of localized constraints;

6. Identify environmental conditions;

7. Determine target value and legibility of candidate CMSs;

8. Determine costs of candidate CMSs; and

9. Select CMS type based on the above considerations.

Considerations Surrounding CMS Function (2,3)

To fulfill their purpose, CMSs must meet the following functional requirements:

1. Conspicuity;
2. Legibility;
3. Comprehensibility; and
4. Credibility.

Conspicuity in reference to CMSs describes the ability of the sign to appear prominent in the visual environment and capture attention. Legibility defines the ability of the CMS message to be perceived and understood through its words and/or symbols. It is often recorded as a threshold value at which the message becomes "legible" to the motorist. Once read, the message must be processed by the observer. The relative ease with which the message is understood by the driver is the measure of the sign's comprehensibility. Credibility refers to the quality of the message being portrayed on the CMS in terms of the information reliability, accuracy, and currency. Obviously, if the CMS were to lack credibility in the eyes of the motorists, it would not serve its function. A commitment is necessary on the part of the operating agency to display messages only when certain of conditions and when the message display can serve a useful and understandable function.

Messages and Message Elements (2,3)

The message selected for the CMS dictates the function of the sign by falling into one or more of the following categorized sign types: advisory, guide, and advance. Advisory signing serves to display real-time information about the roadway status and advises motorists as to the best course of action. Advisory sign message elements potentially include a problem statement, an effect statement, an attention statement, and an action statement. For effectiveness, these elements are combined to concisely provide the motorist with the necessary information. Guide signs "trailblaze" an indicated alternative route that may be unfamiliar to motorists and assist in maintaining the proper path. Message elements associated with guide signing are destination affirmation and route affirmation with direction. These signs are usually fixed signs that serve in coordination with a CMS system to accomplish the system objective. When information will be provided at a later time and it is necessary to inform drivers to be alert of downstream messages displays, advance signing is used. Advance signing message elements include information alert, nature of information, destination for which information applies, and location of the information (2).

The information displayed to the driver must be clearly and concisely presented in order to be useful. Messages can be displayed simply, automatically sequential for successive lines that do not fit on the sign at one time, or in run-on mode. Experience has empirically determined that compact ("blocked" in the sign) and chunk extended (i.e., just on 2 lines) displays are recommended for simple, static displays and that run-on messages are not desired for incident management or route diversion (2). Reference (7) is a thorough discussion of guidelines on the selection and design of messages for CMSs.

Consideration has been given as to when it is appropriate to display messages on the CMS (5). Options are to display a message only when it is necessary or to display a message at all times, whether or not an incident is present. Most operating agencies now only utilize the CMS display when unusual conditions exist. Human factors principles of avoiding relating information drivers already know (trivial and/or redundant information) and using the displays only when a response is required have proven true in driving environments in which CMSs have been located in the past.

Reliability and Maintenance

When making decisions as to the appropriate CMS for use by an agency, it is essential that maintenance concerns not be underestimated. Communication with the manufacturer is essential about the proper scheduling and type of maintenance. Trained personnel are required to carry out the necessary maintenance and ensure the reliability of the CMS. The most thorough comparison of CMS technologies available to the author at the time of this report was conducted for the Ontario Ministry of Transportation by McCormick Rankin Consulting Engineers and Delcan Corporation (8,9) in 1989 and 1992, respectively. Pertinent to the present investigation are facts such as:

1. Electromechanical, reflective disk, and shuttered signs are adversely affected by ice, salt, and snow that affects the moving parts. Manufacturer's improvements are lessening such problems.

2. Fiber optic and bulb matrix signs are affected by input voltage and maintenance involves bulb replacement.

3. LEDs are affected by input voltage and temperature. Cooling must be provided for reliable operation. Super bright LEDs are rated at 100,000 hours of operation, or about 12 years.

To ensure that the CMS system, once selected and installed, will be maintainable, NCHRP has set forth as number of questions and concerns that should be addressed by an agency interested in installing a real-time information system (10):

1. What do you know about the supplier you are dealing with? Can he help you tomorrow? Ten years from now? How long has he been in the business?

2. Have you considered what would happen if the supplier's business fails?

3. Does he have the resources to help you with a tough problem that requires technological know how?

4. Will you get professional counseling as part of you purchase? If not, how much will it cost?

5. Who will train your people to use the equipment? Will they come back to train new people when needed? Is there a cost for this service?

6. How much space will the system require?

7. How often in the past year have you had to add or change equipment? Will you have this same requirement next year? Will you be able to arrange such changes easily?

8. How much does it cost to add equipment? Disconnect it? Move it?

9. Does the supplier make it a practice to design systems with adequate room for expansion?

10. Will the supplier keep up with rapid changes in technology? Will you be able to add new features or other new service developments? Will the system be obsolete before it is fully depreciated?

11. What does the warranty cover? For how long? What is the cost of parts not covered by the warranty?

12. What happens if your equipment doesn't perform as promised? Has your attorney checked your contract to see if the terms of performance are spelled out?

13. What happens if there is a commercial power failure? Will the program in computer memory be destroyed? What is the cost of temporary standby power?

14. How much will it cost to insure your own equipment? If you buy, is your present insurance contract adequate?

15. Is maintenance included in total purchase or lease/purchase price? If maintenance isn't included, exactly how much will parts and labor cost? What are the costs of maintenance contracts after the first few years?

16. How many maintenance men are employed by the supplier? Where are they located?

17. What are the hours of the maintenance representative? How fast will they respond to your calls for service? Can you get 24-hour emergency trouble service if needed? Can you get weekend service if necessary? Do you pay overtime charges?

18. Are all the parts and supplies you will need readily available? Will spare parts be available in 5 years? 10 years? 15 years?

In studies conducted for the Ontario Ministry of Transportation, current technologies were compared by cost (8). The objective analysis included costs for annual energy consumption, routine maintenance and emergencies. The results of this comparison are presented in Table 3. Another assessment included in the same study involved estimated yearly maintenance calls and costs. This information can be found in Table 4. Observation of the tables raises the question of the low maintenance cost of hybrid FO/RD signs when the maintenance of reflective disk signs, only a light reflective technology, is higher.

Table 3. Changeable Message Sign Cost Summary, 1989 (8)

	Annual Energy Maint.	Annual Routine Maint.	Annual Emergency Total	Total Annual Cost	10 Year Operation
LED Cluster	$ 760	$ 8,620	$ 4,200	$ 13,580	$ 135,800
Fiber Optic/Reflective Disk	$ 280	$ 6,780	$ 4,400	$ 11,260	$ 112,600
Fiber Optic-Shuttered	$ 820	$ 10,450	$ 5,020	$ 15,470	$ 154,700
Reflective Disk	$ 640	$ 12,820	$ 4,200	$ 17,660	$ 176,600
Incandescent Bulb	$ 5,000	$ 19,630	$ 3,000	$ 28,830	$ 288,300
LCD Backlit	$ 3,000	$ 14,340	$ 5,000	$ 22,340	$ 223,400

Table 4. Estimated Yearly Maintenance Calls and Cost, 1989 (8)

	Calls/Year	Labor Costs	Material Cost
LED Cluster	3	$ 3,260	$ 5,360
Fiber Optic/Reflective Disk	5	$ 5,140	$ 1,640
Fiber Optic-Shuttered	5	$ 7,090	$ 3,360
Reflective Disk	5	$ 6,930	$ 5,890
Incandescent Bulb	15	$ 33,400	$ 19,370
LCD Backlit	5	$ 6,940	$ 7,400

ENGINEERING THE ARTERIAL CMS

The identification of a driver information "gap" or shortcoming that a CMS can fill provides the impetus for the development of a CMS system. The information shortcoming addressed by the CMS is often part of a larger problem, and the objectives set forth for CMS implementation can contribute to solving more macroscopic problems as well.

In arterial applications, CMSs can play an active role in congestion management, incident management and special events traffic control. Congestion management CMS functions include identification of the presence of downstream queues and delays on freeways, alternate route information and alerts for downstream information (perhaps through highway advisory radio). CMSs used for incident management can display information about the presence and/or location of the incident, the incident impacts (delays, lane blockages, etc), and alternate routes to avoid those impacts. Occurrences that would fall under incident classification include accidents, hazards created by weather (floods, icy bridge, snow, fog), roadwork, spilled loads, and poor facility conditions (broken pavement). Another CMS function is traffic control around scheduled special events. The CMSs can identify and direct drivers to available parking and direct traffic away from congested routes before events. The signs can direct drivers to least congested routes away from the location after the event has taken place. For all of the above purposes, and any others that CMSs are applied to solve, it is necessary to clearly define the problem being addressed and identify the scope and limitations of the CMS role in the solution.

The present study will address the application of CMSs to arterial streets for incident management. When an incident is detected and confirmed by surveillance, the CMS can be used to describe the incident and/or provide alternate route information. The signs can also be used to assist in managing traffic when incidents occur on the arterial street system.

Driver Information Needs

The information required by the driver is fundamentally related to the purpose designated for the CMS and the nature of the target audience. The primary audience for the current incident management CMS study is the commuting driver, though the message applies to all motorists on the arterial. It is anticipated that the commuter is familiar with the general features of the local road network, including major local streets, and the landmarks, large employers, and commercial centers in the region.

Since the audience for the CMS is the commuter, incident locations, if included in the message, should be referenced to the nearest cross street or major landmark (7). The driver can then use background knowledge of the area to select an alternate route. It is essential that the arterial CMS be located upstream of decision points for alternate routes and sufficiently in advance of these points for drivers to process and respond to the message on the CMS. In other words, drivers need timely, accurate, and reliable information (1). Messages should be clear and unambiguous. For instance, "FREEWAY BLOCKED" would be inappropriate if even just one lane remained open. When the arterial CMS displays incident information about a multilane freeway, the number of closed lanes is useful information (7). When alternate routes are suggested, it is recommended that a trailblazing signing system be in place to reassure drivers that they are on the "correct" path. Finally, drivers do not require obvious information. Telling motorists that the roadway is congested when they have been in traffic for half an hour only lessens the credibility of the CMS (7).

Issues in CMS Use and Operation

Placement

Some recommendations have been made for the placement of CMSs on freeways (11). The first concerns CMS placement relative to guide signing. Such spacing should be at least 1000 feet when signs are not co-located to give drivers time to read and comprehend the information before being presented with another sign. The second criteria is that the CMS be located no less than 4000 feet from potential diversion exits. This distance should provide the driver with adequate time to respond to the CMS message. The final criteria involves the timely presentation of information and driver work load. It is recommended that a CMS located upstream of an interchange not portray diversion information that applies downstream of the interchange.

Though these freeway specific criteria cannot directly be applied to CMS use on arterials, the concerns and issues raised apply to arterials and signing in any environment. All static sign and CMS spacing on arterials should be such that drivers have sufficient time to recognize, read, and comprehend one signed message before reaching another. The fact that arterial environments are complicated by numerous traffic signals and roadway and commercial signs is somewhat offset by the lower arterial speeds and high driver attention level. At an assumed speed of 30 miles per hour on an arterial, sign spacings of 500, 750, and 1000 feet give drivers 11, 17, and 23 seconds between information elements presented on successive signs. Developing an equation or standard to locate CMSs for driver information needs would be an extremely arduous task given the myriad variables involved, including sign size, letter heights, visibility, conspicuity, arterial speed, driver vigilance, and the complexity of the driving environment. As an absolute minimum, the assumed arterial speed of 30 mph and an eight word message (8) indicate that a nominal four seconds should be allowed for CMS perception and reaction. CMSs should be located upstream of potential decision points to give drivers time to read and comprehend the message, decide on an alternative route (if called for), and execute the maneuvers necessary to make the diversion. Again, the arterial environment is different from the freeway environment in that traffic signals affect vehicle spacings and flows and lane changing opportunities are limited during heavy traffic. However, the lower speeds compensate for some other environmental factors. At 30 mph, distances between CMSs and decision points of 1000, 2000, 3000, and 4000 feet give motorists 23, 45, 70, and 90 seconds to decide on the desired alternate path, if one is chosen, and make the necessary lane changing maneuvers to take the diversion. To avoid driver confusion, the CMS should be clearly linked with and present information about the freeway interchanged with immediately downstream of the CMS along the arterial.

The Manual on Uniform Traffic Control Devices (MUTCD) (12) recommends sign heights and lateral placements for signs. In business and residential districts, the left edge of the sign should be two feet removed from the inside of curb. For roadside signs, a seven foot minimum height is recommended; for overhead signs, a 17' minimum height is recommended. The MUTCD gives minimums for sign placement; these minimums can and should be exceeded for CMSs when safety concerns are present (for instance, a higher sign height in pedestrian environments). Because of the size, weight, and necessary support structure for CMSs, safety considerations may indicate that the "best" placement is as far from the traveled lanes as possible without impairing the function of the sign to any degree and remaining within the roadway right-of-way. Other potential concerns in CMS placement are limited right of way, height restrictions, and arterial environments with visual clutter. Municipal signing standards and height restrictions are developed for specific reasons and address specific concerns. Exceptions based on the unique qualities of the CMS may be called for only when existing limitations impair the function of the CMS.

Message Type

The arterial street CMS used for incident management should employ an attention statement and an action statement. The attention statement will serve as an incident descriptor and identify the portion of the arterial driving audience being addressed. Other attention information, if it can be fit on the CMS, could include the incident location or identification of the trip destination most impacted by the incident. The action statement is a call for drivers to execute an action in avoidance of the identified incident. Dudek has developed guidelines for CMS message statement design and messages intended for incident management (7); those applying to arterial CMSs are:

1. An attention statement must always be accompanied by an action statement;
2. Generally the word "traffic" after a destination name is not necessary;
3. Names used for cities should be identical to those on existing static signing;
4. Names used for major generators must be specific and address the exact place where an activity takes place;
5. Names describing certain special activities should be displayed rather than the location where the activity is being held;
6. Use of a highway marker is preferred to a written highway number;
7. Highway route numbers should be displayed when referring to highways used for intercity trips;
8. Local highway names can be used for intracity trips if the intent is to communicate with local commuters prior to their entering the freeway;
9. There are local word descriptor preferences drivers ascribe to the frontage road;

10. Giving a diversion route a name which implies characteristics which the facility or route does not possess may weaken confidence in the signing. It is better to use either an appropriate name or one which carries no particular connotations;

11. Before diverting, drivers desire to know that the incident bypass route will eventually return to the primary route and the point at which they will be returned;

12. Drivers being diverted from a freeway will expect the bypass route to be a logical "]" or "[" pattern. That is, a turn right or left, travel parallel to the freeway, and then a return left or right to the freeway;

13. Drivers need to know as a minimum what they should do and one good reason for doing it; and

14. Because of the limitations on the amount of visual information drivers can read and recall, it is preferred to exclude lane blockage information and include diversion information when combination messages are displayed.

Trailblazing, or route guidance, signs for arterial alternate routes apply to three incident management/route diversion cases: diversion to major generators, diversion to a specific highway, and diversion around incidents. Generally, trailblazing signs should be clearly identified with their alternate route and should be located at every point where drivers may become confused. The importance of these signs should not be overlooked.

Environment

Environmental issues in CMS placement and operation refer to the driving environment and local land use. If the arterial is already cluttered with road signs and advertisements, the location may not be appropriate for an effective CMS. In a related concern, if the driving environment is such that the driver work load is high, the CMS may simply be ignored in favor of information of higher priority. It is essential that the CMS provide useful information in a timely fashion and that it not distract driver attention from the driving task. If this condition is not present and cannot be created, or if the arterial is visually cluttered, alternative locations should be found for the CMS.

Sensitivity to local land use and users is essential for the CMS to be accepted and used. Residential areas may not be appropriate locations for CMSs because of the physical bulk of the sign - its potential for being an "eyesore" - and the fact that the signs either emit or reflect light at night - a potential annoyance to local residents. In commercial areas, businessmen may be concerned that the CMS will distract attention from or block their advertising signs. It is the responsibility of the agency planning to install CMSs to keep the public, businesses and local politicians informed as to the impacts and benefits of signs.

Size

A broad guideline for arterial CMSs is that the sign be large enough to convey the desired messages clearly, but not so large as to block other signs, promote visual clutter, or distract driver attention. Important factors in determining the size of the CMS and the letters used to make up the message are the speed on the arterial and the size of the message to be presented on the CMS. Higher speeds indicate a need for larger letter and sign sizes since the sign must be perceived and be readable from a farther distance away. Also, it is preferable to provide a border the around the CMS message.

Reading time and exposure time define the time it takes a driver to read a message and the time available to read the sign once it is legible to the driver, respectively. For the CMS message to be received, the exposure time must be greater than the reading time. Exposure time increases with increasing legibility distance at a given speed. At 30 mph, a sign with a legibility distance of 500 feet will be exposed for 11 seconds. At the same speed, a sign with a legibility distance of 750 feet will be exposed for 17 seconds. Once exposure time requirements have been determined based on the operating speed and the longest message, sign design and placement criteria can be established to fulfill message legibility requirements (2). For a given legibility distance, exposure time will decrease with increasing speed. A CMS legible from 750 feet will be exposed for 17 seconds at 30 mph and 13 seconds at 40 mph. Once the sign is installed, the maximum exposure time is firmly established and the maximum message length is controlled. When sizing all features of the CMS, the following factors that affect reading time should be considered: driver work load, message load, message length, message familiarity, and display format. These factors are further detailed in the following list, developed by Dudek (2):

1. The message must be legible at a distance that allows sufficient exposure time for drivers to attend to the complex driving situation and glance at the sign a sufficient number of times to read and comprehend the message;

2. There is evidence that no more than three units of information should be displayed on one sequence when all three units must be recalled by drivers. Four units may be displayed when one of the units is minor;

3. A unit of information may be displayed on more than one line on the sign. However, a sign line should not contain more than two units of information;

4. There is evidence that an 8-word message, excluding prepositions, is approaching the processing limits of drivers at high speeds;

5. Research has indicated that a minimum exposure time of one second per short word (four to eight characters) or two seconds per unit of information, whichever is largest, should be used for unfamiliar drivers. On a sign with 12 to 16 characters per line, this min. exposure will be two seconds per line; and

6. When a message is chunked into three or more phrases or elements that are sequenced or cycle on a sign, three or more "stars" or asterisks should be displayed on a frame at the end of the cycle to positively separate successive repetitions of the message.

To clarify the relationship between the number of words displayed on the sign and the minimum suggested exposure time, Figure 1 is shown on the next page. Included on the figure are the message length and exposure time relationships from two different studies of static signs for comparison to the minimums for CMSs.

Visibility

The visibility of signs and other traffic control devices depends on the visual capabilities of motorists and the photometric qualities of the devices. As discussed earlier [Considerations Surrounding CMS Function], the two aspects of sign visibility are conspicuity and legibility. Generally, the characteristics that make a sign easier to detect also make it easier to read. However, this is not true if a sign is too luminous, making it easy to detect but hard to read because of glare (5). Visibility concerns differ for light-emitting and light reflecting signs.

Factors affecting the legibility of light-emitting CMSs include character height; font style; pixel size and spacing; spacing of characters, lines and words; sign border size; and contrast ratio (3). Though freeway experience with CMSs has indicated that at least an 18 inch letter height is necessary, no such standard exists for arterial applications. Legibility information is available for various technologies, and it is presented in Table 5. Table values indicate sign legibility under several conditions, including daylight, night, washout (full frontal sunlight), and backlight (sunlight behind the sign). The table distances produce a nominal legibility for light-emitting CMSs of 36 to 40 feet per inch of letter height.

Light reflecting CMSs generally have shorter legibility distances than light-emitting CMSs. Disk matrix signs were found to have daylight, night, washout, and backlight legibility distances of 698, 355, 420, and 219 feet, respectively. Eighteen inch letter height reflective disk signs were found to exhibit daylight legibility of 725 feet for the 50th percentile driver and 500 feet for the 85th percentile driver (2). Optimum performance of reflective signs is reported when the reflective surface returns saturn yellow light (5). A general legibility for reflective CMSs is 28 to 30 feet of legibility distance per inch of letter height.

Contrast ratio refers to the luminance of an object compared to the luminance of its background (3). It has been empirically determined that luminance ratios between 3 and 25 are acceptable, and that optimum performance is obtained with ratios between 8 and 12.

The CMS should have a border around the letters to serve as a buffer and increase message contrast. The recommended border size is one letter/line height.

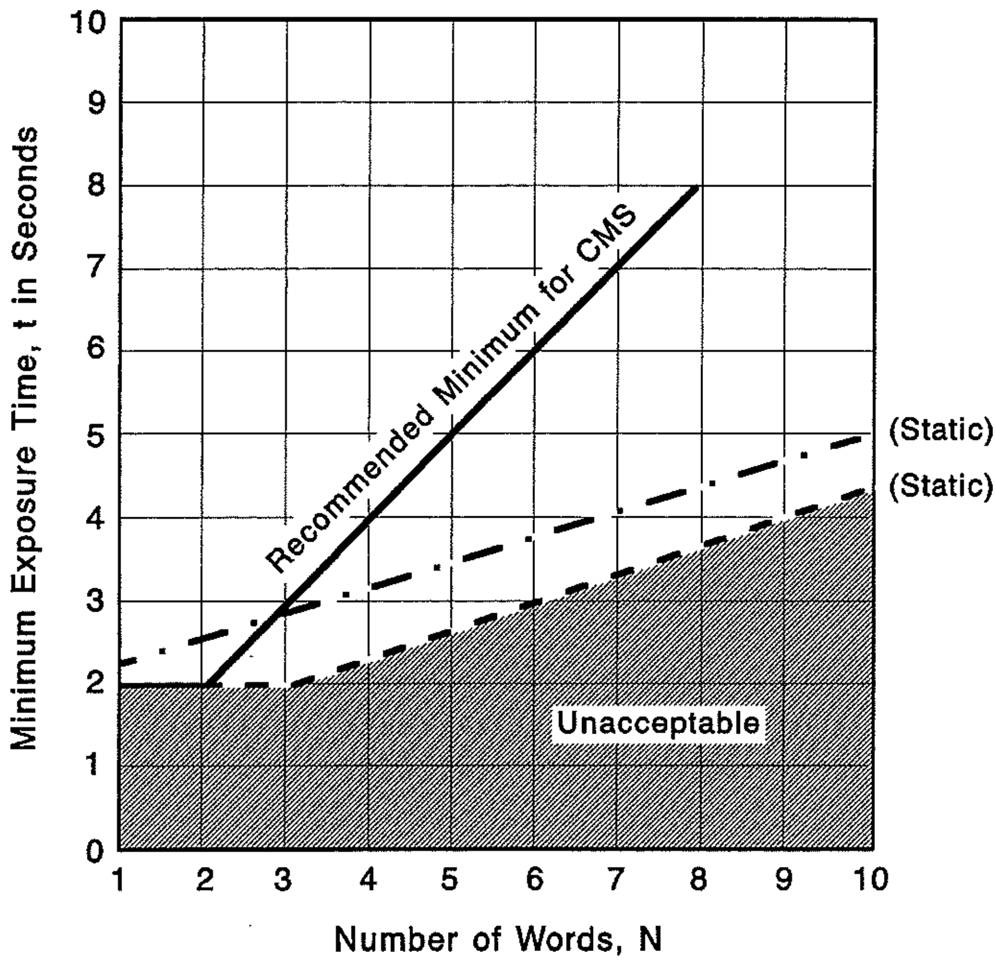

Figure 1. Minimum Reading and Message Exposure Times for Short Word Messages (Adapted from 2)

Table 5. Legibility Distances for Light-Emitting CMSs (2)

Condition	Bulb	Matrix	LED	Fiber Optic
	50th %ile	85th %ile		
Daylight	850	700	743	983
Night			694	678
Washout			487	853
Backlight			502	659

Operation

The CMSs should be an integral part of a system whose function is incident management. Once the system structure is in place and operational, all components of the system must reliably fulfill their function for system effectiveness. If problems are encountered anywhere in the process, the problems must quickly be identified and resolved. Following the philosophy that the CMS should display a message only when a known problem exists, any problems in the process lead to no display, or no function, for the CMS. The flowchart in Figure 2 presents a general system operations outline for an arterial CMS.

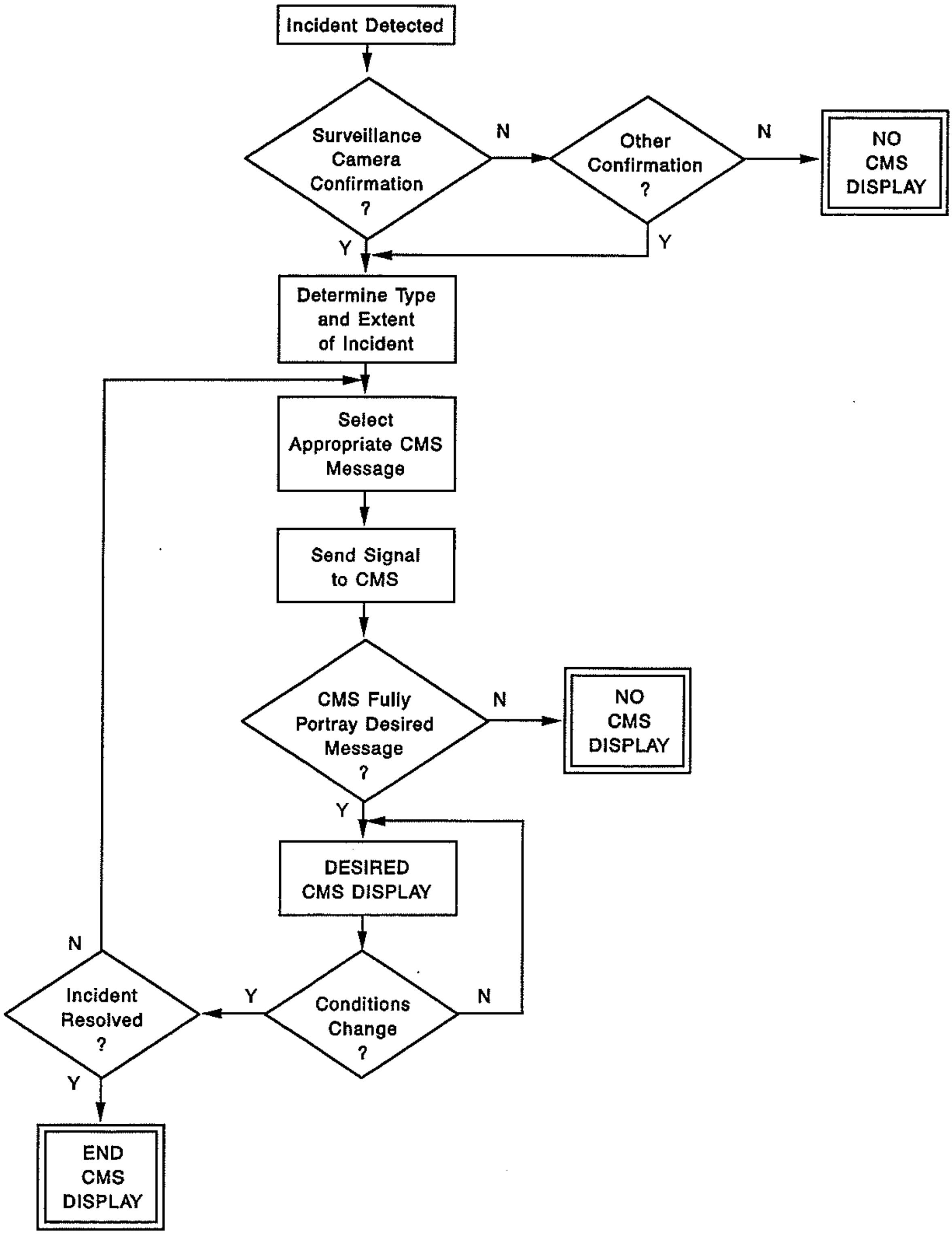

Figure 2. Flowchart for Generalized CMS Incident Management Operations.

ARTERIAL APPLICATIONS OF CMSs

Santa Anna, California (13,14)

The City of Santa Anna is in the process of acquiring and installing the necessary equipment for its CMS system. Sixteen CMSs comprise the sign system and the CMSs are located at strategic points along the arterial street system. The signs will portray messages that relate to the traffic conditions on the freeways served by the arterials. It is intended that the CMSs will serve an incident management function when incidents occur on the freeways, a congestion management function when unusually high congestion burdens the freeways or arterial street network (perhaps during construction or maintenance), and an information transference function when the use of the sign is coupled with information given through Highway Advisory Radio (HAR). The signs are placed 600 to 800 feet in advance of decision points at which drivers who respond to the sign will make alternate route or travel choices.

The messages portrayed on these CMSs will be preset, computer-stored messages that will be used for each foreseeable, unusual traffic condition. Selection of the appropriate messages will be based on loop detector data collected on the freeway main lanes and confirmed by surveillance. The messages on the CMSs serve an informative function and the decision whether or not to take the suggested action is left up to the motorist. For aesthetic reasons, the city desired signs that were as small as possible. The selected signs are two line, 15 character per line signs. A seven and one half inch letter height was selected, but some engineering concern was expressed as to the adequacy of this height - the California Department of Transportation (CALTRANS) uses a twelve inch minimum letter height. The roadside signs are mounted between eight and ten feet high. Physical dimensions of the CMSs are six by thirteen feet. An overriding concern of the city was that the signs not be large and that they not contribute to visual clutter of the city's arterials in the vicinity of the freeways. Special concerns surrounding the CMS use in Santa Anna were:

1. Will local residents and business people accept the signs?

2. Will the motorists accept the signs?

3. Will motorists use the information?

4. Turn signs on only when needed?

The effectiveness of the signs will be assessed and the experience needed to answer the above questions will be obtained in the coming years.

Anaheim, California (15)

Anaheim, California has installed a CMS system to guide motorists to and around the Disneyland amusement park. The intended function of the signs is to guide unfamiliar motorists through the arterial and collector street system to Disneyland. The CMSs primarily provide information about the status of the local road network and parking facilities in the vicinity of the park.

The CMS messages are computer-stored and selected in real time based on the condition of the transportation network. The system was planned before implementation and available technologies were reviewed extensively before LED CMSs were selected. Anaheim's arterial CMSs are full matrix LEDs whose physical dimensions are 20' wide by 5' high. This size on arterials compares favorably with the 25' wide by 6.5' high signs used on freeways in the region. The full matrix LED allows some variability in letter height and style for gaining the attention of drivers and emphasizing important information.

A public review period followed CMS installation, and these concerns were noted:

1. Local merchants complained that the CMSs blocked their signs.

2. Citizens complained that the CMSs added to visual clutter along the city streets.

Active efforts have been made by the city to address and correct these problems, including a new project to improve the appearance and effectiveness of the signs. Overall, the city is pleased with the usefulness and success of the CMS system.

Minneapolis, Minnesota (16)

The CMS system in Minneapolis was developed for congestion mitigation in the vicinity of a recently constructed convention center. One of the conditions for the development of this special events center was that efforts be made to control congestion brought about by its use. The CMS system was proposed to fulfill this function, and the city approved. The signs are located upstream of the convention center and associated parking facilities on the major arterials leading to the complex. The CMSs were erected to direct traffic to streets on which parking is available. Messages are changed throughout the system to account for successive filling of lots near the center. In addition to this pre-event purpose, the signs are also used to direct traffic away from the center after events have taken place.

Messages are stored in pre-established sequences, with each sequence containing a message for each of the four signs in the system. As conditions change, a city employee at the base station selects the appropriate sequence for the given traffic and parking situation. Sign dimensions are five feet high by eight feet wide and two or three lines of text are available. Eight characters per line are possible using a pre-determined 14" minimum letter height. However, character selection is flexible and fewer characters per line can be used with an 22" maximum letter height possible. Electromagnetic reverse polarization flip disk signs were selected for this application. The signs reflect light during the day and are backlit at night.

The four stationary CMSs are used in conjunction with portable CMSs that are strategically placed within the street network. To enhance this coordinated effort, the city is hoping to acquire more CMSs when the budget is available. When the CMS system was initially purchased, the control technology was simple. In an effort to upgrade the system, new controllers and software were purchased. Problems encountered with "bugs" in the software have led the city to explicitly describe its system requirements and need for continued software support in similar future purchases. City engineers researched maintenance concerns before acquiring the CMSs and were aware of the required system support and upkeep. It is recommended that cities considering installing CMSs perform similar analyses and feasibility studies. Future expansion of the Minneapolis system may include automation of the message selection process.

Irvine, California (17)

Congestion relief through en route diversion is the objective of CMS sign possibilities being examined by the city of Irvine in a joint project with CALTRANS. It is intended that motorists will change course given the alternate route information presented on the CMS. A small arterial CMS is being considered along with a second fixed trailblazing sign.

Sign dimensions and features have not yet been established. Special issues surrounding the feasibility of the project are the political and environmental acceptance of the CMS, sign location in a semi-industrial area to avoid residential complaints, and the high cost of the CMS system.

Other Applications

The City of Dallas, Texas used three CMSs on Skillman Avenue for information about the nearby North Central Expressway as early as 1973. The rotating drum signs had 13 possible message displays with four drums. The twelve inch character drums were remotely controlled via phone lines and the system included detection and closed circuit TV.

RECOMMENDATIONS FOR FUTURE ARTERIAL CMS APPLICATIONS

Perhaps the clearest method of presenting specific recommendations for CMS implementation for arterial streets is through a hypothetical case study. Where appropriate, options will be presented and justification will be provided for the decisions made. The following is a recommended procedure for the planning and installation of an arterial street CMS system for incident management:

1. Identify the problem to be solved and the overall objectives of the system. The problem encountered in the hypothetical urban roadway shown in Figure 3 is heavy congestion and delay under incident conditions on the Saints Freeway. The objectives of the incident management program being developed to address this problem are quick detection and confirmation of incidents, development of alternate routes for traffic diversion, and development of a real time motorist information system to warn freeway motorists and arterial street motorists bound for the freeway that an incident condition exists on the freeway downstream of their location;

2. Identify the role of the CMSs within each system and identify the specific objectives of the CMS in the system. The role of the arterial street CMSs in this system is to serve as a real time information display that informs commuting drivers of the presence of freeway and/or downstream arterial incidents and provides alternate route information. The arterial street CMS objectives are provision of incident warnings, incident location information and alternate route information to motorists in a clear and timely fashion;

3. Consider the street network environment in terms of alternate routing potential and the congestion and regular use of the identified routes. An analysis of the available capacity and present traffic volumes should be made of all potential routes suggested as alternates to the freeway or other arterials. Those routes with the most available capacity should be prioritized when alternate route information is displayed on the CMS. Figure 4 shows the hypothetical network under accident conditions. The parallel routes available for freeway alternates and diversion are Pearson and Waylan. With incident congestion on Main in the vicinity of the freeway ramps, the best alternate routes for drivers on Main approaching the freeway from the east and west are Waylan and Pearson, respectively;

4. Identify the driver information requirements for the specific objectives outlined for the arterial CMS. Driver information requirements to be filled by the arterial CMS include the general nature of the incident (accident, weather problem, construction, lane blockage, etc.), the location of the incident (on the freeway or downstream on the arterial, referenced to nearest cross street or landmark), and the suggested alternate route to avoid the problems created by the incident. Confusion can be created using arterial CMSs since, unless informed, the driver does not know whether the incident warning applies to the arterial or the freeway. Since alternate route information can be displayed on CMSs, it is important that signs be located ahead of decision points in time for drivers to decide on and position themselves to take alternate routes;

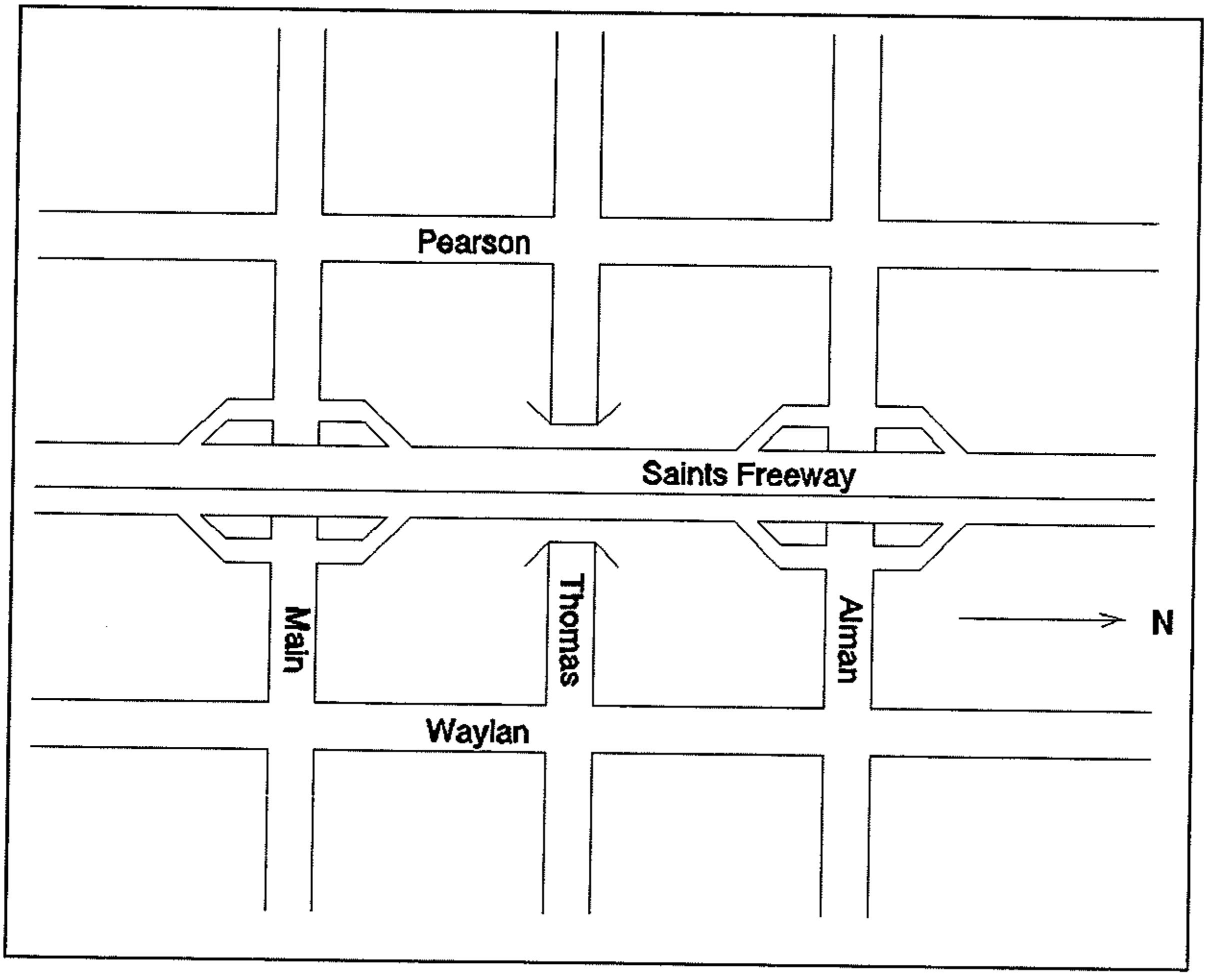

Figure 3. Hypothetical Arterial Network for CMS Implementation.

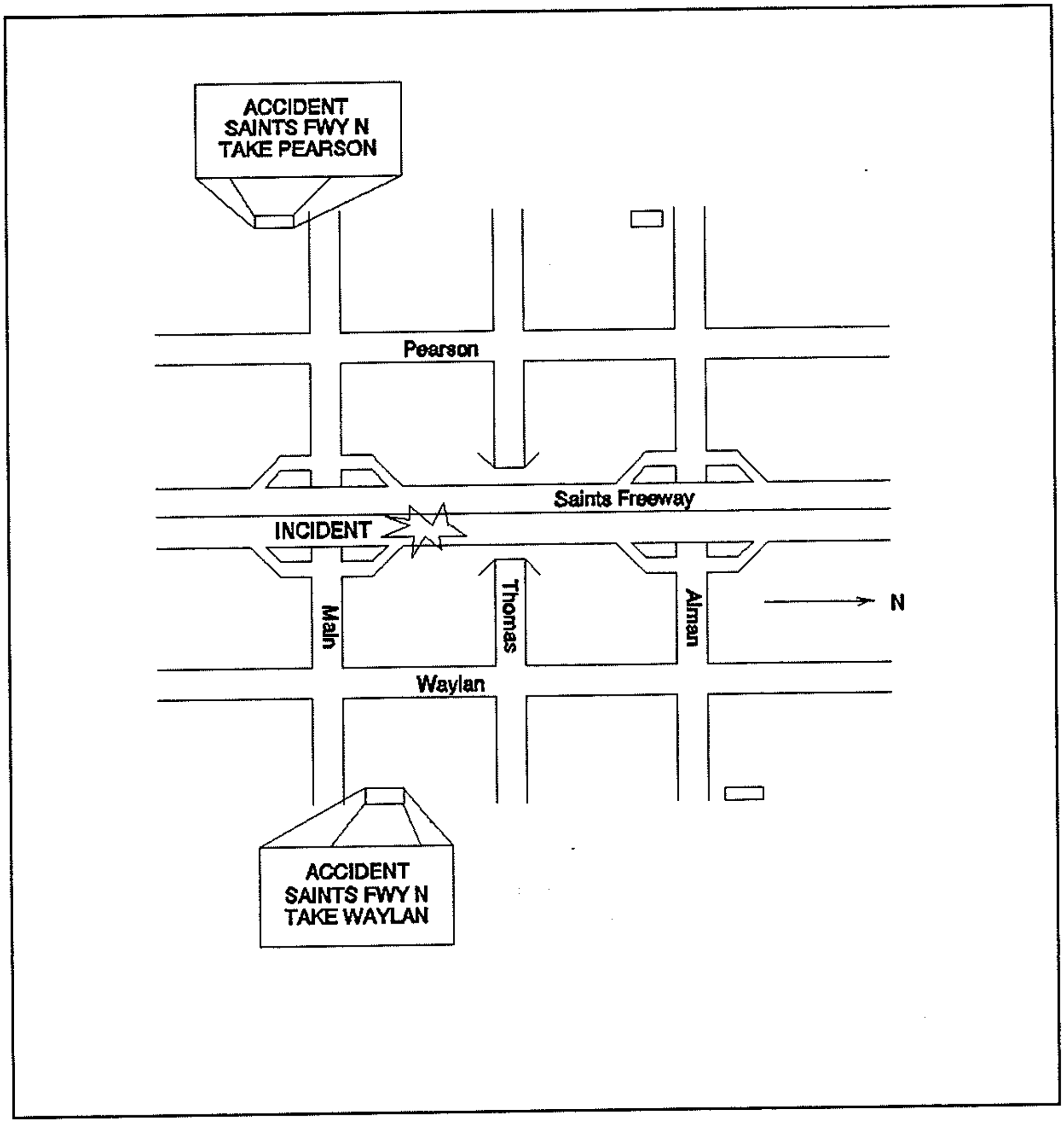

Figure 4. Hypothetical Arterial Network CMS Display for Incident Condition.

5. Develop operations plan for incident scenarios and develop messages for all foreseeable situations. The operations plan developed for the CMS system will be an extended version of the flowchart presented in Figure 2. All eventualities will be accounted for and if any difficulties are encountered, the CMS will not display a message. Message sets for all CMSs will be developed for all types and locations of incidents. The operations plan will indicate the circumstances under which CMSs will display messages and which CMSs will be used. Since inaccurate or untimely displayed information will lessen the credibility of the system, it is essential that CMSs display messages only when there is a confirmed incident.

6. Design the appropriate message/messages to fill the driver's needs. The first element of the arterial CMS message describes the nature of the incident. A vague term such as "INCIDENT" may not connote a serious condition to the driver. A general description, such as "ACCIDENT, ICY OVRPASS, MAINT, or 2 LNS CLSD" identifies a potentially hazardous or traffic-impacting condition to which the driver will respond. The second message element portrays incident location information. Since the CMS can provide information about freeway and arterial incidents, it is necessary to refer by name to the impacted facility. When incidents occur on the freeway, it is also necessary to indicate the direction of travel affected by the incident and the incident location, referenced to a crossing roadway or given as a specified distance downstream of the CMS. When the incident is located on the arterial street system, the incident should be identified and, if possible, referenced by location to the nearest cross street. The final message element indicates suggested alternate routes for the driver. This information has lesser priority than the identification of the incident and its location. The driver has the option of whether to follow the alternate route or not divert. A simple guidance message, such as "TAKE WAYLAN" suffices since the commuter has at least cursory exposure to the street network and is informed of the incident type, location, and impacted travel direction. Trailblazing signs or detour signs may be erected along diverted routes to indicate the freeway re-entrance point;

7. Identify placement and environment restrictions and assess impacts on sign function; design sign placement around intended function. Myriad considerations affect CMS placement. The most general issues are the number of signs to be used in the CMS system and their frequency on the arterials. Ideally, a CMS could be located on every arterial approach to a freeway whose operations are severely impacted under incident conditions (one that is already near capacity). In this fashion, real time information about freeway incidents is available to every motorist accessing the freeway. Such an intricate CMS system would indirectly meter flow onto the freeway, with percentages of drivers diverting to alternate routes as directed by the signs on each arterial. However, the capital expense of developing the CMS system and erecting the signs precludes all but the most necessary installations. It is recommended that the CMSs be installed in a demonstration program by a committed and responsible agency. Four to six CMSs could be installed on successive major arterials that interchange with the same freeway, two per arterial, one for each direction of approach. Complete installation of the CMS system includes trailblazing, or route guidance signs, on diverted arterial routes. The effectiveness of the signs in alleviating some queuing and delay due to incidents and in diverting motorists from incident impacts can be assessed during the demonstration program. If effective (judged based on a benefit/cost ratio applied to the CMS system), CMSs can be installed on other major arterials according to the availability of funds.

Other sign placement considerations include the location of signs relative to the freeway and alternate routes, limits of right of way, lateral clearance standards, and sign height standards. A minimum distance of 1000 (about 25 seconds for a driver to process CMS information and make required lane adjustments, if necessary) feet is recommended for CMS placement upstream of decision points. Thus, the CMS is located a minimum of 1000 feet upstream of an arterial diversion point or, in the absence of an alternate route, the freeway itself. The maximum separation between the CMS and the diversion point or freeway should be 2500 feet (about 55 seconds of driver response time). The maximum is recommended so that the driver clearly identifies the CMS and its message with the upstream freeway and retains the primacy of the CMS information. All sign placement standards should be followed, and special consideration for the CMS should not be sought unless the sign function is impaired by strict adherence to standards. Sensitivity to visual clutter and the signs of local business owners is essential to CMS acceptance and effectiveness;

8. **Balance restrictions with needs (compromise) and design sign and letter height accordingly. Two, three or four lines are recommended for the CMS. Eight inch letters are an experiential minimum and fourteen inches is a reasonable, though exceedable, maximum.** CMS sign design includes technology choice, determination of sign size, and choice of letter height. Making the most of new technology and for their greater average legibility, light emitting signs are recommended over light reflecting signs. Super bright LEDs offer the latest innovations in light-emitting technology and have a projected life of 100,000 hours (12 years). However, this cutting-edge technology comes at a price, and less initial cost can acquire a reliable FO/RD or shuttered fiber optic system. For the incident type, location, and alternate route information displayed on the CMS, a two line sign would probably have to operate in "chunk" mode, with two messages in successive display. More expensive three line and four line signs have the potential to display the entire message at once. Thus, in more complex and cluttered driving environments, the simple display of three or four line signs is recommended. Letter heights of eight to ten inches are acceptable in low speed (less than 30 mph) arterial environments. It is suggested for all installations, and recommended for higher speed arterials, that twelve inch characters be used as a minimum. Where unusual visibility problems exist (for instance, fog), fourteen inch characters are recommended. The twelve inch letter height recommendation produces a sign height, with borders, of four, five, and six feet for two, three, and four line displays, respectively. A nominal 3:4 ratio of character width to height relates to sign widths of nine and 13 feet for 10 and 15 character per line signs, respectively. Signs having less than 10 characters may not be able to display enough information clearly; and, signs exceeding 15 characters per line may be an extraneous expense. The Compromise is essential in obtaining an effective, yet affordable, CMS system;

9. **Design maintenance around CMS manufacturer's recommendations and modify the maintenance schedule as experience is obtained.** Proper maintenance of the CMS system components and the CMSs themselves are essential in ensuring the reliability of the signs. A regular maintenance schedule should be provided by the manufacturer, along with

descriptions of signs of pending problems and solutions to repair any problems encountered. As city maintenance personnel become familiar with the CMS equipment, their input should be obtained in developing maintenance plans and procedures as the system matures.

10. Modify CMS operations with motorist feedback and observation of the sign's effects and ability to fulfill its intended function. Motorist feedback and comments from residents and business owners are important indicators of the strengths and/or weaknesses of the system. And, in addressing the suggestions of the commuting public and local businessmen, headway is made in the public acceptance of the CMS system. Before and after studies of sign implementation will gauge the effectiveness of the CMS system. This information is invaluable in judging the "success" of the system and in deciding whether or not to develop the CMS system further. If the studies determine that the signs are ineffective, public education programs about the signs and their function may be necessary. If such efforts are ineffective in increasing sign utility, or if the agency is no longer convinced of the system effectiveness, the CMSs should be removed.

CONCLUSIONS

For over 30 years, CMSs have been used in urban environments as a means of relating real time information about the driving environment to individual motorists. With CMS information, the drivers are able to make informed route choice decisions and reach their destination via the least congested or incident-free roadways. Not only do CMSs simplify information gathering and provide warnings of congested or potentially hazardous incident conditions, but the signs also increase the efficiency and safety of the transportation network.

CMS technology is continually evolving, and the recent development of super bright LEDs provides agencies pursuing CMS alternatives with a light emitting, highly visible technology that is rated at 100,000 hours, or twelve years of operation. With such advances and the continued accumulation of experience in effective arterial CMS operations, the future of CMSs in providing timely, accurate, and reliable motorist information is assured.

The further use of CMSs on arterials is anticipated as a "second phase" of real time displays to augment freeway CMS installations or, in the absence of freeway CMSs, as a means of addressing a specific incident management problem that can be solved, at least in part, by providing real time information prior to freeway access. Increasing realization by cities that traffic must now be managed, rather than constructed for, will also lead to more frequent applications of real time traffic control and information systems. With the commitment of the operating agency and conscientious design, selection, maintenance, and operation of an arterial CMS system, motorists will benefit from more efficient and safer street networks.

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14. Telephone interview with Mr. Bernie McNeeley of Edwards & Kelcey, concerning CMS use in Santa Anna, California.

15. Telephone interview with Mr. Steve Cyra of Edwards & Kelcey, concerning CMS use in Anaheim, California.

16. Telephone interview with Mr. Jim Stoutland of the City of Minneapolis, concerning CMS use in Minneapolis, Minnesota.

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