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16. Abstract

This report contains the findings of research on relevant issues for effective design and display of dynamic message sign (DMS) messages. Findings resulting from visits and interviews with staff at five Texas Department of Transportation (TxDOT) traffic management centers relative to display of DMS messages are presented. The development and documentation of message design decision logic flow charts are also presented. Details of the experimental design and findings of focus group and human factors laboratory studies address many DMS message design issues including incidents, roadwork, AMBER alerts, major catastrophes, planned special events, and inclement weather and environmental conditions. Discussion of the issues and the contents of the *Dynamic Message Sign Message Design and Display Manual* that was developed as part of this project are also presented.

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EFFECTIVE MESSAGE DESIGN FOR DYNAMIC MESSAGE SIGNS

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DISCLAIMER

This research was performed in cooperation with the Texas Department of Transportation (TxDOT) and the Federal Highway Administration (FHWA). The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official view or policies of the FHWA or TxDOT. This report does not constitute a standard, specification, or regulation. The engineer in charge of the study was Dr. Conrad L. Dudek, P.E. #24320.

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TABLE OF CONTENTS

Page

LIST OF FIGURES

Page

LIST OF TABLES

Page

1. INTRODUCTION

PROJECT OBJECTIVES

Dynamic message signs (DMSs) are being deployed extensively in major metropolitan areas in Texas. It is important that messages being displayed on these signs across the state are formatted consistently from district to district so that the formats are transparent to motorists traveling in different parts of the state. At the same time, there are local issues and situations that arise which require distinct messages. Proper DMS message design is a complex process. Although many messages can be pre-designed and called up from a message library when needed, transportation management center (TMC) operators must often modify existing messages or develop new messages to deal with the unique aspects of an incident or other special situation. The purpose of this project is to develop the logic and prototype of an automated message design system. The primary objectives of this project were to:

1. develop the logic (flow charts, conditional rules, etc.) needed to automate or provide decision support to the various parts of the DMS message design process and
2. develop a proof-of-concept prototype of an automated DMS message design and display system.

BACKGROUND AND SIGNIFICANCE OF WORK

Dynamic message signs are one of the primary links a transportation agency has to the motoring public it serves. Since DMSs represent many motorists' primary concept of intelligent transportation systems (ITS), improperly designed or operated DMS messages will have a negative impact on the public's perception of ITS in general. The design and display of messages on DMSs introduce many challenges to transportation agencies. The following paragraphs briefly summarize some of the relevant issues involved:

- *DMSs are the direct link with the motoring public.* DMSs can be an effective tool for communicating with motorists. However, displaying messages that are too long for motorists to read at prevailing highway speeds or that are too complex or inappropriately designed, leading to motorist confusion, can adversely affect both traffic flow and the transportation agency's credibility.

- *Existing human factors design guidelines need to be supplemented and packaged to meet the needs of DMS message designers and operators.* Existing guidelines are not always easily understood and used by practicing engineers and DMS operators, and do not cover all possible signing situations.

- *Efforts must be made to ensure that DMS messages are standardized and consistently applied throughout the state or region.* The messages displayed must be "transparent" to travelers in the state or region. Therefore, messages need to be presented in a consistent manner and order based on motorists' expectancies.

- *Only a few seconds are available to communicate a message.* At prevailing highway speeds, the DMS message must be presented to motorists in about eight seconds or less. This translates to a message with a maximum of eight words. Uninformed transportation personnel sometimes display messages that are too long for motorists, particularly slower readers such as the elderly, to read while driving at prevailing speeds.

- *Available exposure time controls the maximum length of message that should be displayed.* Research has indicated that the reading times for DMSs are higher than for static guide signs. The distinguishing factor is that motorists can scan guide signs for relevant information, whereas they must read the entire message displayed on DMSs in order to understand the message. Exposure time is directly related to message legibility distance and driving speed. For a specific type and design of DMS, the available message exposure time dictates the maximum length of message that can be displayed for a given highway operating speed.

- *In many signing situations DMS legibility distance constraints dictate the need to reduce the amount of information that is necessary to fully communicate with motorists.* Key DMS objectives include maximizing information transfer to motorists, providing explicit advice, eliciting specific motorist response, and inducing motorist confidence. One major challenge is that this must be accomplished within a short time frame and on signs that may not contain sufficient line capacity to display the desired messages. Trade-offs must be made as to what elements of the message should be omitted. There are many signing situations requiring message design trade-offs which need to be addressed in advancing the state of the art of message design.

- *Measures must be taken when developing DMS messages to enhance motorist understanding of messages.* Research and experience have allowed TTI to determine which words and word combinations are understood by most motorists. In developing messages, factors that enhance understanding of messages include the following:

    1. simplicity of words,
    2. brevity,
    3. standardized order of words,
    4. standardized order of message lines, and
    5. understood abbreviations when abbreviations are needed.

To be effective, a DMS must communicate a meaningful message that can be read and comprehended by motorists within a very short time period (constrained by the sight distance characteristics of the location and design features of the DMS). Extensive human factors and traffic operations research has been previously conducted, most of it by TTI researcher Conrad Dudek and his colleagues, to develop fundamental principles and guidelines for DMS message design (*1*-*16*). Because they are based on a solid understanding of motorist physical and information-processing capabilities, these principles and guidelines are as valid today as when they were first developed *so long as they are consistently and properly applied*. Some of the more important DMS message principles that have been developed relate to message formatting, abbreviations, and how messages are divided and shown on more than one frame (sometimes referred to as a panel).

WORK PLAN

The research was conducted in two phases. Phase 1 (Tasks 1-9) involved development of a DMS operations manual for DMS operators in Texas for incidents and roadwork and computer proof-of-concept software to aid in the design of associated DMS messages. Near the completion of Phase 1, the Project Advisory Committee recommended that a new phase be added to the project which dealt with other types of DMS messages. Phase 2 (Tasks 10-14) involved the conduct of focus group studies, human factors laboratory studies, an update of the DMS operations manual, and additional computer programming for the proof-of-concept to address other types of DMS messages. The other types of messages included AMBER alerts, major catastrophes, planned special events, and inclement weather and environmental conditions. The work plan contained the following 14 main tasks:

- Task 1. Organize and meet with the TxDOT Project Advisory Committee.
- Task 2. Visit and review DMS operations at traffic management centers.
- Task 3. Develop DMS operations procedures, decision flow charts, and models to assist DMS operators in selecting the "best" messages.
- Task 4. Develop and test a DMS operations manual for use by DMS operators in Texas.
- Task 5. Determine the requirements of a computerized prototype to assist operators in DMS message design.
- Task 6. Develop a computer prototype.
- Task 7. Test the prototype.
- Task 8. Revise the prototype.
- Task 9. Prepare project documentation.
- Task 10. Determine motorist information needs and evaluate candidate message designs for AMBER alerts, major catastrophes, planned special events, and inclement weather and environmental conditions.
- Task 11. Develop guidelines and recommendation for DMS messages for AMBER alerts, major catastrophes, planned special events, and inclement weather and environmental conditions.
- Task 12. Develop additional logic to design DMS messages for AMBER alerts, major catastrophes, planned special events, and inclement weather and environmental conditions.
- Task 13. Incorporate additional logic into the proof-of-concept prototype for DMS message design.
- Task 14. Update the DMS operations manual.

2. REVIEW OF DMS OPERATIONS AT TRAFFIC MANAGEMENT CENTERS

TMC VISITS AND INTERVIEWS

In February 2001 during the initial stages of the project, TTI researchers visited and interviewed TxDOT staff from several district TMCs to develop a better understanding of the TMC operations and, specifically, DMS message design and display procedures within the districts. The TMCs visited were: Austin, Dallas (DalTrans), Fort Worth (TransVision™), Houston (TransStar), and San Antonio (TransGuide®). Email and telephone follow-up interviews were conducted between June and August 2001.

The information obtained from the visits and interviews allowed TTI researchers to understand the similarities and differences among each center's DMS operating procedures and to identify specific needs at each TMC. This information was invaluable input to the subsequent project research tasks because it provided the researchers with knowledge of the current practices and capabilities at each TMC. The information obtained from these visits and/or interviews is summarized in the sections below and is discussed in greater detail in Report 0-4023-1 (*17*).

SUMMARY OF DISTRICT DMS OPERATIONS IN 2001

The major focus of this portion of the district reviews was to determine the operational policies, guidelines, practices, and/or procedures for each TMC concerning the display of DMS messages including:

- incident information,
- non-incident-related congestion information during peak periods,
- planned roadwork,
- planned special events,
- public service announcements,
- blank signs,
- travel time information,
- diversion information,
- regulatory or warning speed information,
- special event information,
- severe weather or hazardous pavement condition information,
- advertisements, and
- intermodal information.

To ensure that DMS messages are uniformly designed and displayed, TMCs should have established policies and guidelines concerning the practices and procedures for designing and displaying messages. At the time of the interviews in 2001, none of the five TMCs surveyed operated DMSs under an established written policy. Four of the five TMCs (Dallas, Fort Worth, Houston, and San Antonio), however, did follow a set of written guidelines for design and display of DMS messages. The guidelines, which varied in detail from a set of memorandums to procedural manuals, were intended to provide the DMS operators with a set of procedures to follow when posting messages. However, the procedures did not provide the level of operational consistency that a DMS message policy or standard would establish. The level of detail of the guidelines appeared to be directly proportional to the size of the TMC and the area under surveillance. The smaller TMCs (Austin and Dallas) had few or no guidelines to follow, while the larger TMCs (Fort Worth, Houston, and San Antonio) used DMS operations manuals that included message design and display procedures. It should be pointed out, however, that very few inter-district or statewide operating guidelines existed within TxDOT. This led each TMC to, in many ways, operate autonomously from the others. As the number of districts with TMCs continues to increase throughout Texas, consistent use of DMSs among districts is increasingly important.

DMS Messages for Incidents

Incident messages are generally regarded by transportation agencies nationwide as the highest priority messages for posting on DMSs. This was certainly the case within TxDOT. Each district surveyed considered incident-related messages to be the highest priority message and post such messages accordingly. The concern is for safety and congestion implications that arise when incidents occur compared to normal or recurring congestion. When competing incidents arise, districts either gave priority to the upstream incident or made decisions based on competing scenarios as they arose.

Although all considered incident-related messages to be the highest priority, there was much variability among the districts in the way that incidents were detected, the way that the incident messages were designed, and the way that the incident messages were posted. The incident messaging practices of each district surveyed in 2001 are presented in Table 1.

DMS Messages for Non-incidents

A comparison of district practices for posting of non-incident-related messages is shown in Table 2. Major discrepancies existed in 2001 among the districts' DMS operating procedures when no incidents occurred during both the peak and off-peak hours. In 1996, the TxDOT Traffic Operations Division developed guidelines for DMS message posting for non-incident-related messages that were distributed to district personnel in each of the TMCs in Texas (*18*). Included in this memorandum was a flow chart, shown in Figure 1, for DMS operations under non-incident management conditions. The TxDOT flow chart was developed prior to two districts (Houston and San Antonio) developing the capability for measuring and displaying travel time information.

Table 1. Comparison of District Practices in 2001 Regarding DMS Messages for Incidents.

		Austin	Dallas	Fort Worth	Houston	San Antonio
Written Policy						
Written Guidelines			X	X	X	X
Incident Detection	Call-Ins	X	X	X	X	X
	Cameras		X	X	X	X
	Sensors					X
Incident Verification	Call-Ins	X				
	Cameras		X	X	X	X
Incident Messages Are Highest Priority		X	X	X	X	X
Highest Priority Message When Competing Messages Arise	Upstream Incident		X	X		
	Scenario Specific	X			X	X
Message Library		X		X	X	X
Option to Modify Message		X		X	X	X
Messages Designed by Operator			X			
Automated Incident Messages						X
Hard Diversion						
Soft Diversion			X	X	X	X

X = Affirmative

Table 2. Comparison of District Practices in 2001 Regarding DMS Messages for Non-incidents.

		Austin	Dallas	Fort Worth	Houston	San Antonio
Written Policy						
Written Guidelines			X	X	X	X
Non-incident-Related Congestion Messages	"Congestion"			X		
	Travel Time				X	X
	Manually Entered				X	
	Automated			X		X
Planned Roadwork		X	X	X	X	X
Planned Special Events			X	X	X	X
Public Service Announcements		X	X	X	X	X
Blank Signs	Avoid Blank Signs				X	X
	Blank Unless Message Warranted	X	X	X		
Speed Messages						
Advertisements						
Intermodal Information					X	
Severe Weather or Hazardous Pavement Conditions			X	X	X	X

X = Affirmative

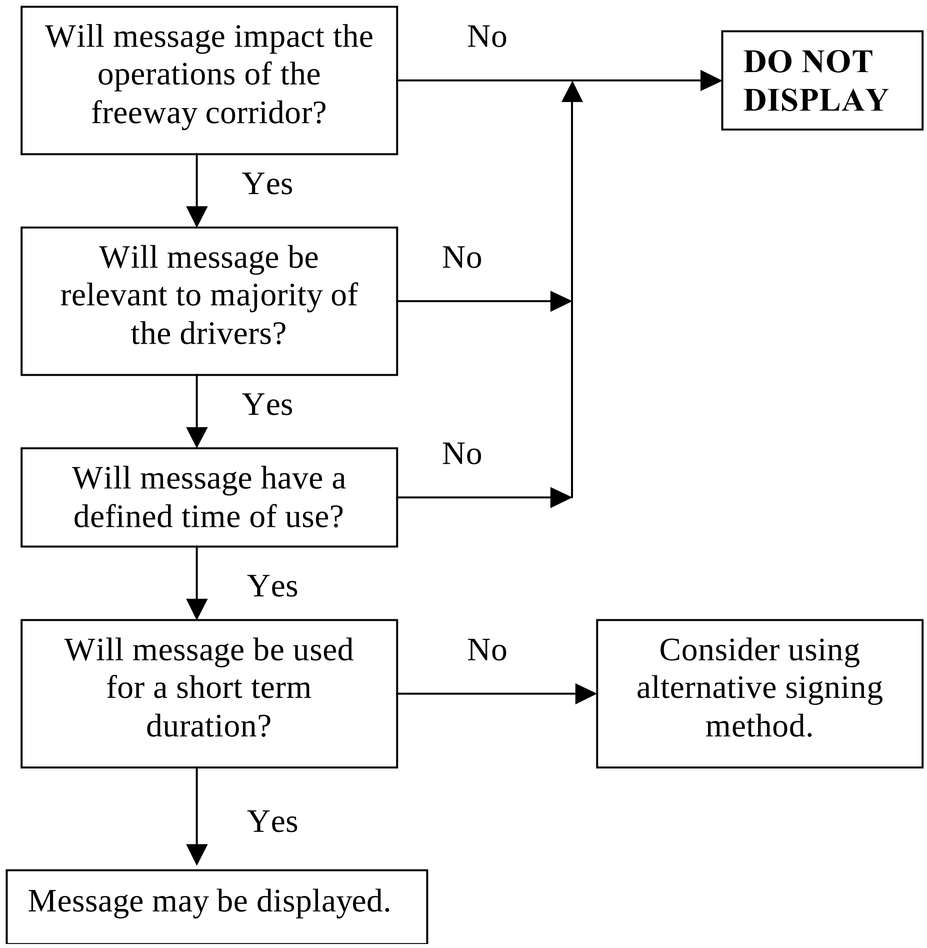

Figure 1. TxDOT 1998 Guidelines for Posting Non-incident DMS Messages (*18*).

All districts interviewed posted messages pertaining to planned roadwork, assuming that sufficient notice is given. The Houston and San Antonio Districts also displayed travel times in the absence of incidents. Four of the five districts (Dallas, Fort Worth, Houston, and San Antonio) also posted messages for large planned special events. Public service announcements were also allowed by each of the districts, provided that the district approved the messages. These messages were usually restricted to those related to traffic safety or air pollution. Regulatory or warning speed messages were not posted on permanent DMSs in any of the TMCs. (Speed-related messages were sometimes displayed on portable DMSs in construction zones.) Severe weather or hazardous pavement condition messages were posted by four of the five TMCs (Dallas, Fort Worth, Houston, and San Antonio). Most of these messages pertained to pavement/weather conditions involving flooding or ice on the roadway. The districts generally did not post messages pertaining to intermodal information, except in Houston where park-and-ride information for planned special event traffic was posted.

Other Message Display Practices

To fully describe the use of DMS messages within the districts, one must consider not only the content of the message, but also the characteristics of the message when it is placed. Table 3 provides a comparison of the district practices in 2001 regarding message characteristics.

Table 3. Comparison of District Practices Regarding DMS Message Characteristics.

<table>
<tr><th colspan="2"></th><th>Austin</th><th>Dallas</th><th>Fort Worth</th><th>Houston</th><th>San Antonio</th></tr>
<tr><td colspan="2">Written Policy</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="2">Written Guidelines</td><td></td><td>X</td><td>X</td><td>X</td><td>X</td></tr>
<tr><td colspan="2">Two-Phase Messages</td><td>X</td><td>X</td><td>X</td><td>X</td><td>X</td></tr>
<tr><td colspan="2">Changing Only Specific Lines in Two-Phase Messages</td><td></td><td>X</td><td>X</td><td>X</td><td></td></tr>
<tr><td colspan="2">Flashing Messages or Lines</td><td></td><td></td><td>X</td><td></td><td></td></tr>
<tr><td colspan="2">Beacons</td><td>X</td><td>X</td><td>X</td><td>X</td><td>X</td></tr>
<tr><td rowspan="2">Message Posting by Other Agencies</td><td>Allowed by District</td><td>X</td><td></td><td></td><td>X</td><td></td></tr>
<tr><td>Message Library Used</td><td>X</td><td></td><td></td><td>X</td><td></td></tr>
<tr><td colspan="2">Message Modification for Local Conditions</td><td>X</td><td></td><td></td><td>X</td><td>X</td></tr>
</table>

X = Affirmative

In 2001, all five districts used two-phase messages with varying exposure times (average of two seconds per phase) when long messages were needed. Three districts (Dallas, Fort Worth, and Houston) also changed one line of a message while leaving the other two static in situations where a certain subject of the message is to be emphasized, such as the specific message audience. The Fort Worth District flashed entire messages or certain lines within messages, but only in situations that were determined to be significant but not urgent enough to use flashing beacons. Flashing beacons were used by all the districts although warrants for their use varied, usually involving messages pertaining to driver safety or the ability to avoid substantial delay, such as for major incidents or construction.

Allowing other agencies to display messages on TxDOT’s DMSs was very uncommon although the Houston District allowed the Houston Metropolitan Transit Authority of Harris County, Texas (METRO) to display messages on DMSs in the high-occupancy vehicle (HOV) lanes and park-and-ride lots. Also, the Austin District allowed city law enforcement agency personnel to display messages after normal TMC operations hours. In each case, a list of allowable messages was given to the other agency.

Occasionally DMSs have been placed in locations where the message legibility distance is relatively small. Such locations include DMS placement at extreme horizontal and vertical curves, near overpasses that restrict legibility, and at locations where glare from the sun is frequent. For these cases, message length and content should be reduced to accommodate for the reduction in readability distance. Three districts (Austin, Houston, and San Antonio) made such modifications to DMS messages.

SUMMARY

The TxDOT TMC reviews helped the researchers in identifying the adequacies and deficiencies at each TMC in 2001 and also the similarities and differences among them. Some of the main points from the TMC visits regarding DMS operations are listed below.

- DMS message posting procedures varied widely among districts.
- No TxDOT TMC operated under a written policy for posting of DMS messages.
- Four of five TxDOT TMCs operated under a written set of operating guidelines.
- No TxDOT TMC displayed messages with “hard” diversion message elements during incidents although messages with “soft” diversion were displayed by most districts.

The information gained from the TMC reviews provided valuable information for the subsequent tasks in the project, and was used accordingly to assist in the development of a DMS message design and display manual and automated message design proof-of-concept software for TxDOT.

3. DECISION FLOW CHARTS AND MODELS AND PROOF-OF-CONCEPT SOFTWARE DEVELOMENT

DMS message decision logic flow charts and models for the design of DMS messages when incidents or roadwork occurs were developed in preparation for the development of the Phase 1 proof-of-concept software. The emphasis of the logic flow charts and models was on incidents and roadwork messages. DMS message design principles that were tested over time were used in the development. The Phase 1 logic and flow charts and models also formed the basis for the Phase 2 proof-of-concept software development which addressed other types of events (i.e., AMBER alerts, major catastrophes, planned special events, and inclement weather and environmental conditions). As a prelude to the use of the DMS message design flow charts, some basic DMS message design principles are provided in the following section.

SOME DMS MESSAGE DESIGN PRINCIPLES

To be effective, a DMS must communicate a meaningful message that can be read and comprehended by motorists within a very short period. To accomplish this, the following message design factors should be considered:

- content—the specific information displayed,
- length—the number of words or characters and spaces,
- load—the number of units of information in the message, and
- format—the order and arrangement of the units of information.

Message Content

Essentially, the key elements of message content are what is wrong ahead, where the problem is located, and what action the motorist should take. Thus, the content must provide information relative to the motorists' needs. Motorists expect the problem or reason to appear first, followed by where the problem occurs. Advice, such as "use other routes," should be presented at the end of the brief message.

In urban areas where cross roads are relatively close and the motorists are familiar with the area, the location of the problem should be referenced to a cross road, ramp, or landmark. In contrast, motorists who are unfamiliar with the area prefer to have the problem referenced in terms of distance from the DMS. In rural areas where cross roads are infrequent, it becomes necessary to reference the location of the problem in terms of distance even for familiar motorists.

When motorists are advised by the DMS message to divert and take a specific highway or route, it is essential that the destination names and routes used in the message are the same as those displayed on the existing guide signs. Inconsistency between the DMS message and the existing guide signs will lead to motorist confusion and may cause some motorists to take incorrect routes. Therefore, the message designer must have a full knowledge of the wording and route markers on the existing guide signs before diversion messages directing motorists to a specific highway or route are used in a DMS message.

Message Length

The maximum length of a DMS message is controlled in part by the reading time—the time the motorist has available to read the message. Thus, the entire message must be short enough to allow motorists to glance at the sign, read it, and comprehend it while attending to the complex driving environment. Below are some of the items that need to be considered when determining message length.

- It takes unfamiliar motorists longer to read a DMS message than familiar motorists who see the sign regularly.
- Motorists time-share their attention to the roadway and traffic with reading signs.
- Motorists must read the entire message on a DMS to obtain relevant information.
- There is evidence that an eight-word message (excluding prepositions) is approaching the processing limits of motorists traveling at speeds of 55 mi/h or more.
- It takes motorists longer to read: 1) flashing messages, 2) messages with one of the lines flashing, and 3) messages on a three-line DMS where one line alternates text and the other two lines of text remain the same.

Message Load

An informational unit refers to each separate data item given in a message which a motorist could recall and which could be a basis for making a decision. The following example of a DMS message in response to a crash serves to illustrate the concept of units of information.

UNIT OF INFORMATION

Question	Answer	Unit of Info
1. What happened?	ACCIDENT	1 unit
2. Where?	PAST ROWLAND	1 unit
3. Who is advisory for?	FAIR PARK	1 unit
4. What is advised?	USE FITZHUGH	1 unit

Research and experience have shown that on urban freeways, DMS messages must not exceed four units of information when the freeway operating speed is greater than 35 mi/h. When speeds are equal to or less than 35 mi/h, no more than five units should be displayed on a single DMS.

The *Basic DMS Message* is the totality of information that the motorists will need on the DMS in order to make a rational driving decision. For incidents and roadwork the *Basic DMS Message* consists of the following message elements:

- incident or roadwork descriptor,
- incident or closure location,
- lanes affected or closed,
- closure descriptor (when all lanes are closed),

- closure location (when all lanes are closed),
- effect on travel,
- action,
- audience for action, and
- one good reason for following action statement.

However, in most cases the *Basic DMS Message* will exceed the informational unit maximum of four or five units. Therefore, priorities must be set to ensure that the most relevant information is displayed, albeit sub-optimal.

Message Format

The order and arrangement of the units of information are important to allow motorists to easily read and interpret the information and make rational decisions based on that information. Placement of message elements on the wrong line or in the wrong sequence will result in driver confusion and will increase message reading times.

In many cases, messages are too long to display at one time. Therefore, the message must be divided into two parts and displayed on two frames. In no case should the message be longer than what can be displayed on two frames. Each message frame must be cohesive and understandable, and the information units on a specific frame must be compatible.

When a specific unit of information does not fit on a DMS line because of the limitation in the number of characters that can be displayed on a line, it sometimes becomes necessary to use abbreviations. Some abbreviations take longer to read and comprehend and thus must be used with care. There is a library of words and phrases of acceptable abbreviations that have been tested via human factors studies in Texas and elsewhere (*19*).

ADVISORY COMMITTEE RECOMMENDATIONS

Prior to and following the development of the logic flow charts and models for the design of DMS messages, the researchers met with the Project Advisory Committee to obtain input from the members regarding special needs and provisions for the TxDOT districts operating DMSs. It was important to develop the logic and models and subsequently the proof-of-concept software to be responsive to the needs of the districts.

DMS MESSAGE DESIGN FLOW CHARTS

The DMS message design flow chart for incidents and the DMS message design flow chart for roadwork are shown in Appendices A and B, respectively. The user of the DMS message design flow charts will find a degree of repetition; however, the repetition is necessary in order to allow the user to reference successive pages when designing a message for the specific DMS location relative to the incident or roadwork.

Incidents

The DMS message design flow chart for incidents includes detailed guidelines for the following three scenarios:

1. lane-closure (blockage) incidents,
2. incidents that block all lanes, and
3. incidents that require closing the freeway.

The guidelines are further subdivided with respect to the DMS location:

- same freeway and relatively close to the incident,
- same freeway but relatively far from the incident, and
- a different freeway than the incident.

Roadwork

The DMS message design flow chart for roadwork includes detailed guidelines for the following two scenarios:

1. lane closures and
2. closing the freeway.

As with the flow chart for incidents, the guidelines are further subdivided with respect to the DMS location:

- same freeway and relatively close to the roadwork,
- same freeway but relatively far from the roadwork, and
- a different freeway than the roadwork.

PROOF-OF-CONCEPT DMS MESSAGE DESIGN SOFTWARE

The proof-of-concept software for DMS message design was developed using the principles of effective message design that are documented in Report 0-4023-P3 (*19*). The stand-alone software package, referred to as the DMS Message Optimization Software Tool (MOST), was developed with eventual integration into ATMS) and other TxDOT mainframe TMC packages in mind. The software currently exists on CD-ROM and contains limited data for the TMCs in Austin, Dallas, and San Antonio. The current software can be used to develop new messages at the TMCs for incorporation into the mainframe system. In addition, the software can be used as a training tool. Software design requirement specifications for MOST were documented in Report 0-4023-2 (*20*).

4. FOCUS GROUP AND HUMAN FACTORS LABORATORY STUDIES

BACKGROUND

Focus group and human factors studies were conducted in Phase 2 of the project as a means of determining effective DMS message design for special situations, namely AMBER alerts, disaster response and evacuations, planned special events, and adverse weather and environmental conditions. The Project Advisory Committee provided the TTI research team with input from the perspective of their districts regarding difficulties and issues involved with displaying DMS messages during the aforementioned special situations. Indicators of possible information deficiencies with current DMS messages included observed driver behavioral problems and feedback from the motoring public (e.g., telephone calls).

The objectives of the focus group study, held in six Texas cities, were to obtain initial responses from drivers concerning information needs and to help develop and/or evaluate potential messages for DMSs. The focus group discussion process was the mechanism used to obtain driver feedback concerning DMS message needs and possible deficiencies.

The results of the focus group discussions were then used as a basis for the experimental design of the subsequent human factors laboratory study that was then conducted in six Texas cities. The laboratory study provided more objective and detailed results that led to recommendations for effective DMS message design.

The results of both studies are summarized in this section of the report. Details of the studies are presented in Report 0-4023-4, *AMBER Alert, Disaster Response and Evacuation, Planned Special Events, Adverse Weather and Environmental Conditions, and Other Messages for Display on Dynamic Message Signs* (*21*).

STUDY OBJECTIVES

The goal of this part of the project was to assist TxDOT in improving the effectiveness of messages displayed on DMSs during special situations other than incidents and roadwork. Additionally, terms that identify the location of incidents were investigated to better understand how motorists associate location descriptors with cross streets and exit and entrance ramps. To accomplish this goal, TTI researchers focused on identifying, developing, and evaluating DMS messages and terminology in current or proposed use. The research to determine those messages or terms that best convey information required and desired by motorists in the given situations was conducted to two parts. In Part 1, a focus group study was conducted in six cities in Texas. Part 2 involved the more objective and extensive human factors laboratory study that was also conducted in six Texas cities.

RESEARCH ISSUES

The research issues that were explored for the primary four categories of special DMS signing situations are listed below.

AMBER Alerts

- What does a driver want to know when a child is abducted?
- Are drivers confusing AMBER alerts with the Homeland Security warning levels?
- Are license plate and telephone numbers more difficult to read and recall?

Disaster Response and Evacuation

Floods

- What does a driver want to know when the road is flooded and impassible?
- What are the most effective locations for providing this information?

Hurricanes

- What does a driver want to know during and after hurricane evacuations?
- What are the most effective locations for providing this information?

Terrorist Attacks

- What does a driver want to know during terrorist attacks?
- What are the most effective locations for providing this information?

Adverse Weather and Environmental Conditions

- What types of weather conditions would drivers like to see displayed during adverse weather or environmental conditions?
- What types of information should be provided to drivers?
- What are the most effective messages for various situations (i.e., ozone alert and pavement breakup)?

Planned Special Events

- What type of information would drivers like to see displayed if attending the event?
- What type of information would drivers like to see displayed if not attending the event but traveling on the affected freeway?
- What type of information would drivers like to see displayed for special events with arterial street closures?

Other Issues

In addition to the above, a secondary issue was explored: How can improvements be made to messages for greater motorist understanding?

STUDY APPROACH FOR FOCUS GROUP STUDY

Locations

Focus group discussions were held in the following six cities selected by the Project 0-4023 Project Advisory Committee: Amarillo, Arlington, El Paso, Houston, Laredo, and San Antonio. The discussions were held in the TTI facilities in Arlington, Houston, and San Antonio and in hotel meeting rooms in Amarillo, El Paso, and Laredo.

Participants

Seven to ten licensed drivers participated at each location for a total of 54 subjects. The goal was to select a sample of drivers based on the demographics of the driving population of Texas with regard to gender, age, and education level. However, because of recruiting and scheduling difficulties at some of the study sites, the researchers did not quite reach this goal. The actual sample had a higher percentage of female drivers and drivers between the ages of 18 and 39 years old than the Texas driving demographics. Since most of the messages evaluated were intended for DMSs that would be used on freeways or highways, all participants were required to have a current Texas driver's license, drive at least 8000 miles per year, and travel on a freeway or highway at least 12 times per year.

Discussion Techniques

Five different techniques, listed below, were used during the focus group discussions:

1. *Listing*—The participants in each focus group were asked to list the types of situations and/or types of information they felt were important and what types of information should be displayed on a DMS during specific events.

2. *Rating*—After the lists were prepared, the participants were asked to rate each item in the list. The rating was a way to determine how each item listed (selection, alternatives, test messages, etc.) would be considered by each participant on its own merit.

3. *Ranking*—The participants were then asked to rank the items in the list according to either preference or importance. The ranking scale was an attempt to determine the relative importance of the items in the list.

4. *Recall*—Several messages were projected onto a screen to determine whether the participants were able to recall the information after it was displayed for eight seconds. Eight seconds is the approximate amount of time that DMS messages are within the view of drivers as they travel at 65 mi/h. The moderator then queried the participants as to the specific information they could or could not remember.

5. *Building Test Messages*—This technique involved "building" a DMS message using the input from the participants. The process started by placing the group's preference for the most important information on the top line of a DMS that was projected on the screen. Following further discussion, the group's preference for the next unit of information was placed on the second line of the DMS. Then based on further discussion, the third unit of

information was placed on the third line. Finally, group discussion continued until all different opinions were satisfied.

Study Protocol

Upon arrival, participants were given a verbal explanation of the study and a participant information form to complete which included a request to write down the meaning of the term AMBER ALERT. The objective of this latter request was for the TTI researchers to obtain an unbiased assessment of the drivers' understanding of the term prior to the focus group discussions. The outcome of this question is addressed in the AMBER alert messages section of this report.

The researchers addressed each of the identified topics individually through the use of a focus group guide. The focus group guide was developed to set the agenda for the group discussions and provide direction for the TTI facilitator. The topics were approached such that each situation allowed the participants to engage in open discussions. The focus group guide was tailored to the local area of the particular city in which the group discussion was held. In other words, street names and scenarios used within the group discussions were changed as appropriate for the area. Prior to beginning the discussion, several rating and ranking forms were distributed for use during the discussion.

STUDY APPROACH FOR HUMAN FACTORS LABORATORY STUDY

Locations

The human factors laboratory study was conducted in the following six cities: Arlington, Austin, El Paso, Houston, Laredo, and San Antonio. Note that although Amarillo was one of the locations for a focus group study, upon review of the results, the Project 0-4023 Advisory Committee recommended that Amarillo be replaced with Austin for the laboratory study. The study was conducted in community centers, senior citizen centers, private residences, rented hotel conference rooms (when necessary), and TTI research implementation offices located in Arlington, Austin, Houston, and San Antonio.

Participants

There were 192 individuals who participated, 32 from each of the six study locations. The sample was based on the demographics of the driving population in Texas according to age, education, and gender. As with the focus group study, since most of the messages evaluated were intended for DMSs that would be used on freeways or highways, all participants were required to have a current Texas driver's license, drive at least 8000 miles per year, and travel on a freeway or highway at least 12 times per year.

Laboratory Instrument and Protocol

The human factors study utilized several different methods of participant interface including laptop computer programs, card selection processes, and map experiments. The method of interface selected depended on what was appropriate for the issue being addressed. The study consisted of eight sessions, each addressing a specific topic. Each session contained between 7 and 15 DMS messages for the subjects to evaluate or presented different scenarios for them to evaluate and create appropriate messages. To avoid the occurrence of primacy bias, the order of the message displays was counterbalanced. There were two groups in each city, where Group A viewed the messages in one order and Group B viewed the messages in the opposite order, in all of the applicable sessions.

The study administrator recorded all responses. Although many of the laboratory sessions were conducted using laptop computers, it was not necessary for the participants to have any prior computer experience. The participants simply needed to press the space bar and use the mouse to click on objects at certain points in the sessions. The study took approximately two hours to complete, and the participants were compensated financially for their participation. Laboratory sessions were administered one at a time to participants.

Pilot Study

A preliminary laboratory instrument was developed and tested with four individuals in the Bryan/College Station area. The purpose of the pilot study was to assess the administration procedures, determine the length of time needed for each participant to complete the laboratory session, assess the format of the laboratory instrument, and identify any question deficiencies. The preliminary laboratory instrument and procedures were modified based on the results and participants' comments.

AMBER ALERT—FOCUS GROUP STUDY

Summary of Findings

The findings of the focus group study relative to AMBER alert messages are summarized below.

1. Only 67 percent of the 54 participants in the focus group study understood the meaning of the term AMBER ALERT.

2. The following alternative terms were identified as appropriate to use during a situation where a child had been taken by a stranger:

    - AMBER ALERT,
    - ABDUCTED CHILD or CHILD ABDUCTED,
    - KIDNAPPED CHILD or CHILD KIDNAPPED, and
    - MISSING CHILD or CHILD MISSING

3. Forty-four and 43 percent of the participants preferred the terms KIDNAPPED and AMBER ALERT, respectively. ABDUCTED (17 percent) and MISSING (2 percent) were least preferred.

4. However, when asked to rate the terms with respect to how well they would be understood by other drivers, the terms were rated almost equally as well. When asked to

rank the terms according to the relative understanding of the terms, AMBER ALERT and KIDNAPPED were rated highest, followed by MISSING and ABDUCTED.

5. The participants viewed four candidate DMS messages. The messages varied in design but included one or more of the following: incident descriptor (e.g., KIDNAPPED CHILD), vehicle make and color, license plate number, state abbreviation for an out-of-state license, telephone number to call, and radio station. The following is a summary of the results.

    - All of the participants remembered the incident descriptor (e.g., KIDNAPPED CHILD).
    - Most also remembered the vehicle description.
    - The majority did not recall the entire license plate number; most agreed that it was easier to remember the letters in a license plate than the numbers.
    - Messages that contained both license plate and telephone numbers overwhelmed the participants' recall capabilities.
    - The consensus was that most drivers do not know the abbreviations for most states.
    - Most participants agreed that if no telephone number was in the message, they would dial 911.
    - The majority of the participants indicated a preference for a message that displayed the radio station.

6. The participants thought that the following information should be included in the message:

    - vehicle make/model,
    - vehicle color,
    - vehicle license plate,
    - child description,
    - location of kidnapping or location last seen,
    - radio station to tune to, and
    - telephone number to call.

7. In terms of the importance of the information in item 6 above, the participants rated vehicle color, vehicle make/model, and radio station the highest, followed by vehicle license plate, child description, location of kidnapping, and location last seen next. The telephone number to call was a distant last.

8. In terms of the relative importance of the information in item 6 above, the participants' ranking was as follows: vehicle make/model, vehicle color, radio station, child description, location of kidnapping, location last seen, vehicle license plate, and telephone number to call.

Implications of Results for Human Factors Laboratory Study

The implications of the findings relative to possible human factors laboratory study are listed below.

1. There was not a clear consensus as to which of four descriptor terms would best describe that a child was abducted. However, the term MISSING had connotations that a child would not be in a dangerous situation and thus should be eliminated from further study. The incident descriptor terms AMBER ALERT, KIDNAPPED, and ABDUCTION should be further evaluated to determine the "best" term to use in a message.

2. The placement of CHILD relative to the incident descriptor (i.e., CHILD KIDNAPPED versus KIDNAPPED CHILD) should be further explored.

3. Assessment should be made of the ability of drivers to read and recall license plate numbers. Also, studies should be designed to determine the equivalency of license plate numbers in terms of units of information.

4. Assessment should be made of the ability of drivers to read and recall telephone numbers. Also, studies should be designed to determine the equivalency of telephone numbers in terms of units of information.

5. The utility and importance of the incident descriptor containing the gender of the child (e.g., KIDNAPPED BOY [GIRL]) should be explored.

6. The relative importance of information to display should be further assessed.

7. Reading times and comprehension of alternative messages for AMBER alert situations should be determined.

AMBER ALERT—LABORATORY STUDY

Study Approach

Using the above implications of results from the focus group study, the TTI research team developed a laboratory study that consisted of two parts. Part 1 involved a card sort experiment to determine driver priorities and preferences for elements of AMBER alert messages. The card sort experiment was similar to the one previously used by Dudek et al. in developing human factors DMS message guidelines (*5*). Part 2 was a series of experiments using DMS messages displayed on the screen of laptop computers to determine the equivalent units of information of telephone and license plate numbers by measuring reading times and comprehension.

Summary of Findings

Driver Preference and Priority

Message Element Preferences. The objective of this portion of the laboratory study was to evaluate different formats and message elements to be included in AMBER alert messages.

There were two different parts of this session; the first was to identify which of a series of different elements would be the most appropriate within a specific category of information to use in the DMS message. The following are the most commonly selected options for each of the categories:

- situation description—AMBER ALERT (32 percent), ABDUCTED CHILD (22 percent);
- vehicle description—BLUE MAZDA 05 PICKUP (49 percent), BLUE MAZDA PICKUP (38 percent);
- license plate number—LIC # SR8-493 (includes # and -) (68 percent);
- telephone number—CALL 511 (59 percent); and
- radio—TUNE TO 530 AM (63 percent).

The results of this study do not show a majority opinion for what term should be used as a situation descriptor although AMBER ALERT was the most commonly selected. Also, the results do support earlier focus group findings that the term MISSING has the connotation that a child would not be in a dangerous situation and so would not be a preferable descriptor for AMBER alert messages.

With regard to a vehicle description, participants typically indicated that they would prefer to have as much information as possible with which to identify the vehicle and therefore favored the more detailed options consisting of vehicle color, make, body type, and possibly year. For the vehicle license plate, participants believed the inclusion of the symbols "#" and "-" helped to keep the words from visually running together. Finally, for a telephone number, participants selected the shorter number (i.e., 511) 87 percent of the time because it was easier to remember than a typical 10-digit telephone number.

Message Element Importance. The results of the message element order, rating, and rankings all indicated to researchers that the following order of importance exists for the message elements to be included in AMBER alert messages:

1. situation description,
2. vehicle description,
3. license plate number,
4. telephone number, and
5. radio information.

Unit of Information Equivalents of Telephone and License Plate Numbers

The researchers observed difficulty during the focus group study with participants being able to recall either long telephone numbers, such as 800 numbers, or license plate numbers. Based on this information, researchers determined that a reading time and comprehension study would be conducted to determine the unit of information equivalents for both telephone and license plate numbers when included in a DMS message. The findings of this portion of the study are summarized below.

- Long telephone numbers (e.g., 800 numbers) should be considered to be equivalent to three units of information.

- Short telephone numbers (e.g., CALL 511) should be considered as one unit of information.
- License plate numbers have a learning curve necessary to recognize the formatting and possibly the abbreviation (LIC) used; however, once the format becomes familiar to motorists, it should be considered to be equivalent to three units of information.

Also, the researchers investigated the use of both license plate numbers and long telephone numbers combined in a message. Based on the exceedingly low comprehension levels recorded, the use of this combination of information is not recommended for DMS messages. This amount of information appeared to be overwhelming to the study participants and would have a much higher unit of information equivalency than would be appropriate for use on a DMS.

HIGH WATER AND FLOODS—FOCUS GROUP STUDY

There were questions regarding the content of messages that should be displayed when high water is downstream of the DMS on the following types of facilities:

- freeway,
- frontage road,
- freeway and frontage road, and
- intersecting freeway.

Furthermore, there were questions regarding the content of DMS messages that should be displayed during the following conditions:

- high water (flood) requiring closing the road, and
- water on the road but passable and not requiring closure.

Summary of Findings

The findings from the focus group study are listed below.

1. The participants were evenly split as to whether they would continue to drive on the highway when only a message similar to I-45 NORTH/FLOODED was displayed. The consensus was that if flooding conditions existed, more information was needed about the location of the flood and the exit ramps that should be used. The term ROAD CLOSED would be more meaningful.

2. Most participants agreed that the specific highway (e.g., I-45) of the flood should be in the DMS message. The participants from five of the study locations indicated that the cardinal direction was needed; only the participants from El Paso felt that the cardinal direction was not necessary.

3. No clear consensus was found for preference among the six cities for three terms studied (FLOODED, HIGH WATER, and DEEP WATER) although FLOODED was used in messages designed by five of the six groups and HIGH WATER was used by one group.

Implications of Results for Human Factors Laboratory Study

The implications of the findings relative to possible human factors laboratory studies are listed below.

1. The three message terms FLOODING, HIGH WATER, and DEEP WATER should be further evaluated to determine the "best" term to use on DMSs.

2. Studies should be conducted to determine the words and/or terms that best describe flooding situations. In particular, studies should determine the best way to communicate:

   - that the highway is impassable or passable,
   - that the frontage road is flooded and impassable,
   - the location of flooding downstream of the DMS,
   - ramp closures due to flooding, and
   - instructions as to where to exit.

3. Message content should be further evaluated to determine the most effective message in conveying the necessary information.

HIGH WATER AND FLOODS—LABORATORY STUDY

Study Approach

There were two parts to the study. Part 1 involved a study in which the participants looked at schematic maps of a freeway corridor and created DMS messages or message elements that would be appropriate to the given situation. Part 2 involved a laptop computer study in which the participants were asked their preferences among sets of messages displayed and the reasons for their selections. No secondary task loading was used during the laptop part of this study.

Participants in each of the study cities were divided into two groups (Group A and Group B) for the purposes of counterbalancing. Group A consisted of 50 percent of the participants in the city, and Group B consisted of the other 50 percent. The participants in each group were balanced as much as possible according to age, education, and gender.

During the Part 1 map portion of the study, the participants were asked to assume that they were traveling on a specified freeway in the city in which the survey was conducted. The participants were given a series of 11 × 17 inch schematic maps one at a time that showed a freeway with frontage roads on both sides, several cross streets, a cross freeway, and a parallel alternative street. Each map depicted a different location where water had collected on the freeway, frontage road, or both. The study administrator asked participants a series of questions while they viewed each map. The questions were designed to ascertain term(s) to describe the following:

- the roadway next to the freeway (e.g., frontage road, feeder road, etc.);
- a passable situation when water collects on or flows across the freeway in low areas and drivers can still travel on the road;
- an impassable situation when water collects on or flows across the freeway in low areas and drivers cannot travel on that road;
- an impassable situation when water collects on or flows across the frontage road in low areas and drivers cannot travel on that road; and
- an impassable situation when water collects on or flows across both the freeway and frontage road in low areas and drivers cannot travel on those roads.

The maps used were altered for each location so that road names and locations were familiar to the study participants. For the discussion of this part of the study, the cross streets represented in the tables and text will be those used at the Houston study location.

During the Part 2 laptop portion of the study, the participants were shown DMS messages on the video monitor and were asked to respond to questions about the messages.

Summary of Results

Water Is Passable

For situations where water is on the road but it is passable to traffic, researchers found that 91 percent of the participants believed a message should be displayed to alert drivers of the conditions. The most preferred information elements to include in that message were:

- situation description—WATER ON ROAD (given by 45 percent of the participants) and
- location—[distance] AHEAD (given by 41 percent of the participants).

The participants also stated that telling drivers to either reduce speed or use caution would let them know that they can continue on the road and not need to exit.

Water Impassable Situation Descriptor

In a situation where the water on the roadway is impassable, no clear consensus was garnered from the participants as to the situation description that should be used in a DMS message. However, in all three situations presented to the participants, the highest percentage response was to use the term CLOSED. This was selected by:

- 28 percent when only the freeway is impassable,
- 35 percent when the frontage road is impassable, and
- 50 percent when both the freeway and frontage road are impassable.

The use of this term was further supported in the preference selections of the study where 69 percent of the participants preferred the term CLOSED over FLOODED when the driver could not continue on the road.

The researchers also presented participants with three different terms for water on the road and asked them if they would continue or get off the road based on the given message. This was done to identify which term would be more appropriate for alerting motorists that they needed to exit the freeway for the conditions. The following were the percent of people who would leave the freeway in response to each term:

- FLOODED—94 percent,
- DEEP WATER—88 percent, and
- HIGH WATER—75 percent.

These results indicate that the term FLOODED would likely be the most effective term of those studied in convincing drivers to leave the freeway. However, from the questions related to the creation of a message, many participants also believed that the term CLOSED would convince drivers that they needed to leave the freeway.

One final comparison was made of situation descriptions FLOODED AND CLOSED or FLOODED with the inclusion of exit information. Given this option, 79 percent of the participants indicated that they would prefer the message that included exit information, indicating the importance that motorists place on the inclusion of an action to take in this type of message.

Flooding Location Description

Another portion of the study was designed to investigate participants' preferences regarding the specification of the location of the flood water on the road. For each situation, at least one of the primary responses made reference to the road nearest to the flooding, either as the location (e.g., at, near, after) or as an exit. Another common response was to give a distance away from the flooding. It is likely that this preference is dependent upon the condition and familiarity of the road nearest the flooding. Specifically, if the road is less well known to drivers, researchers hypothesize that it may be less desirable as a location identifier in a flooding message. On the other hand, if the road is well known to drivers, it is likely to be preferred in the flooding message.

Action to Take due to Flooding

Within the messages created by the participants, the inclusion of an action term was common both when only the freeway was flooded and when both the freeway and frontage road were flooded. The common action terms used by participants in creating their messages are listed below.

- FREEWAY FLOODED—87 percent included exit information
- FREEWAY AND FRONTAGE ROAD FLOODED:
  - EXIT INFORMATION—59 percent and
  - USE ALTERNATIVE ROUTE—42 percent.

Also, when asked to identify what information should be added to certain standard messages (which included situation description and road name), 57 percent of the participants believed that flood messages should include exit information.

The preference part of the study further investigated different formats or terms to use regarding an action in a flooding message. When given a choice between including the term CLOSED or exit information, 79 percent of participants preferred to have the exit information. Additionally, researchers identified an overwhelming preference (98 percent) for specific exit information over the use of the phrase TUNE TO RADIO in flooding messages. As a final comparison related to this topic, researchers presented two different formats of exit information to participants. The first included an exit number, and the second included the street name associated with the exit. In this case, 75 percent preferred the use of a street name with regard to identifying an exit.

Freeway Indicator

Finally, researchers investigated different methods for identifying the roadway on which the flooding was located. Initially, researchers asked participants which of three formats was preferred for indicating the roadway itself, the results of which were:

- I-XX [direction]—71 percent,
- FREEWAY—15 percent, and
- I-XX —14 percent.

Participants stated their primary reason for this selection was that it allowed the driver to know which direction of the freeway was flooded (50 percent).

The researchers also looked at a preference for abbreviations of interstate as either I or IH. In this case, 68 percent stated a preference for the abbreviation I; however, regional differences did exist for this question. Austin, Laredo, and San Antonio participants were split nearly 50/50 in preference, whereas Arlington, El Paso, and Houston participants preferred the use of the abbreviation I by more than an 80/20 margin.

Finally, the researchers queried participants as to their preference for the message element placement of both the incident descriptor (i.e., FLOODED) and the freeway indicator. In this case, the two messages contained the same element in reverse order for lines 1 and 2 of the message. Eighty percent of participants preferred to have the freeway indicator on the top line and FLOODED on the second line. They believed this was easier to read (54 percent) and allowed them to know it applied to their road first (36 percent).

HURRICANE—FOCUS GROUP STUDY SUMMARY OF RESULTS

During the focus group study, the participants were asked to imagine themselves in two different situations related to hurricane events. The first was that they were evacuating prior to a hurricane and there was bumper-to-bumper traffic moving at a very slow pace on the highway they were traveling. The second situation related to returning to an area where a hurricane had just passed. In both of these cases, the participants were asked what information they thought would be vital for a driver to have.

The weakness of this part of the study was that none of the focus group participants had been in a situation where they had to evacuate because of a hurricane and had a difficult time imagining themselves in this type of emergency. The results of the studies are therefore suspect, and the researchers did not have full confidence to translate the results into meaningful motorist information needs and to design effective DMS messages. Thus, results should be considered very preliminary.

Hurricane Rita in September 2005 impacted the Texas Gulf Coast and resulted in mass evacuation from major cities such as Houston and Galveston. It was deemed desirable to take advantage of the plight and evacuation experiences of some of the citizens who could provide more meaningful responses to queries about driver information needs. A task was added to Project 0- 4296, “Development of Guidelines for Hurricane Evacuation Signing and Markings,” to conduct focus group studies and to support TxDOT in developing messages for DMSs and portable changeable message signs.

A summary of the results from the focus group study are listed below. The results should be considered very preliminary and should be interpreted with the caveat discussed above.

1. Ten items of information were primarily mentioned by the focus groups as being important. Evacuation routes, travel time/delay, and time until hurricane were identified by all six focus groups. Road closures, shelters, and gas stations were identified by five of the groups. A radio station to tune to was selected by four groups. Interestingly, the group in Houston did not choose gas stations and shelters. The need for food/lodging information was identified by only two groups (El Paso and Laredo), and only one group identified restroom (Laredo) and hospital (San Antonio).

2. The participants rated all 10 types of information as important. The ratings were between 1.1 and 2.5, using a scale from 1 to 5 where 1 was most important. The rankings in terms of the relative importance of information indicated that gas station (5.6), food/lodging (6.5), and restroom (7.0) were least important among the information needs. Of additional interest is that radio station was rated and ranked very high, which confirms the interest of the drivers to be able to obtain more detailed information via radio.

3. There were also several things that, when asked, some of the groups felt should not be included on DMSs in this type of situation. These items included the location of hotels, restrooms, and restaurants. Several of the groups mentioned that these types of amenities are listed on highway logo signs and therefore are not necessary on a DMS.

4. The participants listed 17 items of information needed when returning after the hurricane had passed. All 17 items of information were rated very high, with ratings between 1.2 and 2.8. A review of the ranking results showed that road closures (1.2), areas affected/closed (2.3), and safe return routes/areas and detours (2.3) were ranked the highest among the 17 items. Information about hospitals (7.5), available merchants (8.0), safe water (9.0), and curfew (9.0) were ranked the lowest.

TERRORIST ATTACK—FOCUS GROUP STUDY SUMMARY OF RESULTS

As in the case of hurricanes, none of the focus group participants had been in a terrorist attack situation. The information needs they cited and the subsequent ratings and rankings might have been different had they experienced a terrorist attack. Thus, the results should be interpreted with this limitation in mind.

Because of this limitation, the Project Advisory Committee recommended that the TTI researchers contact and interview personnel from New Jersey, New York, and Virginia that were affected by the 9/11 attack. The objective was to obtain information about their experiences with the use of and effectiveness of permanent and portable DMS messages during and after the terrorist attack.

With respect to subsequent human factors laboratory studies, the results suggest that there is a list of 12 information needs for situations when a driver is approaching an area attacked by terrorists; 14 information needs were identified for situations when the driver is in the affected area. The information needed far exceeds that which can be accommodated via DMSs. There is a need to determine the specific information that should be and can be accommodated via DMSs and the information that should be provided by other means. Although the information needs cited by the focus group participants can provide initial perspectives of needs, data gathered from New Jersey, New York, and Virginia will most likely prove more relevant.

A summary of the results from the focus group study is listed below. The results should be considered very preliminary and should be interpreted with the caveat discussed above.

1. There were 12 pieces of information that were mentioned by the groups as being important as they were driving toward the affected area. The results showed that event alert, location of attack, roads/areas closed, type of attack, and what to do were identified by four or more of the focus groups as being important.

2. All of the 12 pieces of information were rated high with the exception of schools affected (3.5) and safe water (3.6), which were rated lower than the other information. With respect to relative importance, information about event alert (1.8), location of attack (2.4), security level (2.7), type of attack (3.0), and alternate route (3.5) was ranked the highest, while information about hospital/medical stations (7.0), schools affected (7.0), and safe water (8.0) was ranked much lower than the other information.

3. With respect to information needs as they were traveling away from the affected area, the majority of the participants believed that the information provided to a driver would need to be more detailed than when they were driving toward the affected area. This was due to the fact that the situation of being in the area was viewed as more urgent and that it could be a threat to their health (as in the case of biological or chemical weapons).

4. Fourteen pieces of information needs were identified for the situation when the drivers were leaving the affected area. All of the information was rated high with the exception of schools affected (3.5) and safe water (3.6), which were rated lower than the other information in the table. With respect to relative importance, information about what to

do (1.0), evacuation routes (2.3), areas affected (2.5), safe areas (3.0), and type of attack (3.5) was ranked the highest, while information about security level (7.0), schools affected (8.0), and safe water (9.0) was ranked much lower than the other information.

OZONE ALERT—FOCUS GROUP STUDY SUMMARY OF RESULTS

1. Only 57 percent of the participants indicated that they knew what the term OZONE meant. Some of the participants that did not understand the meaning stated they believed it was associated with respiratory problems or the atmosphere, but did not feel it would be related to traffic or traffic conditions.

2. The majority of the participants stated they would not change their driving behavior based on this message. Three participants remarked that they might change their driving behavior if they had advance warning. Additional comments made by participants who felt this message would alter their driving behavior were: they would slow down, they would go home, or they would carpool. The consensus of the participants from Arlington was that the message meant nothing related to travel behavior.

3. In response to the terms OZONE WARNING, OZONE WATCH, and OZONE ALERT, 94 percent of the participants felt that the three terms had different meanings. Twenty-eight percent thought that OZONE WARNING was the most severe. Twenty percent felt that OZONE ALERT was the most severe, and 13 percent stated that OZONE WATCH was the least severe but could develop to a warning situation. Interestingly, 24 percent (13) of the participants felt that the different meanings of the ozone messages were related to when the event would occur, now or in the future.

Implications of Results for Human Factors Laboratory Studies

The results suggest the following with respect to the human factors laboratory studies:

1. The information needs for adverse weather and environmental conditions far exceed that which can be accommodated via DMSs. There is a need to determine the specific information that should be and can be accommodated via DMSs and the information that should be provided by other means. The information needs cited by the focus group participants provide a base that can be used to design the laboratory studies.

2. Driver comprehension and possibly reading times of candidate messages should be evaluated.

3. There seems to be a misunderstanding by a high percentage of drivers of the meaning and possible actions related to ozone alert messages displayed on DMSs. In addition, the descriptors tested to indicate the degree of health danger because of ozone levels did not adequately describe the situation. These issues should be further explored.

OZONE ALERT—LABORATORY STUDY SUMMARY OF RESULTS

1. Only 68 percent of the participants understood the word OZONE. This was a slightly greater percentage than had been identified during the focus group study. However, 32 percent of the participants in this study had to have the word OZONE defined to them before the rest of the session was administered. Most of these participants lived in Austin, Houston, or Laredo.

2. Fifty-eight percent of the participants stated that the terms OZONE ADVISORY and OZONE WATCH had different meanings. The participants were evenly split as to whether the terms OZONE ALERT and OZONE WARNING meant the same or had different meanings. Eighty-six percent stated that OZONE WARNING had a different meaning than OZONE ACTION. The researchers believe this could indicate that participants were unsure of what the difference between the descriptors was or that they were unsure of the meaning of the individual descriptors. However, many of the participants indicated the difference between the terms was based on the severity (24 percent), but there was not a clear response as to which of the terms was the most severe. Thirteen percent of the participants indicated that ADVISORY was more severe, while 11 percent felt WATCH was more severe.

3. The primary reasons listed for the differences between the ALERT and WARNING descriptors again focused on the severity of the messages. Fifty-one percent of the participants based their distinction between the terms on severity; however, there was no consensus as to which term was the most severe. Thirty-one percent of the participants felt ALERT was more severe compared to 20 percent stating WARNING was more severe.

4. Responses indicated that a WARNING was not urgent or that the event would occur in the future. In contrast, the majority of comments about the term ACTION indicated that it implied that drivers needed to do something now. However, 19 percent of the participants stated they did not know what ACTION meant, even though they believed the meaning would be different than WARNING.

5. Overall, approximately 20 percent of the participants out of each message comparison set felt that the different meanings of the ozone messages were related to when the event would occur, either now or in the future. This interpretation is consistent with comments received during the focus group studies conducted in the six Texas cities.

6. Overall, none of the terms (OZONE WARNING, OZONE ADVISORY, OZONE ALERT, or OZONE ACTION) garnered a majority opinion with respect to the severity of the situation. Rather, participants appeared to be fairly divided as to whether the various terms imply similar levels of severity, or whether one or another term implies a more severe condition than the other. This trend was apparent across each of the six cities as well.

7. Overall, approximately 90 percent of the participants stated that when any of the terms (OZONE WARNING, OZONE ADVISORY, OZONE ALERT, or OZONE ACTION) are displayed on a DMS, the message applies to today rather than tomorrow.

8. In response to questions about what they would do differently if one of the ozone messages was displayed on a DMS, approximately 50 percent stated that they would do nothing different. Only about a quarter of the participants indicated they would reduce trips, carpool, or ride the bus.

9. In response to the message terms RIDE THE BUS, REDUCE TRIPS, or WALK TO LUNCH, 92 percent of the participants stated that they would comply with the actions included in the message by reducing trips (47 percent), riding the bus (27 percent), and/or walking to lunch (18 percent). An additional 9 percent of the participants indicated that they would carpool; however, 18 percent would do nothing different in terms of their driving plans.

10. In response to the message terms RIDE BUS (FREE) or SHARE A RIDE, 74 percent of the participants indicated that they would follow the given suggestions. The researchers did note that the participants mainly based this decision on the fact that the bus would be free. An additional 17 percent of the participants stated they would reduce trips as the previous message suggested. However, 28 percent of the participants indicated they would do nothing different in terms of their driving plans.

11. Overall, more than 65 percent of the participants believed that the action information in the message was very important or important to display. The majority (greater than 90 percent) of those who felt this way stated that the information gave motorists good suggestions on what actions to take. Only 9 to 11 percent of the participants felt that the action information was unimportant or very unimportant to display.

12. Overall, the participants were evenly split as to whether either of the words ACTION or WARNING would have the greatest impact on getting drivers to change their behavior.

PLANNED SPECIAL EVENT—FOCUS GROUP STUDY

Summary of Results

1. The participants from five of the six focus groups believed that DMSs should be used to display information regarding planned special events. Participants from the sixth location, Amarillo, felt that the signs could be used during special events if there was a major impact on traffic to warn a driver about traffic conditions, but that they should not give information regarding any upcoming events because this seemed like advertising.

2. The following information needs were considered important by the participants from three or more of the focus groups for drivers going to the planned special event:

   - parking information (availability, cost);
   - directions (exits to use, routes); and
   - park-and-ride information.

The following information needs were cited by participants from one or two of the focus groups:

- alternative routes,
- travel time to the event,
- closed roads,
- time of the event,
- duration of the event,
- event description, and
- passenger drop-off and pick-up locations.

3. The information needs for drivers who were not attending the planned special event which were cited by participants from three or more of the focus groups are as follows:

    - alternative routes and
    - time and date of the event.

    The information needs cited by one or two of the focus groups were:

    - roads closed,
    - expected delay,
    - duration of the event, and
    - event description.

4. The groups were divided as to how long prior to an event information should be displayed. The Arlington group indicated that for most events one day would be enough advance notice. Two other groups agreed that one day would be a sufficient amount of advance warning. The final two groups indicated that a week or five days would be the appropriate amount of time to display messages. The participants from Amarillo did not feel that the DMSs should be used to give advance warning of an event, only to respond to traffic conditions and road closures.

5. The participants from four of the five groups who believed the signs should be used thought that the information should be provided on all of the routes that are in the region of the event. The actual distance away that the messages should be displayed varied from 3 to 15 miles. Specific locations mentioned by the groups included: at exits near the event, at park-and-ride locations, and at the airport for people traveling into the area. It was noted in several different groups that the distance should be far enough away so that people are able to select alternate routes if necessary.

6. For planned special events held in a downtown area that will involve closing local streets, the following information needs were cited by three or more of the focus groups:

    - road/street closures,
    - alternative routes, and
    - time of closure.

The following information needs were cited by one or two of the focus groups:

- highways/streets affected;
- parking information;
- where to get information (TV, radio, phone number);
- congestion; and
- "watch for pedestrian" warnings.

At the Houston focus group, the participants indicated that they believed this type of information should be displayed for drivers one week prior to the event so that people have an opportunity to change their travel plans in the area of the event.

Implications for Human Factors Laboratory Studies

The results suggest the following with respect to the human factors laboratory studies:

1. The information needed far exceeds that which can be accommodated via DMSs. There is a need to determine the specific information that should be and can be accommodated via DMSs and the information that should be provided by other means. The information needs cited by the focus group participants provide a base that can be used to design the laboratory studies.

2. Driver reading times and comprehension of candidate messages should be evaluated.

After meeting and discussing the focus group results with the Project Advisory Committee, the committee recommended that laboratory studies should not be conducted on this topic. Instead, the researchers were instructed to rely on information based on the experiences within TxDOT and by other state departments of transportation.

SPECIFYING LOCATION OF AN INCIDENT—FOCUS GROUP STUDY SUMMARY OF RESULTS

The guidelines in TxDOT's *Dynamic Message Sign Message Design and Display Manual* specify that acceptable terms for the incident location in a DMS message include AT [*highway, street name*], BEFORE [*highway, street name*], and PAST [*highway, street name*] (*19*). Recent studies indicated that drivers may not understand some of the descriptors currently used to describe the location of an incident, and thus are confused as to whether the incident is upstream or downstream of the exit ramp they intend to use. The same confusion exists when the location of floods are displayed. Thus it was important to conduct studies in an attempt to resolve the issue.

When the three candidate incident location terms (AT [*cross street name*], N OF [*cross street name*], PAST [*cross street name*]) were displayed to the participants, 83 percent preferred the term AT [*cross street name*]. The reasoning behind their selection is that this term seems to give a more specific location. With both of the other options, the accident could have occurred a great distance away (e.g., PAST could be many miles farther). Also, with respect to the message where cardinal directions are used, several of the participants mentioned that drivers are not always aware of the direction they are traveling.

SPECIFYING LOCATION OF AN INCIDENT—HUMAN FACTORS STUDY

Study Protocol

During this part of the study, the participants looked at schematic maps of a freeway corridor. Each map illustrated a DMS displaying a message. Located on these schematics were small boxes on the freeway that the participants could mark in response to the DMS message presented. The participants could select one of the following five locations (boxes):

1. approximately ½ mile upstream of the specified cross street,
2. just prior to the specified cross street exit ramp,
3. between the exit ramp and specified cross street,
4. between the specified cross street and the specified cross street entrance ramp, or
5. downstream of the specified cross street entrance ramp.

Summary of Results

1. The term PAST [*cross street*] was interpreted by 95 percent of the participants to mean that the incident is past the given cross street. Furthermore, 99 percent interpreted the term to mean that the incident was past the exit ramp leading to the cross street.

2. In response to the term BEYOND [*cross street*], 95 percent of the participants interpreted the location of the incident as being after the cross street exit ramp. Also, 89 percent of the participants interpreted this term to indicate a location that is beyond the cross street given in the message. Seventy-four percent stated that the incident was downstream of the cross street entrance ramp.

3. The term AT [*cross street*] was interpreted by 82 percent of the participants as a location beyond the exit ramp but prior to the entrance ramp for the cross street. Also, 85 percent interpreted the term to imply that the exit ramp to the cross street is not blocked by the incident and can still be used.

4. When presented with the term BEFORE [*cross street*], 65 percent of the participants believed this message would mean that the incident was located prior to the exit ramp, thereby making it impossible to exit at the street that is referenced in the message. However, another 34 percent interpreted the message to mean that the incident was located between the exit ramp and the cross street, which implies that those participants believed they could still use the exit ramp for the cross street referenced in the message. In this case, there was no clear interpretation by participants as to whether or not drivers would be able to use the exit.

5. Eighty-six percent of the participants interpreted the term pair FROM [*cross street 1*] TO [*cross street 2*] as beginning after the exit ramp for cross street 1, and 97 percent interpreted the message to mean the end of the closure as being prior to the entrance ramp

of cross street 2. The results imply that the participants interpreted the message to mean they could reenter the freeway immediately after cross street 2.

6. The interpretation of the term pair BETWEEN [*cross street 1*] AND [*cross street 2*] was similar to the FROM/TO term set. The majority of participants (94 percent) indicated that the closure began in an area after the cross street 1 exit ramp and ended prior to the cross street 2 entrance ramp (97 percent). Again, this result implies that drivers interpreted the meaning of the message to mean that they must leave the freeway at the cross street exit ramp and that they could enter again using the cross street 2 entrance ramp.

7. In response to the term pair BEYOND [*cross street 1*] TO [*cross street 2*], 79 percent of the participants believed that the start of this closure was after cross street 1. Perhaps more importantly, 97 percent again believed that the message would mean that the closure began after the cross street 1 exit ramp. Regarding the location of the end of the closure, 90 percent of the participants stated that the end was prior to the cross street 2 entrance ramp.

OTHER DMS MESSAGE ISSUES—FOCUS GROUP STUDY SUMMARY OF RESULTS

In addition to the information needs or the primary situations discussed previously, the researchers took the opportunity of the focus groups to examine other DMS message issues that are either currently unresolved or should be explored to validate previous research findings. Limitation of administration time did not allow further assessment in the human factors laboratory studies. The additional issues examined were:

- use of the term CRASH versus ACCIDENT,
- use of the phrase RIGHT (LEFT) 2 LANES CLOSED versus 2 RIGHT (LEFT) LANES CLOSED,
- interpretation of the phrase TRUCK ACCIDENT versus MAJOR ACCIDENT,
- formatting two-phase messages containing four units of information,
- understanding of USE OTHER ROUTES,
- blank DMSs, and
- public service announcements.

ACCIDENT versus CRASH

All of the participants preferred the term ACCIDENT over CRASH. Several reasons commonly given by the participants for this preference included:

- CRASH sounds like slang or is juvenile,
- ACCIDENT is a more familiar term for this situation, and
- CRASH reminded some of the participants of an airplane incident.

RIGHT 2 LANES versus 2 RIGHT LANES

Five of the six focus groups preferred RIGHT 2 LANES CLOSED. The reasoning for this preference was that the direction was the most important part of the information. For the group that preferred 2 RIGHT LANES CLOSED, they believed that the number should be at the front of the line; otherwise, it gets lost in the text.

TRUCK ACCIDENT versus MAJOR ACCIDENT

All of the participants preferred MAJOR ACCIDENT as the incident descriptor. The groups believed that this would cover a severe situation, including an incident that would cause multiple hours of delay for the driver. Other comments in support of this were that TRUCK ACCIDENT could imply that only a single small truck was involved in the crash, which is not necessarily a serious situation. It was also commented that the term MAJOR covers more situations that might occur on the roadway and that the specific circumstances of the incident (i.e., that a truck is involved) are not critical for the driver to know.

Format for Two-Phase, Four-Unit Messages

The two DMS messages shown below were presented to the participants.

I 35 ACCIDENT AT EVANS RD	**USE OTHER ROUTES**
Phase 1	*Phase 2*

Message 1

ACCIDENT AT EVANS RD	**RGT 2 LANES CLOSED USE OTHER ROUTES**
Phase 1	*Phase 2*

Message 2

The majority of the groups (4 of 6) preferred message 2. Message 2 was preferred primarily because it provides the driver with information regarding which lanes are closed due to the incident. For the two groups that preferred a different message, they believed message 1 was shorter and simpler. However, one of groups that preferred message 1 eliminated the highway name from this message to suit their preferences. Overall, 87 percent of the participants believed that the message did not need to include the name of the highway if it was the same road that the driver was traveling on.

Understanding of USE OTHER ROUTES

Eighty-four percent of the participants believed that USE OTHER ROUTES was a suggestion and not a requirement for the driver. Suggestions as to how to make diversion a requirement included:

- MUST USE OTHER ROUTES,
- DETOUR [road name], and
- CLOSED.

Public Service Announcements

Five of the six focus groups agreed that they preferred to have public service announcements (PSAs) displayed on the DMS versus seeing them blank. In San Antonio they specified that although the DMSs should be used for messages rather than being blank, the only messages that should be allowed would be related to driver safety or traffic information. Also, in Houston, the entire group agreed that before using PSAs, they would prefer to see travel time information displayed. However, all of the groups agreed that if PSAs are used, the messages must be changed frequently to ensure that people continue to pay attention to the DMSs. Five of the groups agreed that the messages should be changed daily.

RECOMMENDATIONS

Based on the results of the focus group and laboratory studies, the recommendations listed below are offered.

AMBER Alerts

1. No clear preference was determined for the following situation descriptors: AMBER ALERT, KIDNAPPED, ABDUCTED, and MISSING. However, it is recommended that the term MISSING not be used for this situation.

2. When possible, a message should include a detailed description of the vehicle involved in the situation.

3. When there is a need to display a telephone number, short numbers (e.g., 511) or easily remembered call letters (e.g., 1 FIND A CHILD) are recommended for these messages.

4. Use of the message element TUNE TO RADIO or a specific radio station indicator is recommended as a means of providing motorists with further details regarding the situation.

Floods

1. Messages should be displayed when there is standing water on the road, even if the water is passable. The situation descriptor WATER ON ROAD may be used in this situation.

2. If water on the road is impassable, use of either the term CLOSED or FLOODED is recommended to alert drivers to exit the roadway.

3. Flood messages should include action terms (specifically exit information) and use street names over exit numbers in reference to exit information.

4. If a roadway indicator is to be included in the messages, it should be the first line of the message and have the format of I-XX [*direction*].

Ozone

1. If the alert is for other than current conditions (i.e., conditions tomorrow), specify this in the message.

2. Include driving behavior suggestions in the message.

Incident Location

1. Use any of the terms PAST, BEYOND, or AT to indicate that the incident is after the referenced cross street exit ramp.

2. Use PAST or BEYOND to indicate that the incident is after the cross street.

3. Use the term BEFORE if it is not possible to use the referenced street exit ramp.

4. Any of the term combinations studied (FROM/TO, BETWEEN/AND, and BEYOND/TO) indicate a start point that is past the first referenced street exit and the incident area that ends prior to the entrance ramp from the second referenced street.

5. DYNAMIC MESSAGE SIGN MESSAGE DESIGN AND DISPLAY MANUAL

BACKGROUND

The *Dynamic Message Sign Message Design and Display Manual* (*19*) that was developed as part of Project 0-4023 was designed for use by personnel in TxDOT who have responsibility for the operation of and/or message design for large permanent or portable DMSs. The manual was written to help both new and experienced users of DMSs at various levels of the agency including:

- entry level personnel,
- personnel very experienced with traffic operations, and
- managers.

It provides very specific information for entry-level personnel, reminders for experienced personnel, and higher-level information for managers regardless of whether or not they work in one of the TMCs in the state.

The design and display of messages on DMSs introduce many challenges to transportation agencies. The following paragraphs briefly summarize some of the relevant issues involved.

Dynamic message signs, previously termed changeable message signs (CMSs) and sometimes referred to as variable message signs (VMSs), are one of the primary links a transportation agency has to the motoring public it serves. Although they have been in existence for more than 40 years in some parts of the United States, only the recent emphasis and financial support of the ITS legacy has allowed most state transportation departments to purchase them and build the electronic monitoring systems necessary to operate them as a key component in an Advanced Transportation Management System.

Since they represent many motorists' primary concept of ITS, improperly designed messages or operation of DMSs will have negative impacts on the public's perception of ITS in general. It is imperative that TxDOT districts take steps to ensure that the content, format, and application of information on the DMSs under their jurisdictions are of the highest possible quality and consistency statewide. The fact that DMSs are operated by different TMCs in different cities should be transparent to motorists as they travel from one region of the state to the other.

The design and display of messages on DMSs introduce many challenges. Recommendations to meet these challenges are presented in the manual. The manual includes the latest objective data and information that meet the specific needs of TxDOT.

DMS MESSAGE DESIGN PROCESS

The *Dynamic Message Sign Message Design and Display Manual* was written with a focus on the design of effective DMS messages for incident conditions and roadwork, and when and where to display messages. This emphasis is intentional for the following reason: DMS operations require the user to have a good understanding of not only traffic operations but also a working knowledge of how messages are designed. The DMS message design procedure in the manual, in effect, helps the user to learn more about traffic operations and to understand the strengths, limitations, and possible consequences of the messages the operator displays.

Emphasis is given throughout the manual on effective message designs for DMSs located on:

- the same freeway and relatively close to the incident or roadwork,
- the same freeway but relatively far from the incident or roadwork, and
- a different freeway than the incident or roadwork.

The DMS message design process begins with the development of a Base DMS Message using guidelines of acceptable words and message terms for either incident or roadwork events. The Base DMS Message is the sum total of all the information that motorists need on a DMS in order to make a fully informed driving decision (e.g., whether to take an alternative route). In most cases, the Base DMS Message must be shortened because it will exceed the amount of information that motorists can read and comprehend in the short time they have available to read the message, or the message will exceed the amount of information that can physically fit on the DMS.

The maximum length of message that can be displayed on a DMS depends on how far away motorists can adequately view the message and on their perception and information processing capabilities. Viewing distance will be affected by the type of sign used (light-emitting diode [LED], fiberoptic, etc.), the sun position, geometric design, and environmental conditions at the DMS location. Travel speed will affect the amount of information that motorists can read and comprehend.

Guidance is given in the manual in tables on the maximum number of units of information that can be displayed on a DMS based on type of DMS, travel speed, and sun position. In some cases when portable DMSs are used, it may be necessary to reduce the maximum number of units of information (using tables in the manual) because of sight distance restrictions to the DMS due to vertical grades or horizontal curves. Additional guidelines are given for sight distance restrictions to the DMS because of fog or heavy rain.

After the maximum number of units of information that should be displayed on a DMS is determined, detailed guidance is provided to shorten the Base DMS Message so that the maximum is not exceeded while keeping the most important information in the message. The process provides for consistency of information and format. Furthermore, the process assures that motorists will be able to read and understand the messages. The underlying objective is to keep messages as complete and concise as possible.

OVERVIEW OF MANUAL MODULES

The *Dynamic Message Sign Message Design and Display Manual* contains the following 22 modules and four appendices:

- Module 1. Introduction;
- Module 2. Principles of DMS Operations;
- Module 3. DMS Operating Fundamentals;
- Module 4. Principles of DMS Message Design;
- Module 5. Designing the Base DMS Message for Incidents;
- Module 6. Designing the Base DMS Message for Roadwork;
- Module 7. Establishing the Maximum Message Length;
- Module 8. Dealing with Long Messages;
- Module 9. Designing DMS Messages for Incidents;
- Module 10. Designing DMS Messages for Roadwork;
- Module 11. Quick Reference Guide for Designing DMS Messages;
- Module 12. Modifying Messages to Improve Effectiveness;
- Module 13. Priorities When Competing Message Needs Arise;
- Module 14. Message Design Examples for Incidents: Large DMS;
- Module 15. AMBER Alert;
- Module 16. Catastrophic Event;
- Module 17. High Water and Floods;
- Module 18. Ozone;
- Module 19. Planned Special Events;
- Module 20. Hurricane Evacuation;
- Module 21. DMS Operations Policies;
- Module 22. DMS Operations Procedures and Guidelines;
- Appendix A Message Length Reductions for Vertical Curves;
- Appendix B. Message Length Reductions for Horizontal Curves;
- Appendix C. Message Length Reductions for Rain and Fog; and
- Appendix D. Effects of Large Trucks on DMS Legibility.

As discussed below, Modules 5, 6, 9, and 10 address details of the DMS message design processes for incidents and roadwork. These modules were written in a style to simplify the message design process for the DMS message designer. In addition, the intent was to reduce the amount of information the user has to search within the manual when messages are designed. As such, the user will find a degree of repetition if Modules 5, 6, 9, and 10 are read from the beginning to the end. The manual user will recognize the value of the repetition in these modules when messages are actually designed. A summary of the type of material covered in each module is provided below.

Module 1. Introduction

The first module includes a discussion of the background and significance of the *Dynamic Message Sign Message Design and Display Manual*. The importance of the design of effective DMS messages is discussed, and the message design process is summarized.

Module 2. Principles of DMS Operations

Base principles of DMS operations including the use of DMSs and the importance of maintaining DMS credibility are presented in the second module.

Module 3. DMS Operating Fundamentals

Module 3 contains a discussion of the five basic considerations when operating DMSs. These are:

1. determine the purpose for using a DMS,
2. determine which DMS(s) is (are) appropriate to use,
3. determine what to display on the DMS,
4. determine how long to display the message, and
5. resolve any message signing conflicts that exist.

Module 4. Principles of DMS Message Design

Basic principles for designing DMS messages are presented in Module 4. It contains an overview of issues for message design, discussion of selecting the audience for the message, and definitions and message design considerations. Details are given for the first step in the DMS message design process: the design of the Base DMS Message needed to satisfy motorist information needs when the DMS is used to advise motorists of an accident or roadwork. Meanings of words and phrases based on human factors research are also given. The module also includes classification, definition, and discussion of six types of diversion routes that might apply in a diversion situation.

Module 5. Designing the Basic DMS Message for Incidents

Module 5 is devoted to presentation of the details, including message elements and words or terms, for designing the Base DMS Message when the sign is used to advise motorists of incidents. It includes detailed guidelines for 1) lane-closure (blockage) incidents, 2) incidents that block all the lanes, and 3) incidents that require closing the freeway. The guidelines are addressed for DMSs located on 1) the same freeway and relatively close to the incident or closure, 2) the same freeway but relatively far from the incident or closure, and 3) a different freeway than the incident or closure.

The user of the manual will find a degree of repetition in this module. The repetition is necessary in order to allow the user to reference successive pages when designing a message for the specific DMS location relative to the incident (i.e., relatively near, relatively far, on a different freeway) rather than shuffling through several sections of the manual.

Module 6. Designing the Basic DMS Message for Roadwork

Module 6 is similar to Module 5 with the exception that it addresses the design of the Base DMS Message when the sign is used to advise motorists of roadwork. Also, similar to Module 5, the manual user will find a degree of repetition in this module. The repetition is necessary in order to allow the user to reference successive pages when designing a message for the specific DMS location relative to the roadwork (i.e., relatively near, relatively far, on a different freeway) rather than shuffling through several sections of the manual.

Module 7. Establishing the Maximum Message Length

Guidelines for the maximum DMS message length in terms of the maximum number of units of information that can be displayed are given in Module 7 based on DMS type, travel speed, and sun position. Guidelines for reducing this maximum on LED DMSs due to adverse vertical grades, horizontal curves, rain, or fog are also presented. A discussion and data concerning the number of motorists who may fail to read the DMS message because of the presence of trucks in the traffic stream are also given.

Module 8. Dealing with Long Messages

In most cases, the Base DMS Message designed in Modules 5 and 6 and reduced in length based on data in Module 7 will exceed the amount of information that motorists can read and comprehend in the short time they have available to read the message, or will exceed the amount of information that can physically fit on the DMS. Module 8 contains guidelines for several ways to reduce the message length and units of information. It includes guidelines on using abbreviations, deleting "dead" words, reformatting the message, and combining message elements. Guidelines for splitting a message onto two phases when the message is too long to fit on one phase are also presented.

Module 9. Designing DMS Messages for Incidents

A detailed step-by-step procedure for designing DMS messages for incidents is provided in Module 9. It includes detailed procedures for 1) lane-closure (blockage) incidents, 2) incidents that block all the lanes, and 3) incidents that require closing the freeway. The procedures are given for DMSs located on 1) the same freeway and relatively close to the incident or closure, 2) the same freeway but relatively far from the incident or closure, and 3) a different freeway than the incident or closure.

Module 10. Designing DMS Messages for Roadwork

Module 10 is similar to Module 9, with the exception that it addresses designing DMS messages when the sign is used to advise motorists of roadwork.

Module 11. Quick Reference Guide for Designing DMS Messages

The objective of Module 11 is to provide a quick reference guide for designing and selecting DMS messages. It is intended for TMC supervisory personnel and for DMS operators who have considerable experience with using the guidelines in Modules 9 and 10.

Module 12. Modifying Messages to Improve Effectiveness

Module 12 is a quick reference guide illustrating how messages that violate good and sound principles for effective design can be improved. The module includes examples of both incident and roadwork messages.

Module 13. Priorities When Competing Message Needs Arise

Occasionally, two or more events occur simultaneously that require a decision as to which event should be displayed on the DMS. Module 13 contains a set of tables to help the DMS operator establish signing priority.

Module 14. Message Design Examples for Incidents: Large DMS

Two examples are given that illustrate how Module 9 is used to design DMS messages for large DMSs when incidents occur that close all the lanes of a freeway.

Module 15. AMBER Alert

Federal and State of Texas policies are discussed as well as the importance of statewide coordination of AMBER alert DMS messages. Recommended information elements that should be included in an AMBER alert message and recommended message design for a variety of scenarios are presented.

Module 16. Catastrophic Event

Brief discussions of the National Incident Management System, Texas Office of Homeland Security, Governor's Division of Emergency Management, and State Operations Center are presented. Federal policy on displaying DMS messages for emergencies and security is also presented. Recommendations are given for effective DMS message design during catastrophic events.

Module 17. High Water and Floods

Driver information needs and recommended DMS message design are given for situations when high water is on the freeway but drivers are still able to pass through, and when the freeway is flooded and drivers are not able to continue on the freeway.

Module 18. Ozone

Module 18 contains DMS design recommendations for ozone alerts on the day prior to an ozone action day and the day of the ozone action day.

Module 19. Planned Special Events

Module 19 contains a listing and discussion of the categories of planned special events. Typical DMS messages for drivers who are traveling to the event and those not traveling to the event but are impacted by the event traffic are shown.

Module 20. Hurricane Evacuation

A brief discussion is presented concerning the focus group studies that were conducted as part of Project 0-4023. Given that following the focus group studies, Hurricane Rita impacted the Texas

Gulf Coast and resulted in mass evacuation from major cities, it was deemed desirable to take advantage of the plight and evacuation experiences. A recommendation was made that Module 20 be completed after the results of further study in Project 0-4296 become available.

Module 21. DMS Operations Policies

Module 21 is divided into two major parts. The first part contains summaries of available DMS operations policies and guidelines at the federal level. In the second part, guidelines are presented to assist TxDOT in developing statewide and regional policies for the operation of DMSs. Twenty-four candidate policy issues are presented. The following information is given for each of the issues:

- an explanation of the policy,
- a policy statement example that TxDOT can use in developing a policy, and
- a discussion of justification and/or considerations that may influence TxDOT's decision to elect to include the statement in its policies.

Module 22. DMS Operations Procedures and Guidelines

Module 22 contains a listing and discussions of items that TxDOT may want to include in a manual on DMS operations procedures and guidelines.

Appendix A. Message Length Reductions for Vertical Curves

The theory and procedure for determining the sight distance to a DMS when there are restrictions because of a vertical curve are presented in Appendix A. Four examples using the procedure in Appendix A are also included.

Appendix B. Message Length Reductions for Horizontal Curves

The theory and procedure for determining the sight distance to a DMS when there are restrictions because of a horizontal curve are presented in Appendix B. Two examples using the procedure in Appendix B are also included.

Appendix C. Message Length Reductions for Rain and Fog

The theory and procedure for determining the sight distance to a DMS when there are visual restrictions because of a heavy rain or fog are presented in Appendix C. An example illustrating the procedure is included.

Appendix D. Effects of Large Trucks on DMS Legibility

The theory and procedure for determining the effects of large trucks on DMS legibility are presented in Appendix D. Two examples illustrating the procedure are included.

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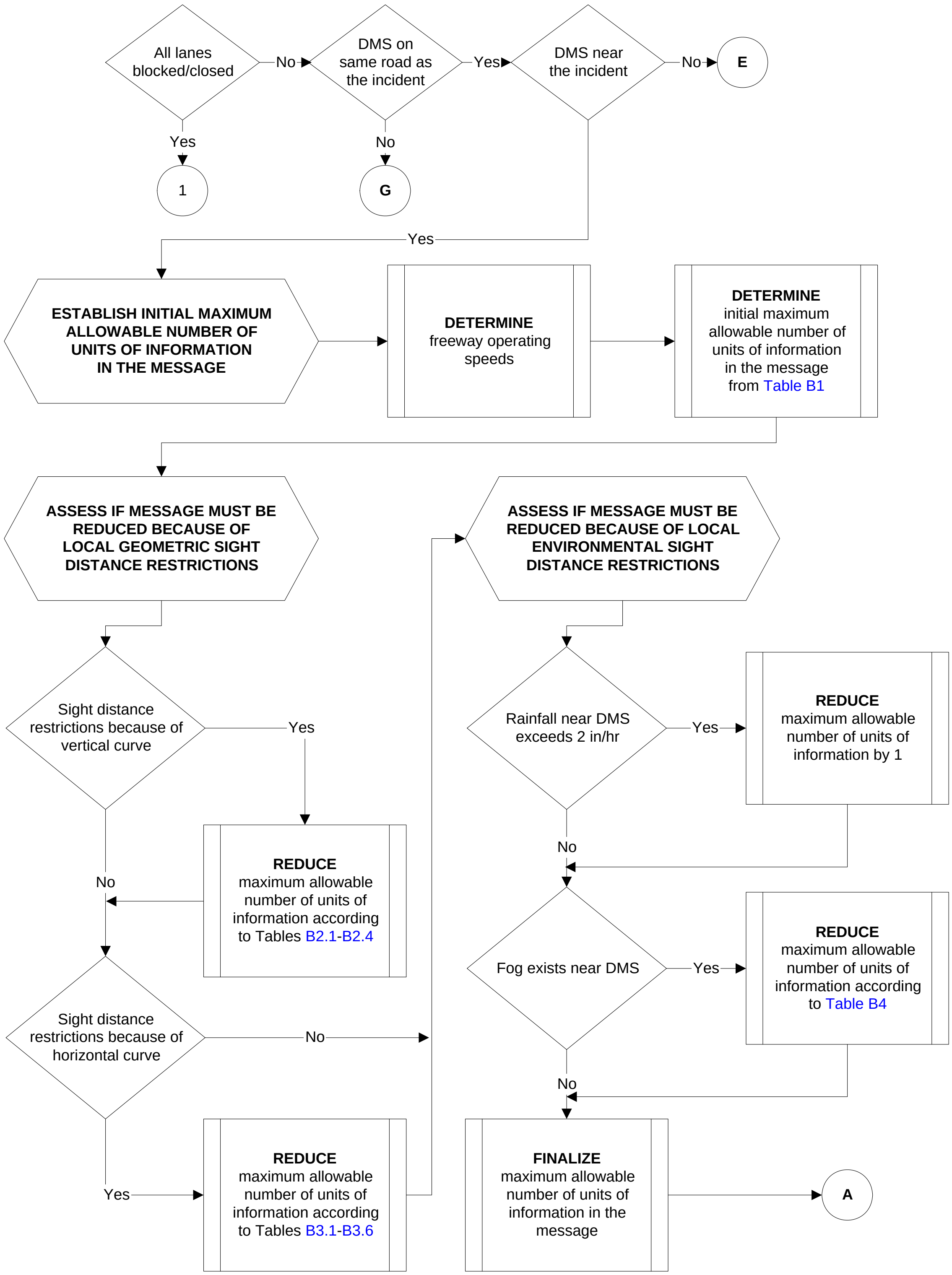
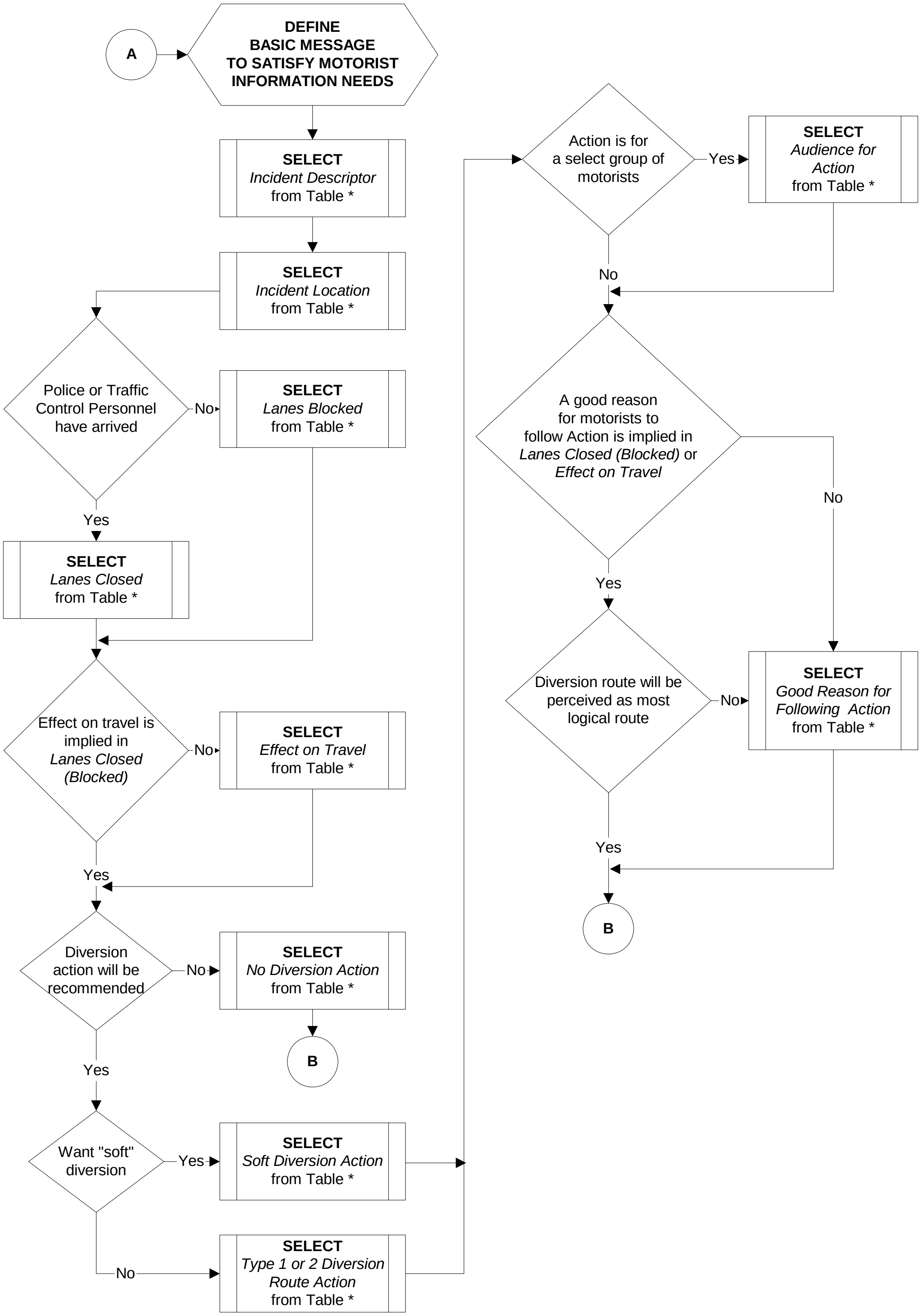
APPENDIX A—DMS MESSAGE DESIGN FOR INCIDENTS AND ROADWORK



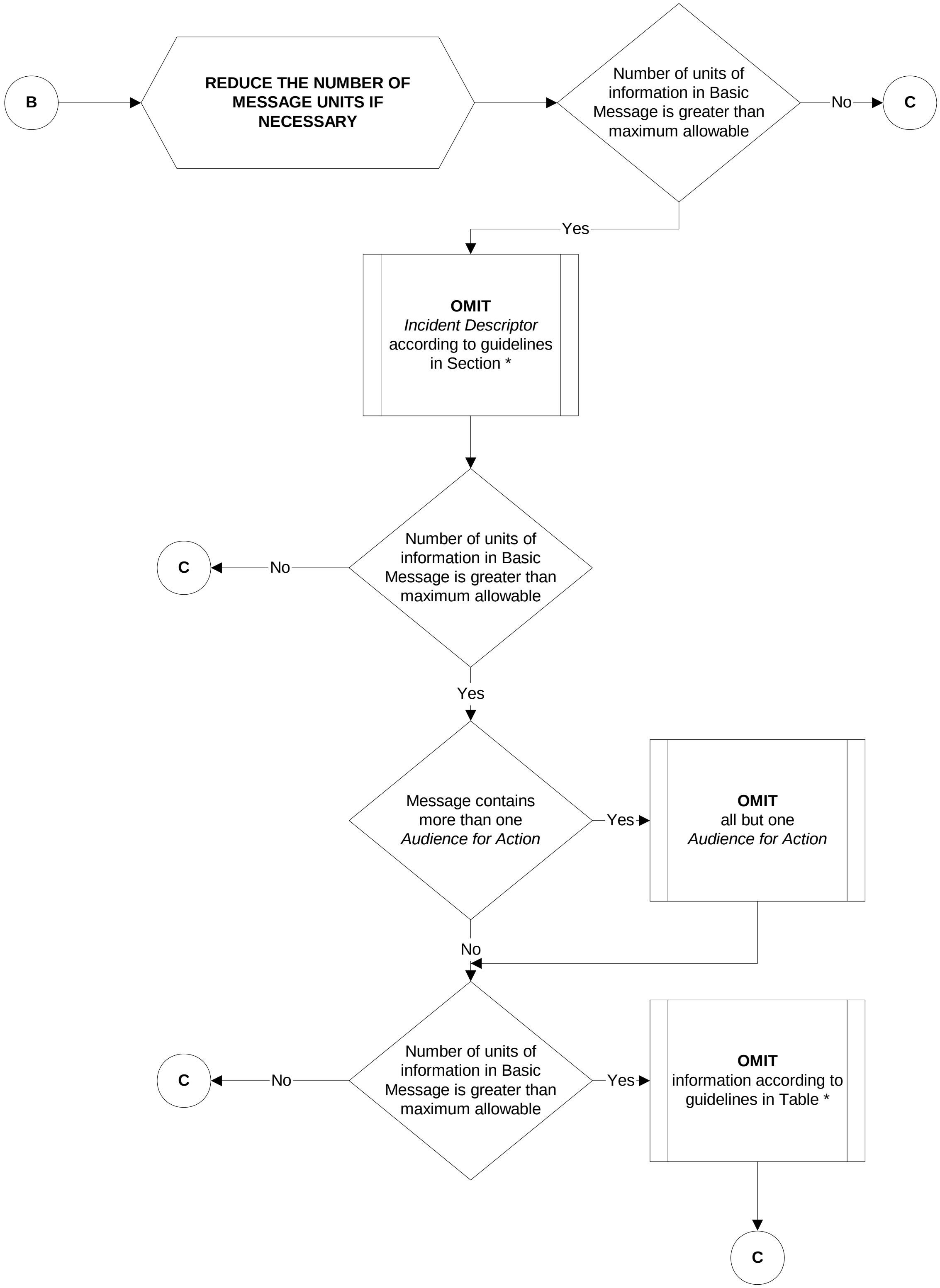
(a) Lane Closure (Blockage)

Figure 2. DMS Message Design Flow Chart for Incidents.



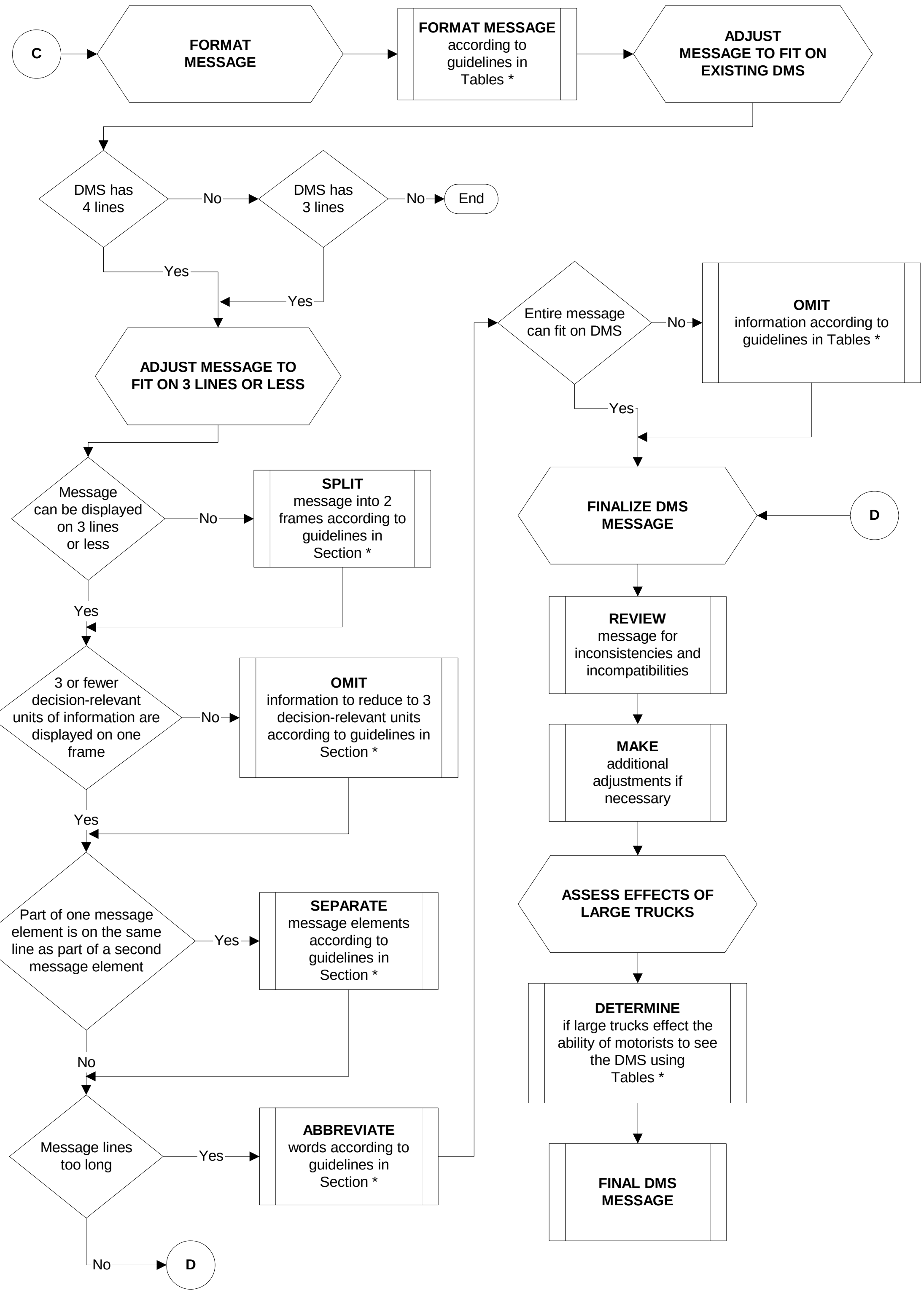
(a) Lane Closure (Blockage)

Figure 2. DMS Message Design Flow Chart for Incidents (Continued).



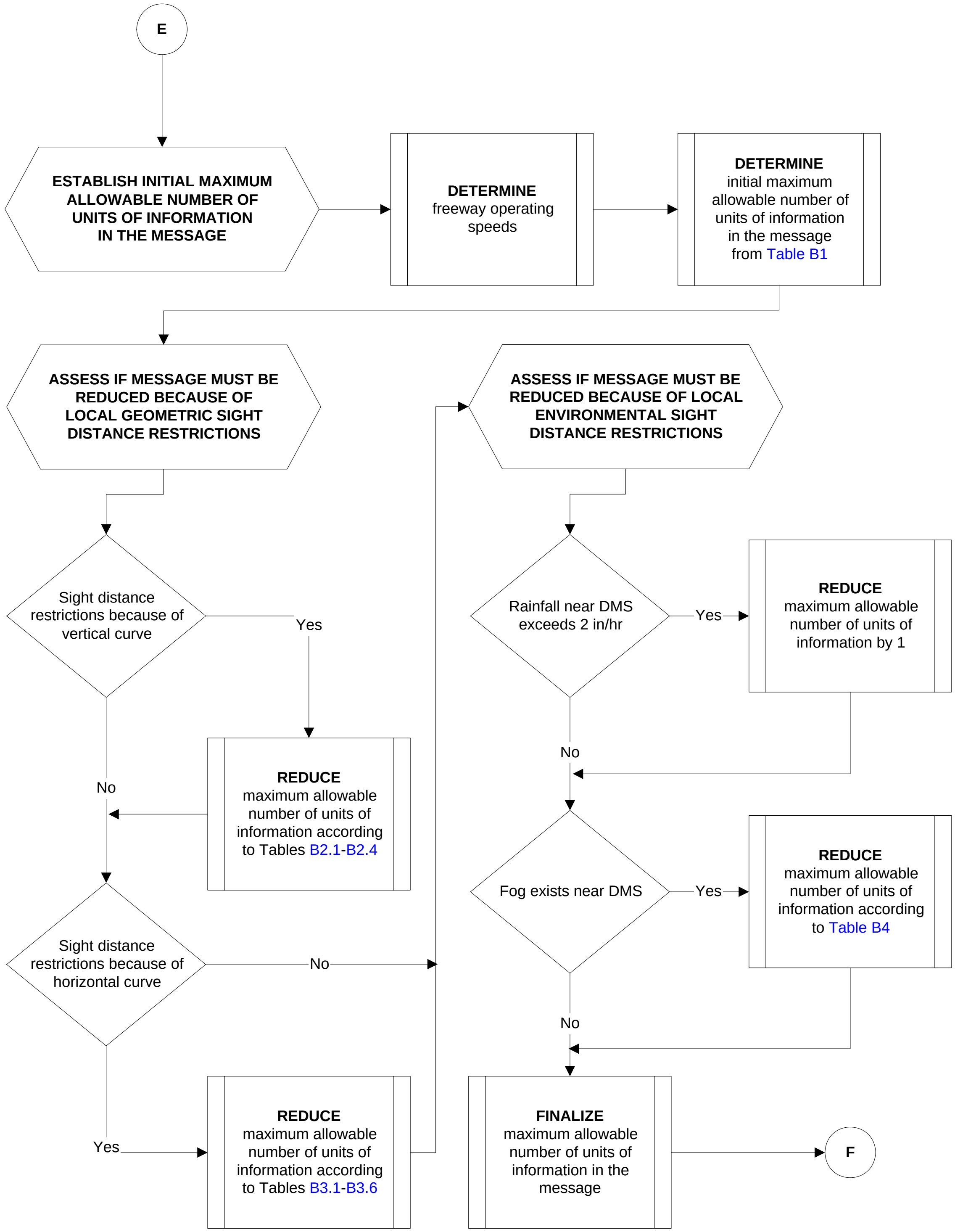
(a) Lane Closure (Blockage)

Figure 2. DMS Message Design Flow Chart for Incidents (Continued).



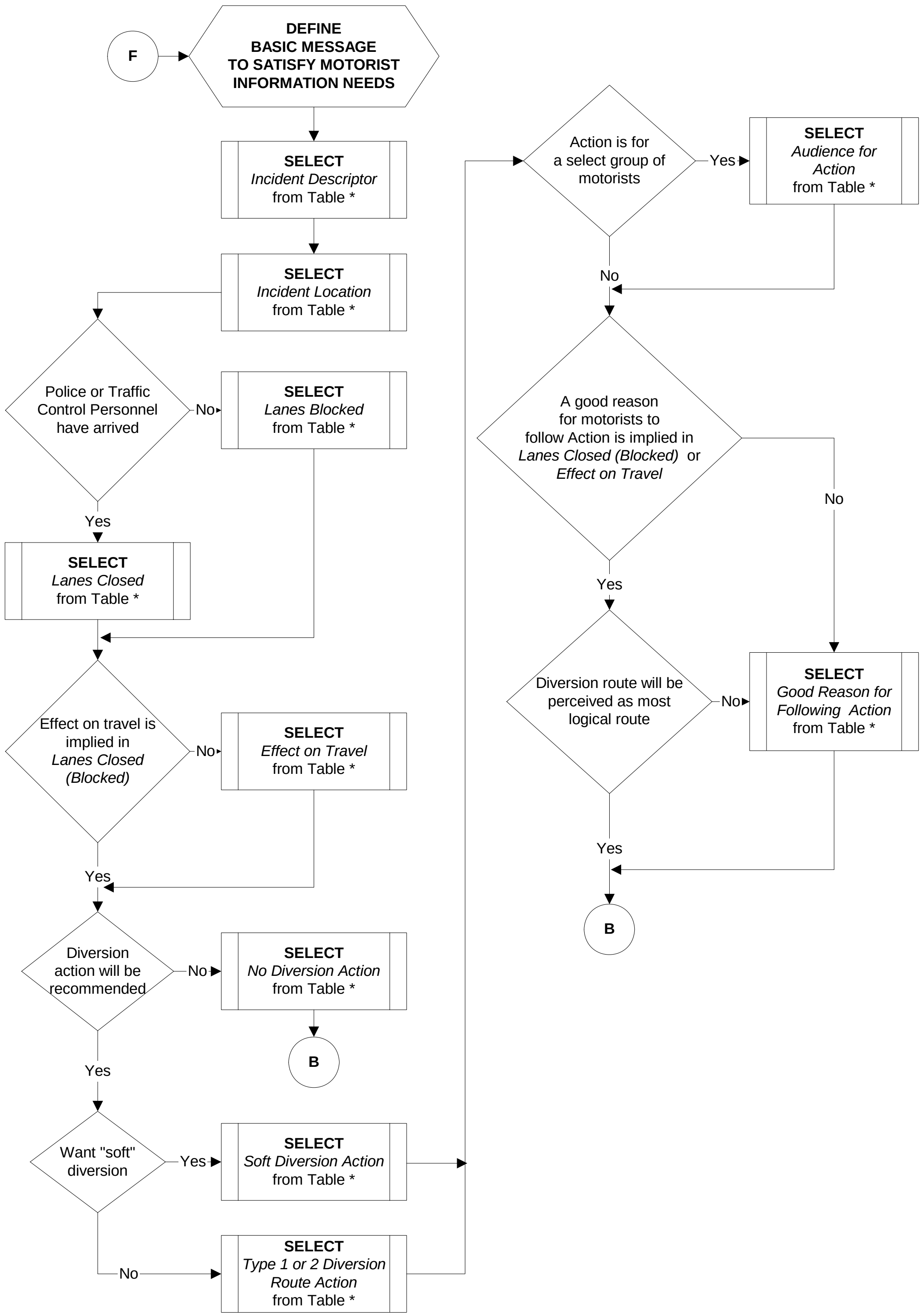
(a) Lane Closure (Blockage)

Figure 2. DMS Message Design Flow Chart for Incidents (Continued).



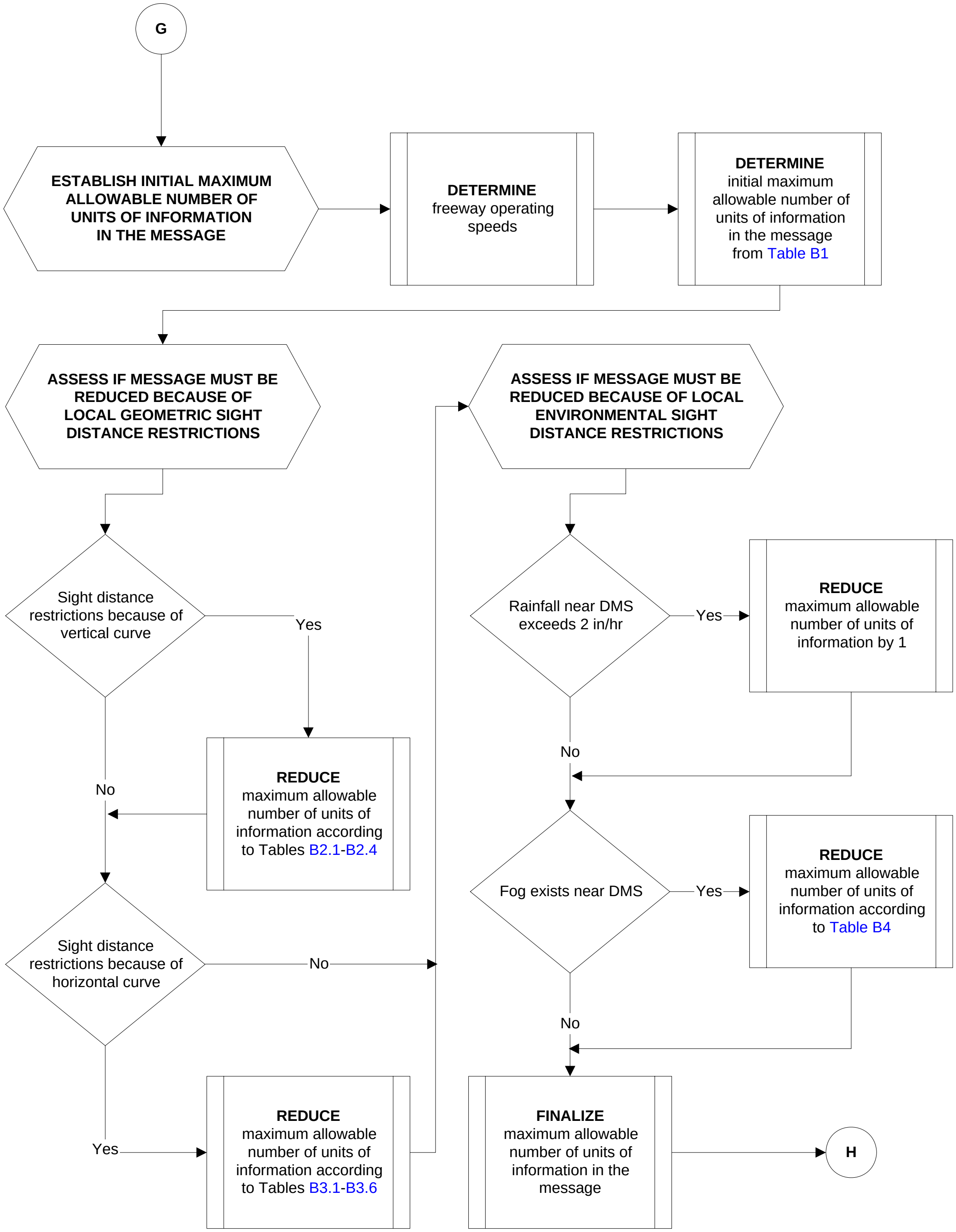
(a) Lane Closure (Blockage)

Figure 2. DMS Message Design Flow Chart for Incidents (Continued).



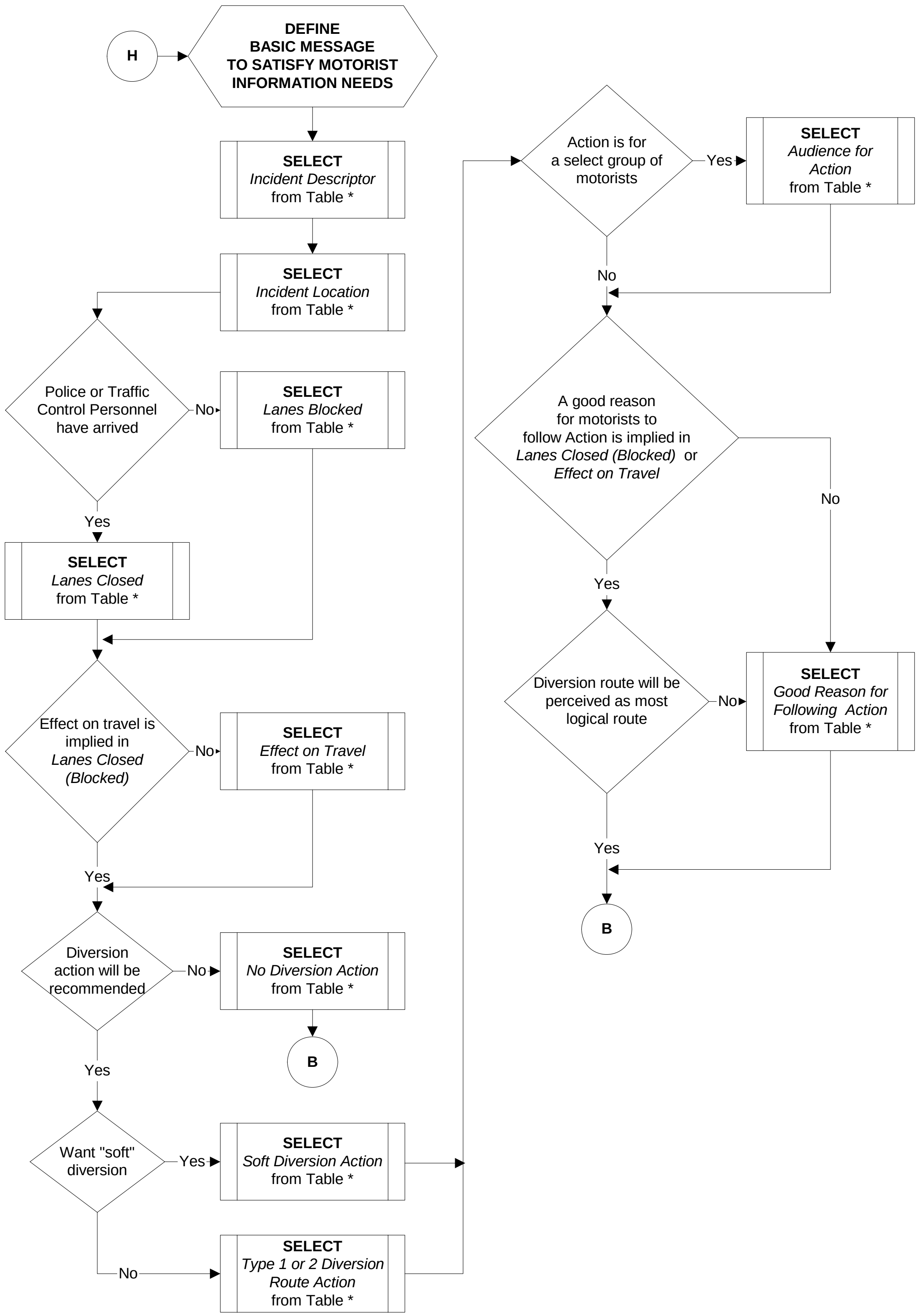
(a) Lane Closure (Blockage)

Figure 2. DMS Message Design Flow Chart for Incidents (Continued).



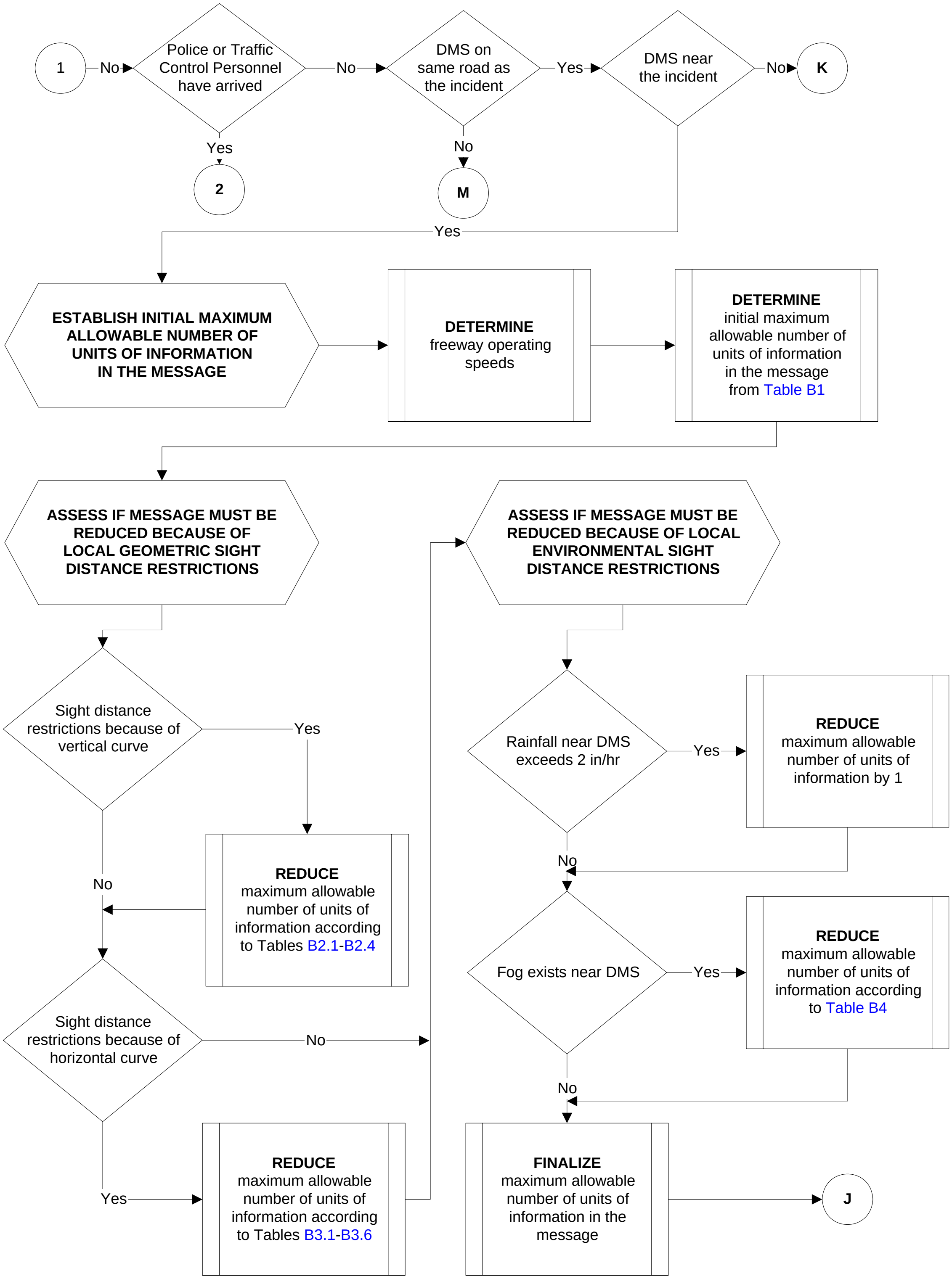
(a) Lane Closure (Blockage)

Figure 2. DMS Message Design Flow Chart for Incidents (Continued).



(a) Lane Closure (Blockage)

Figure 2. DMS Message Design Flow Chart Incidents (Continued).



(b) Block All Lanes

Figure 2. DMS Message Design Flow Chart for Incidents (Continued).

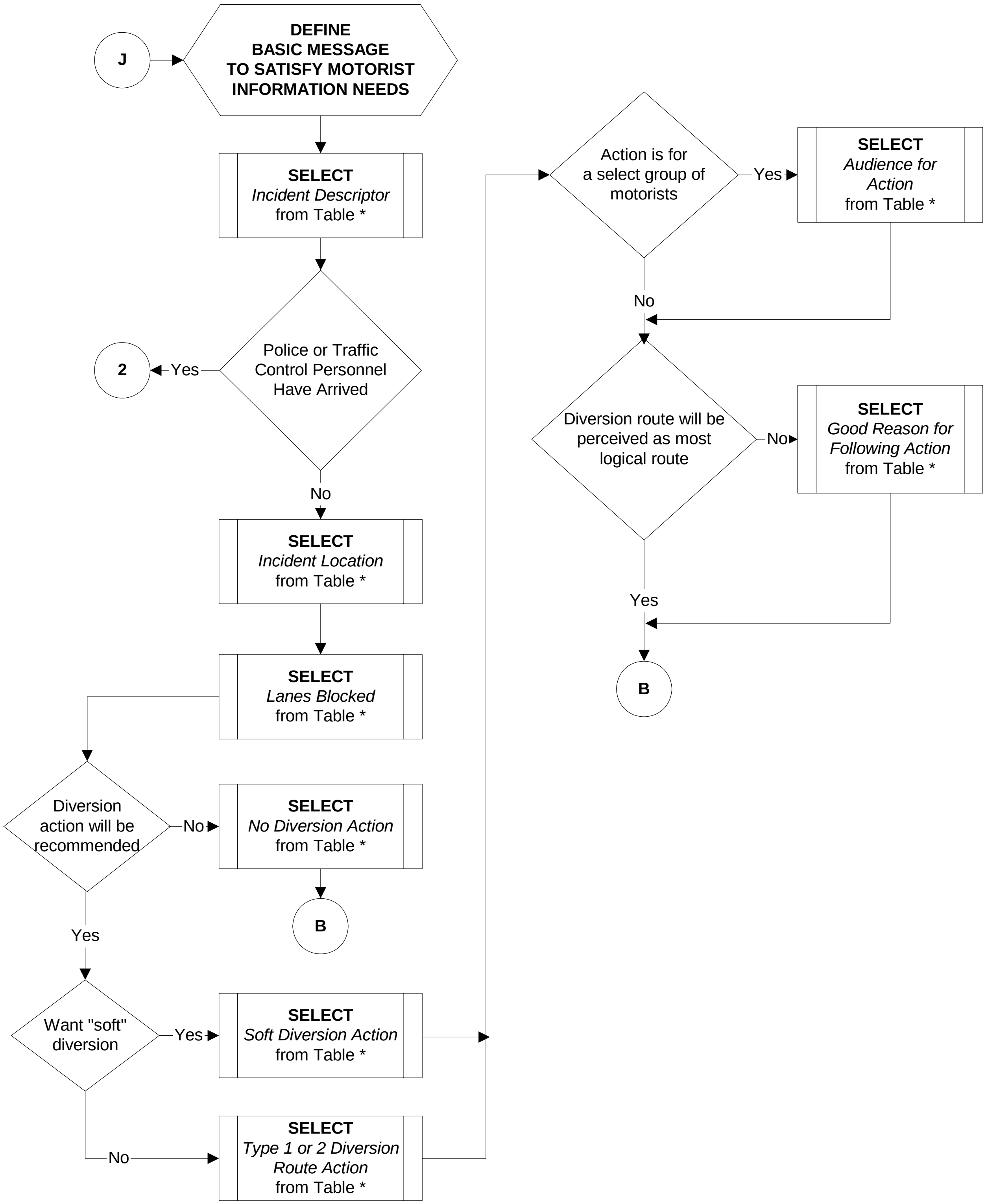


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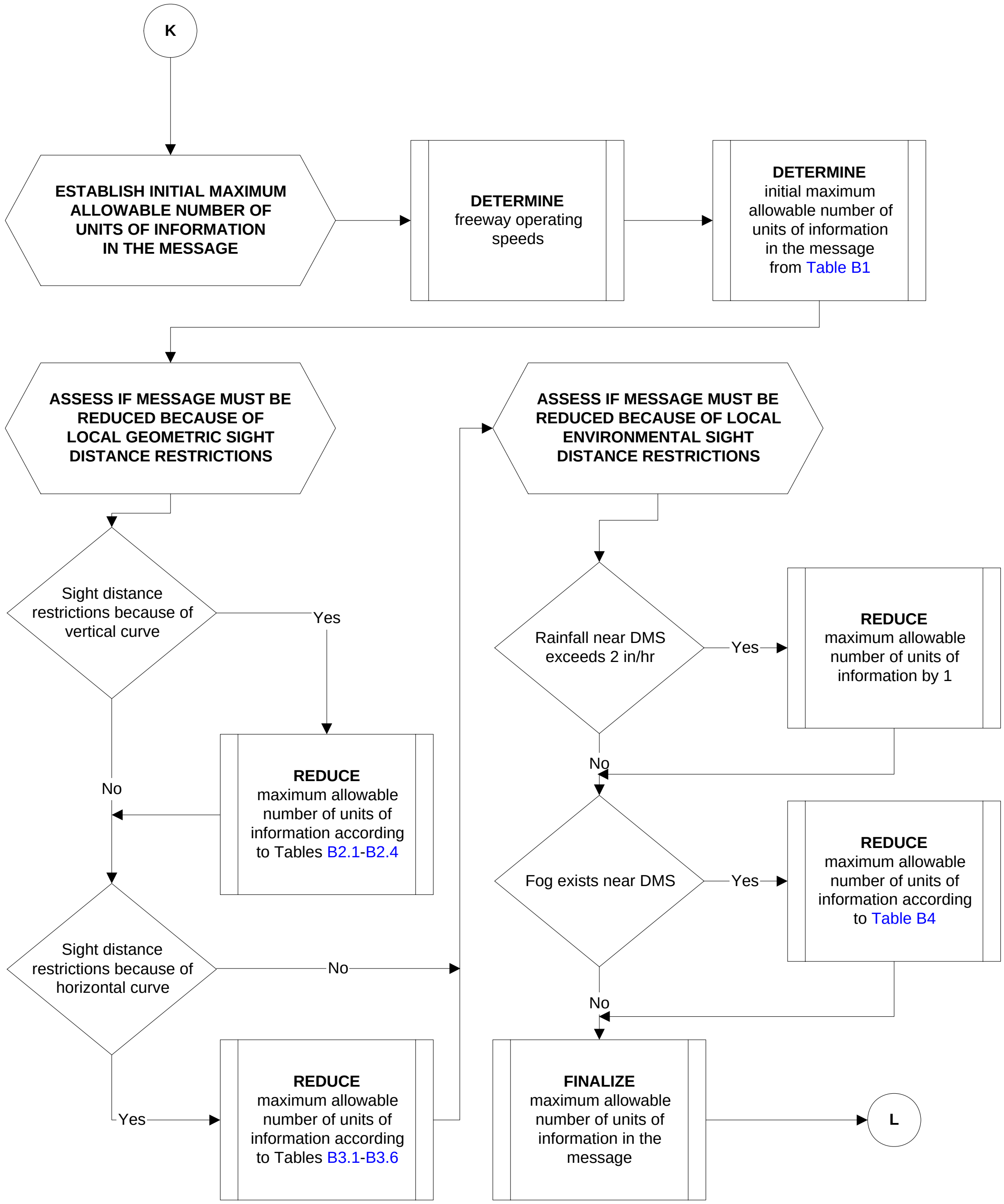
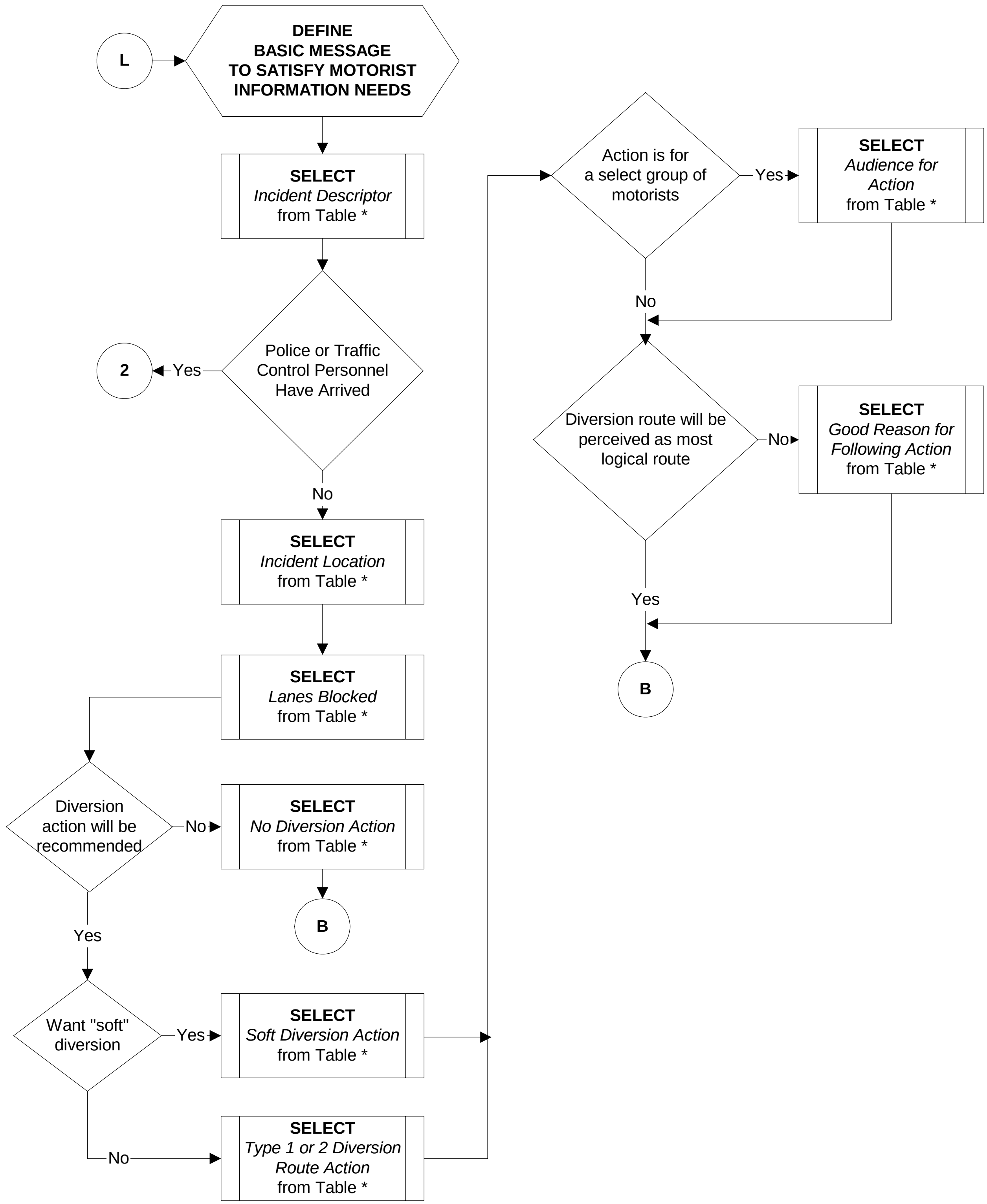
Figure 2. DMS Message Design Flow Chart for Incidents (Continued).



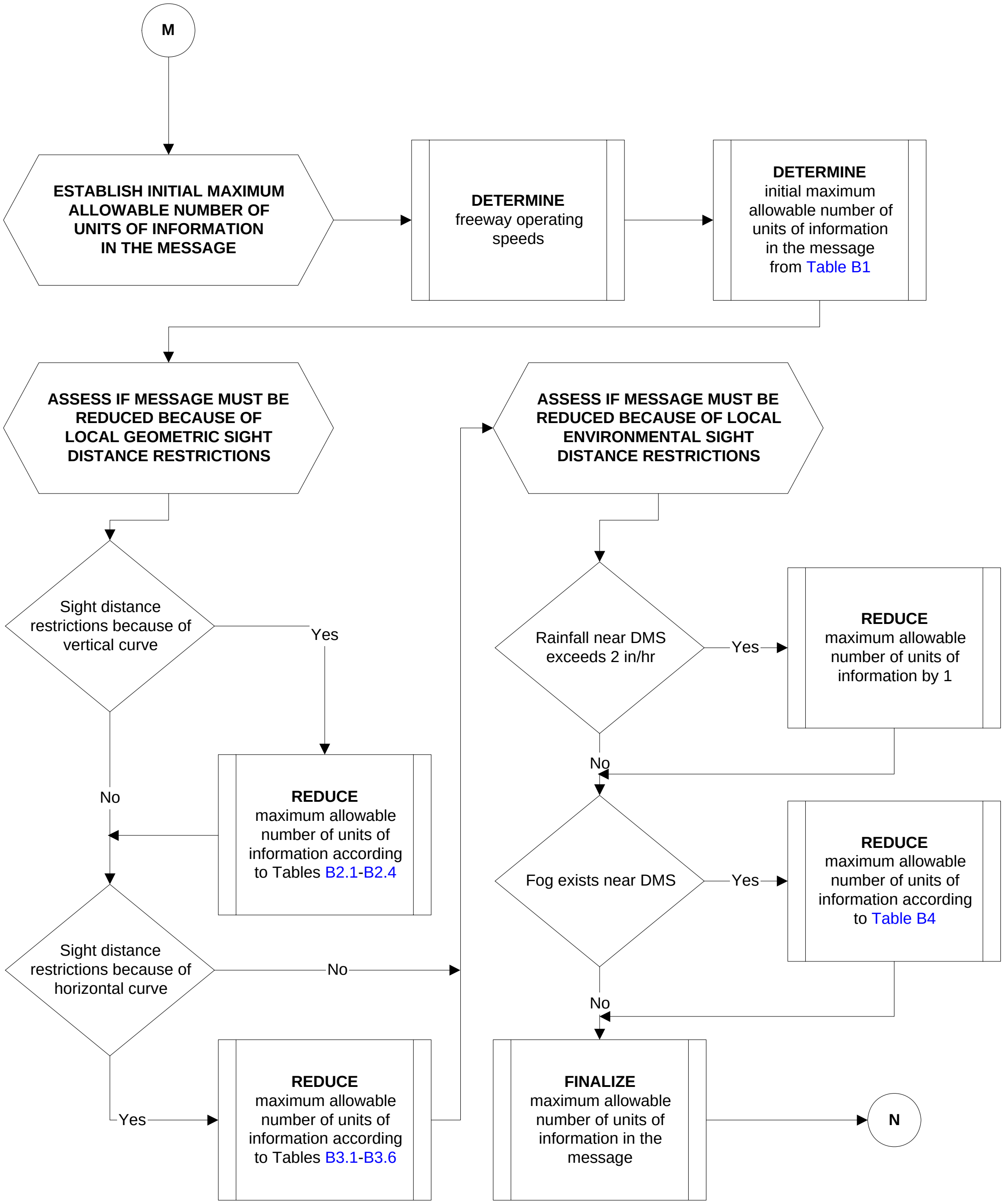
(b) Block All Lanes

Figure 2. DMS Message Design Flow Chart for Incidents (Continued).



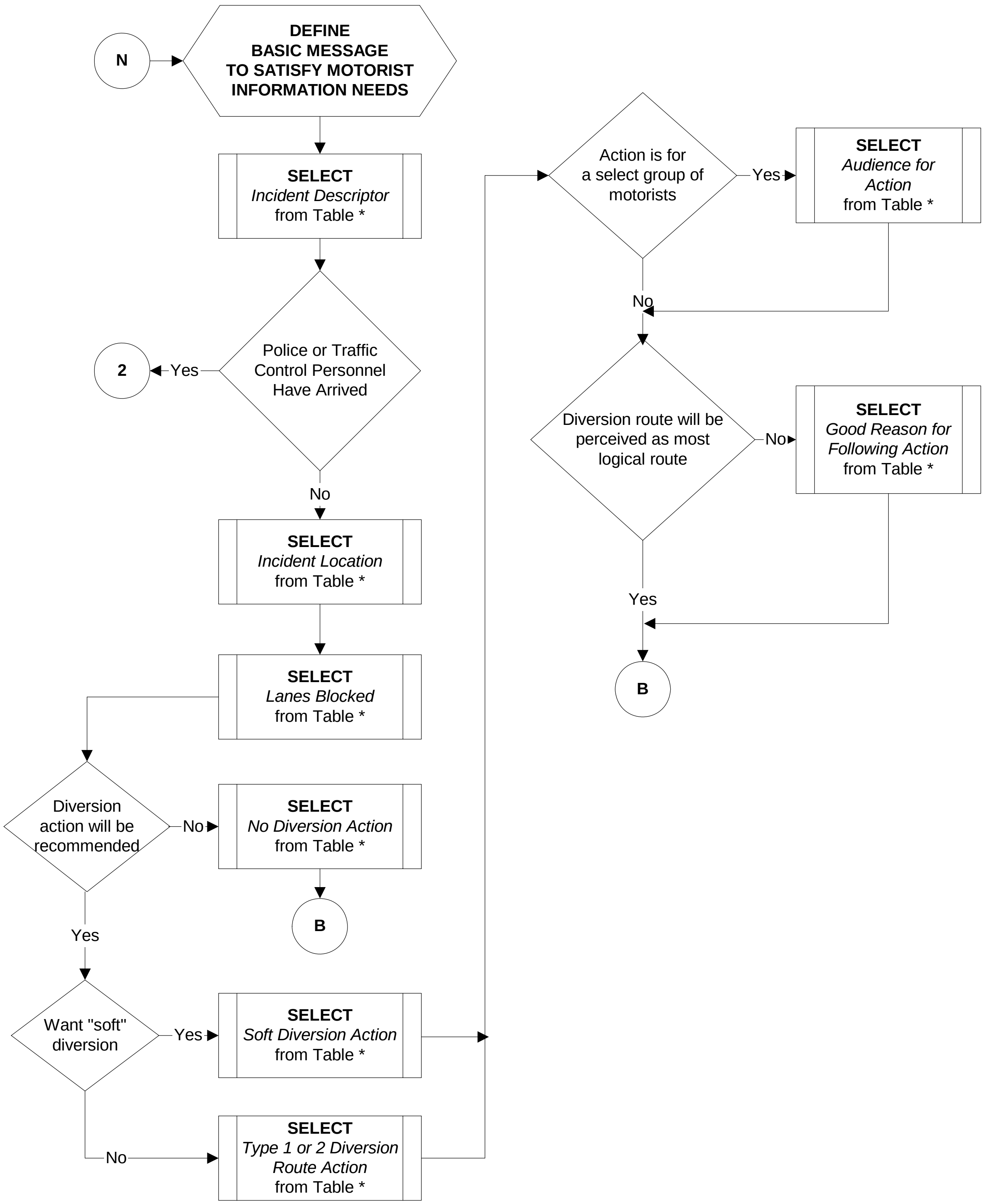
(b) Block All Lanes

Figure 2. DMS Message Design Flow Chart for Incidents (Continued).



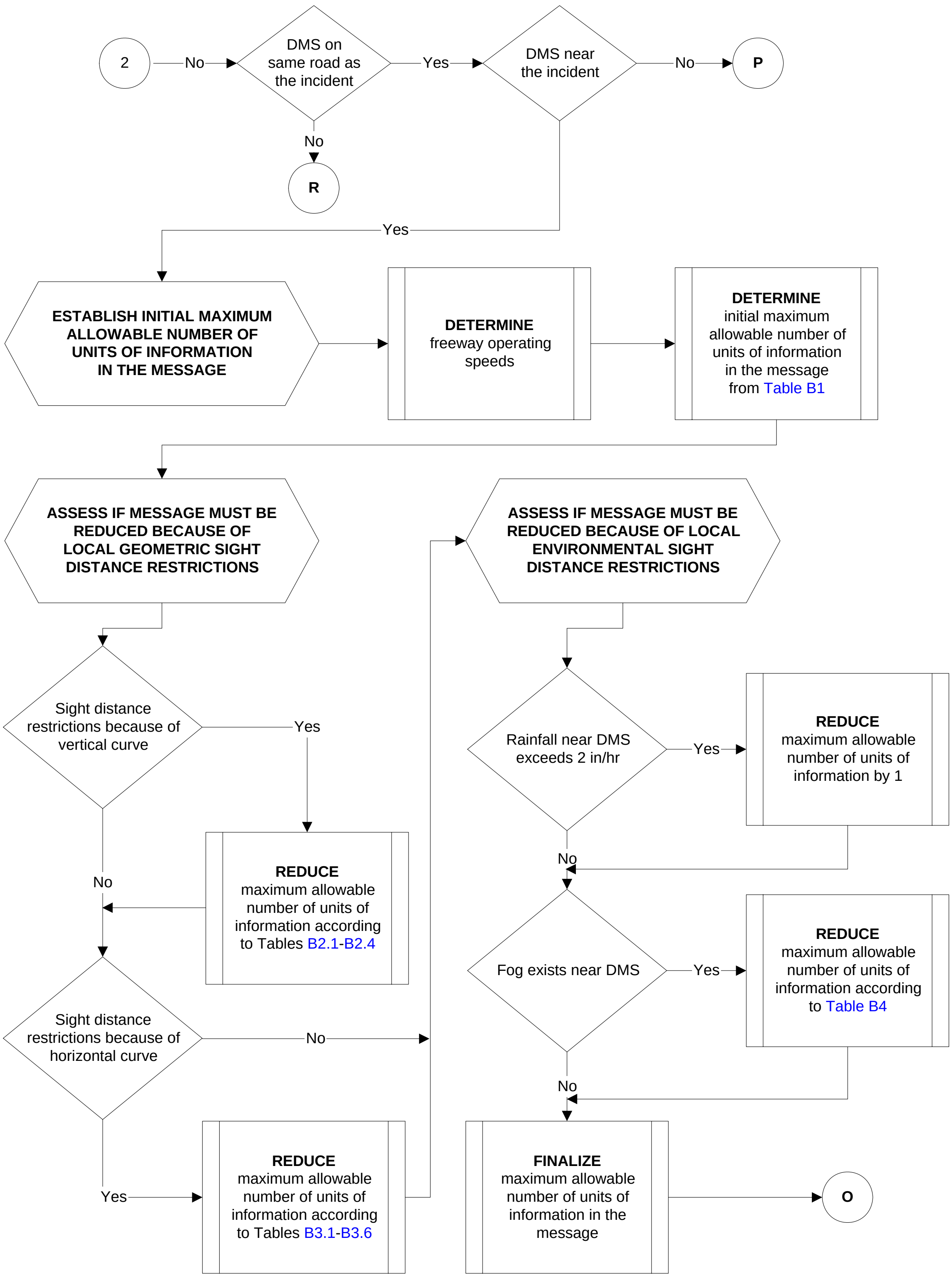
(b) Block All Lanes

Figure 2. DMS Message Design Flow Chart for Incidents (Continued).



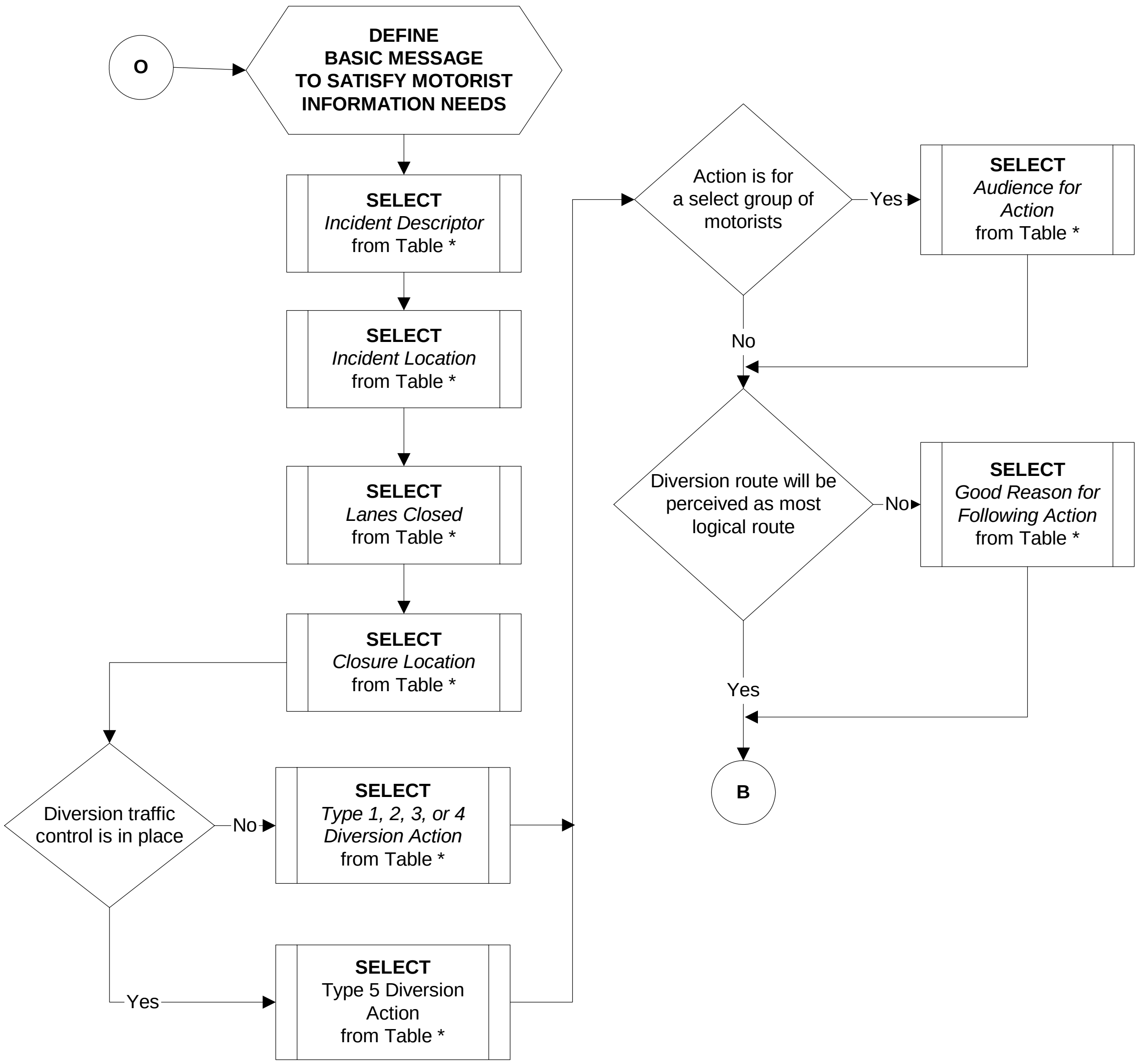
(b) Block All Lanes

Figure 2. DMS Message Design Flow Chart for Incidents (Continued).



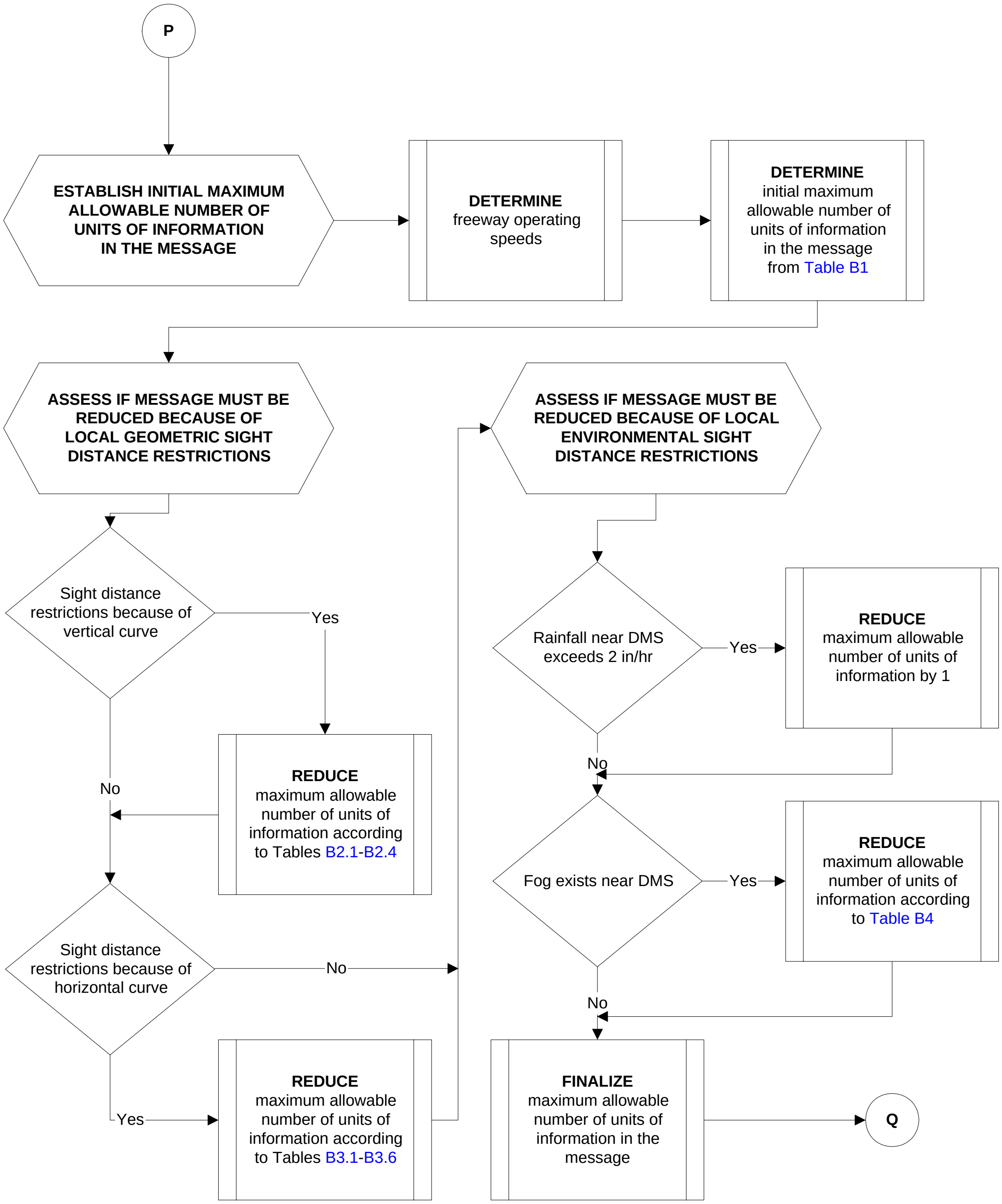
(c) Closing the Freeway

Figure 2. DMS Message Design Flow Chart for Incidents (Continued).



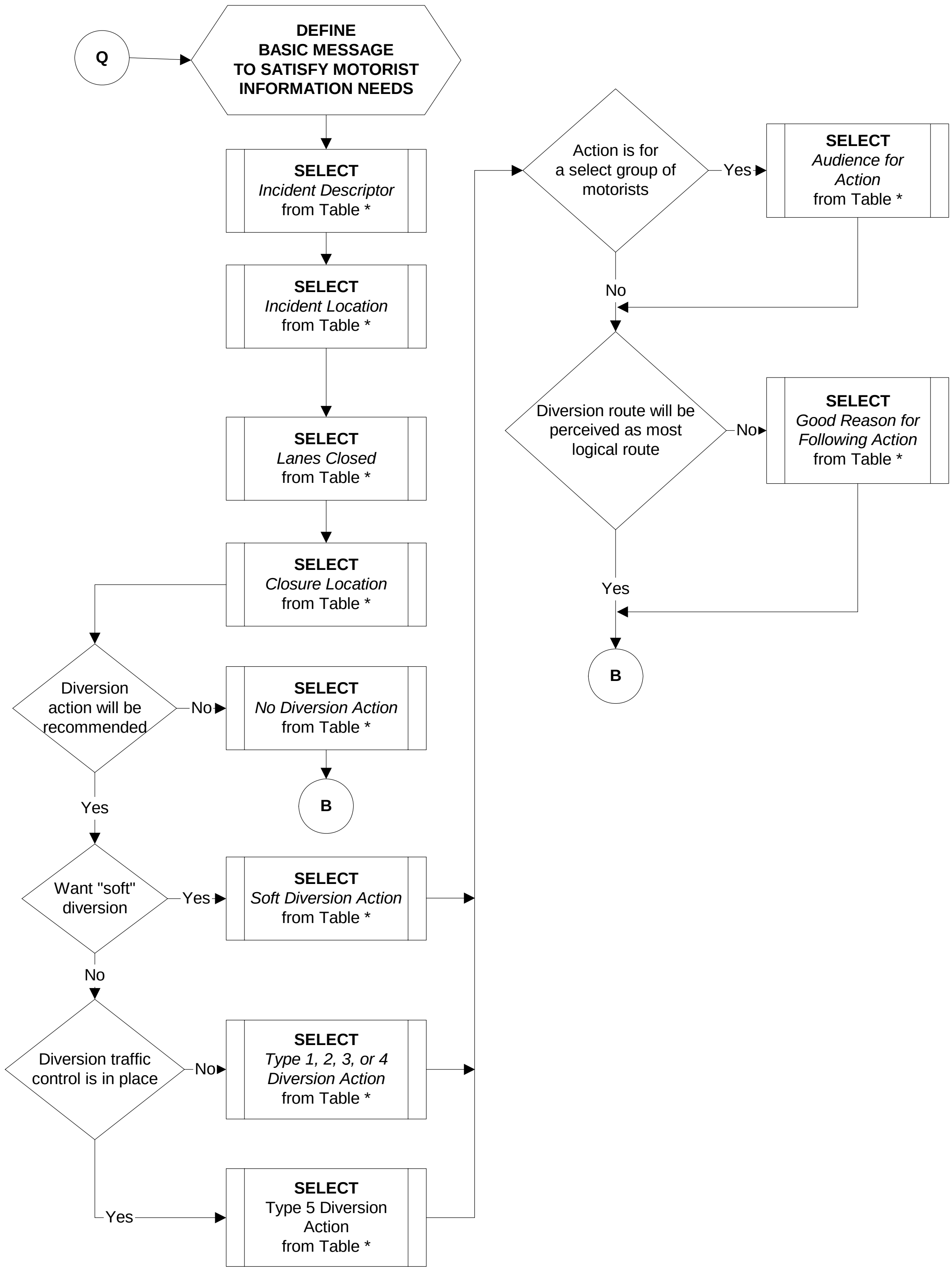
(c) Closing the Freeway

Figure 2. DMS Message Design Flow Chart for Incidents (Continued).



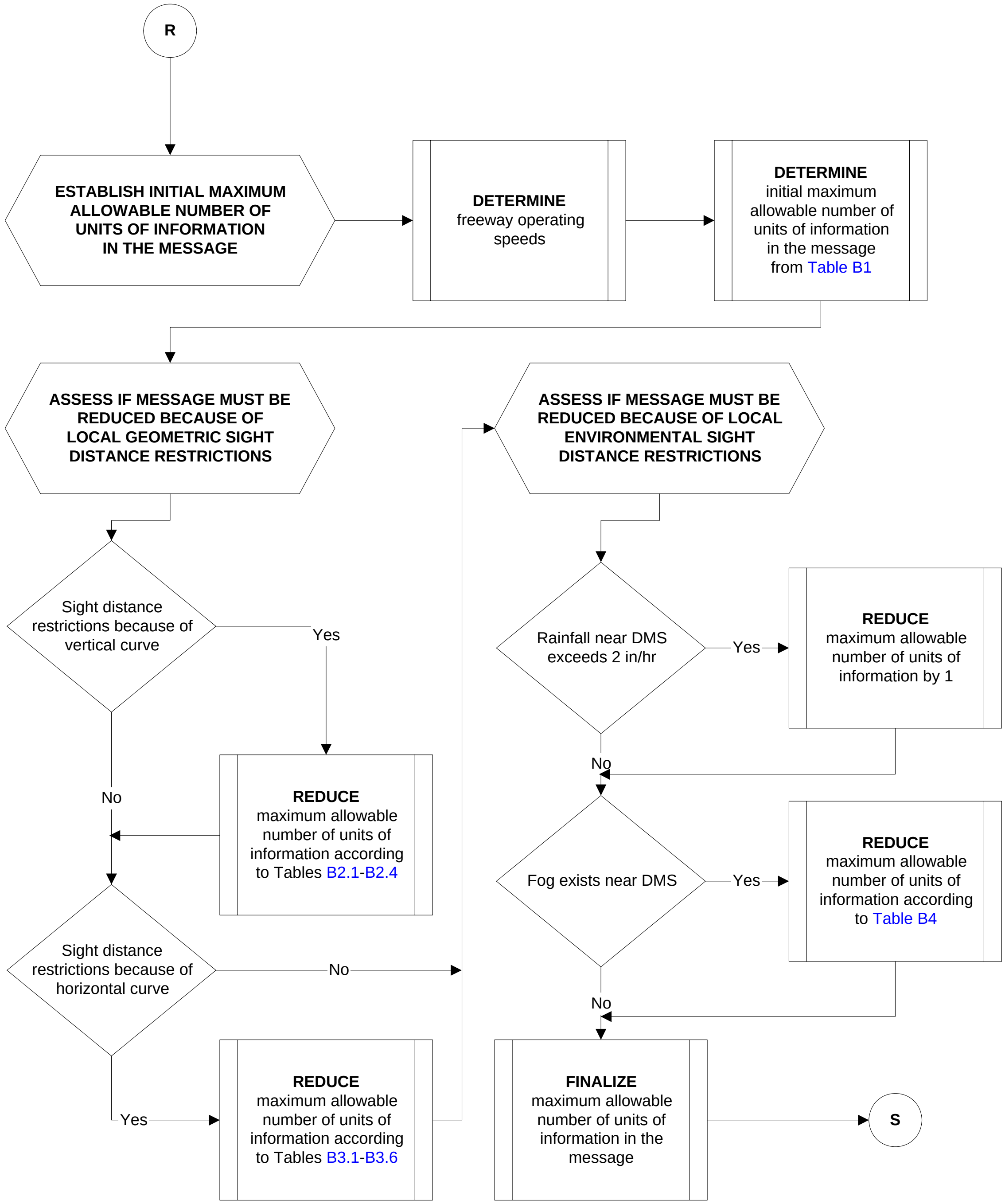
(c) Closing the Freeway

Figure 2. DMS Message Design Flow Chart for Incidents (Continued).



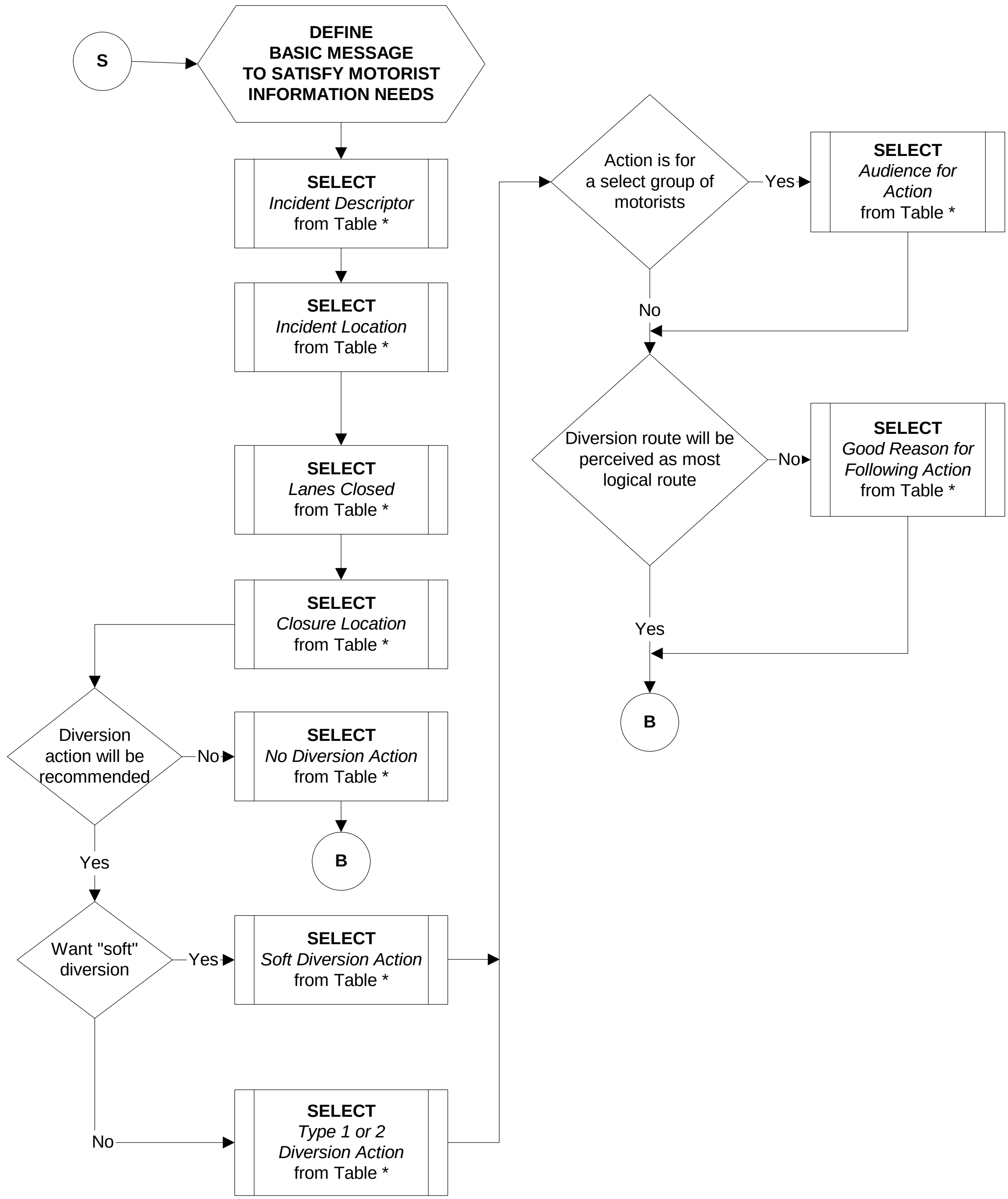
(c) Closing the Freeway

Figure 2. DMS Message Design Flow Chart for Incidents (Continued).



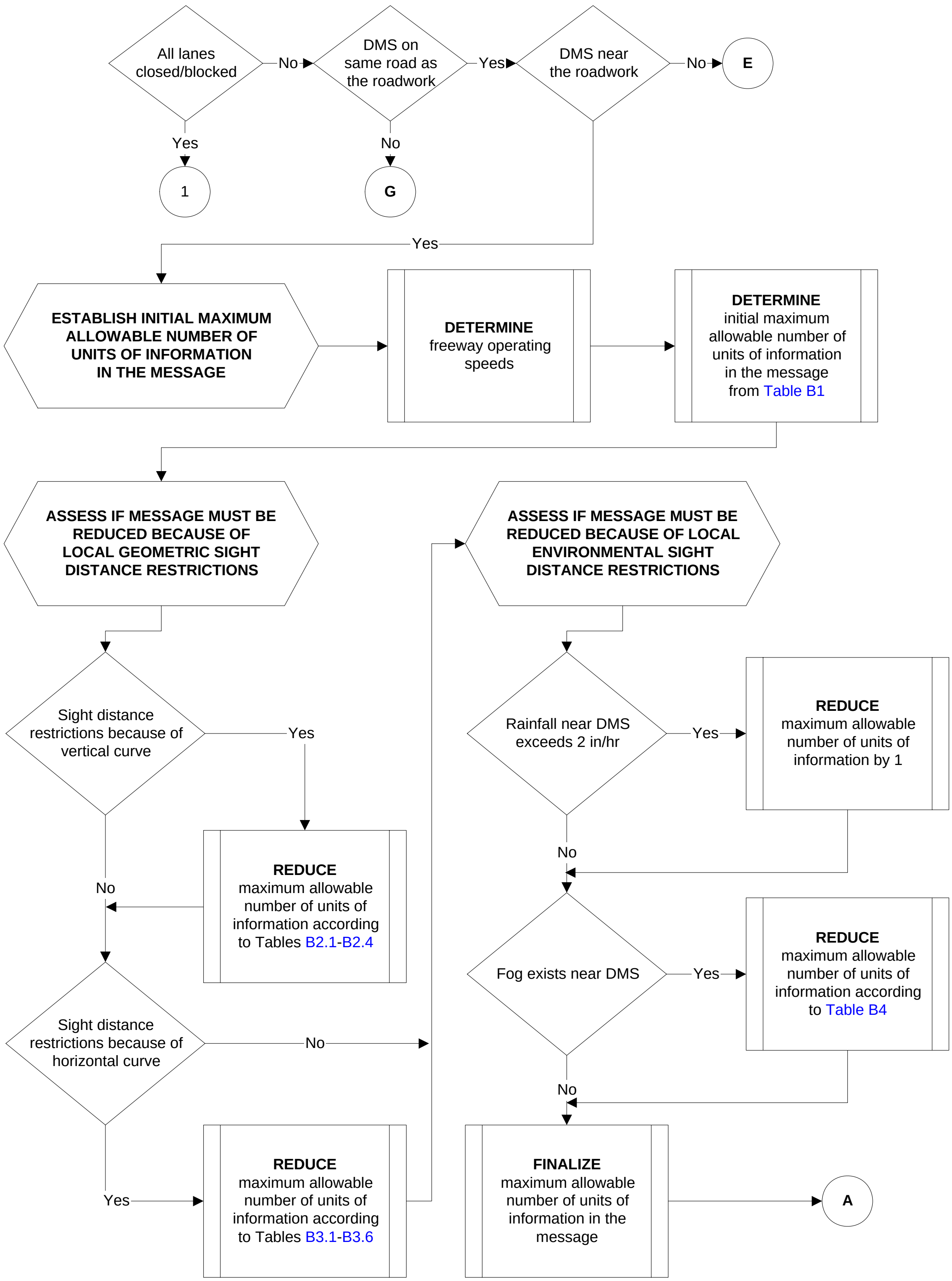
(c) Closing the Freeway

Figure 2. DMS Message Design Flow Chart for Incidents (Continued).



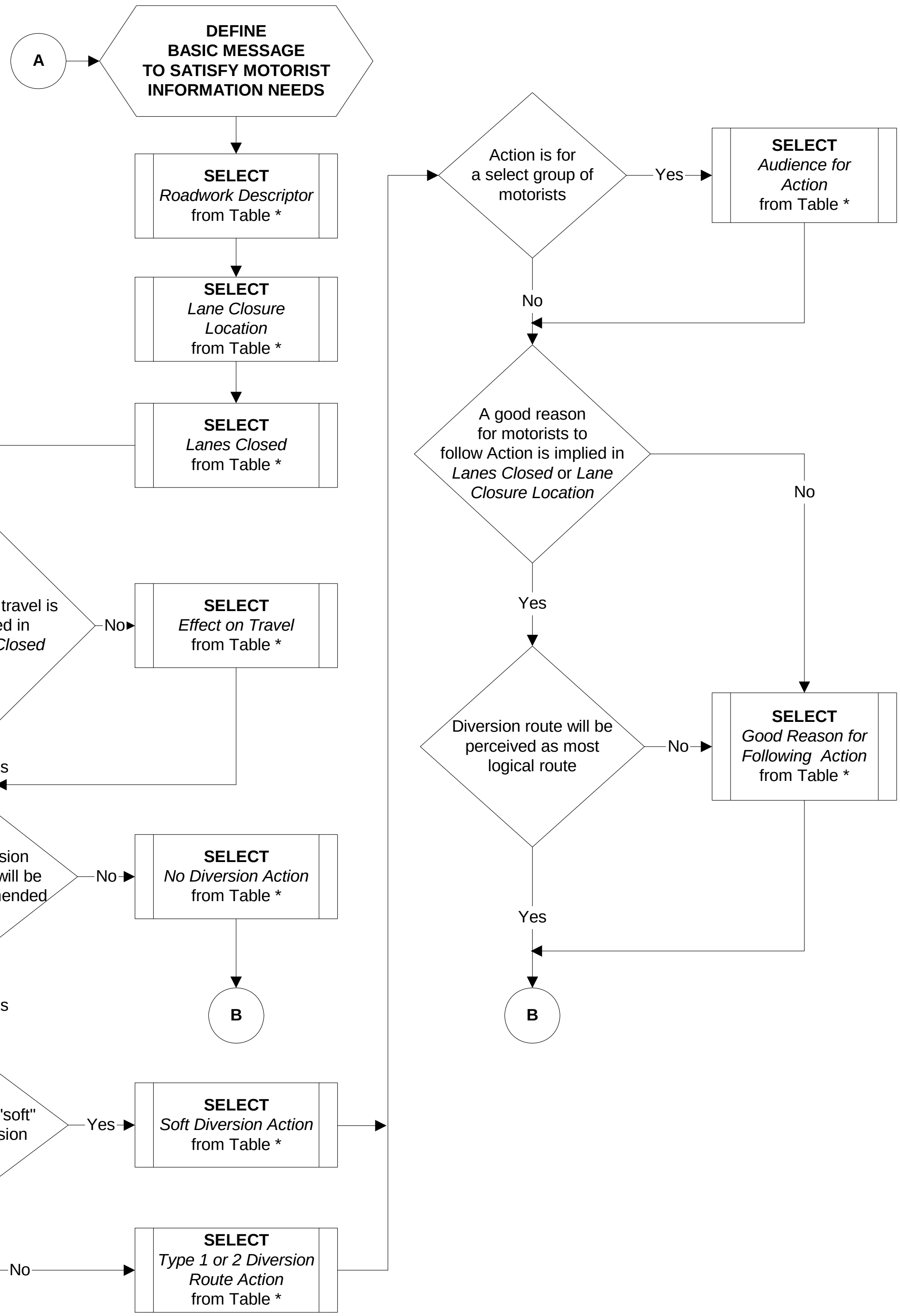
(c) Closing the Freeway

Figure 2. DMS Message Design Flow Chart for Incidents (Continued).



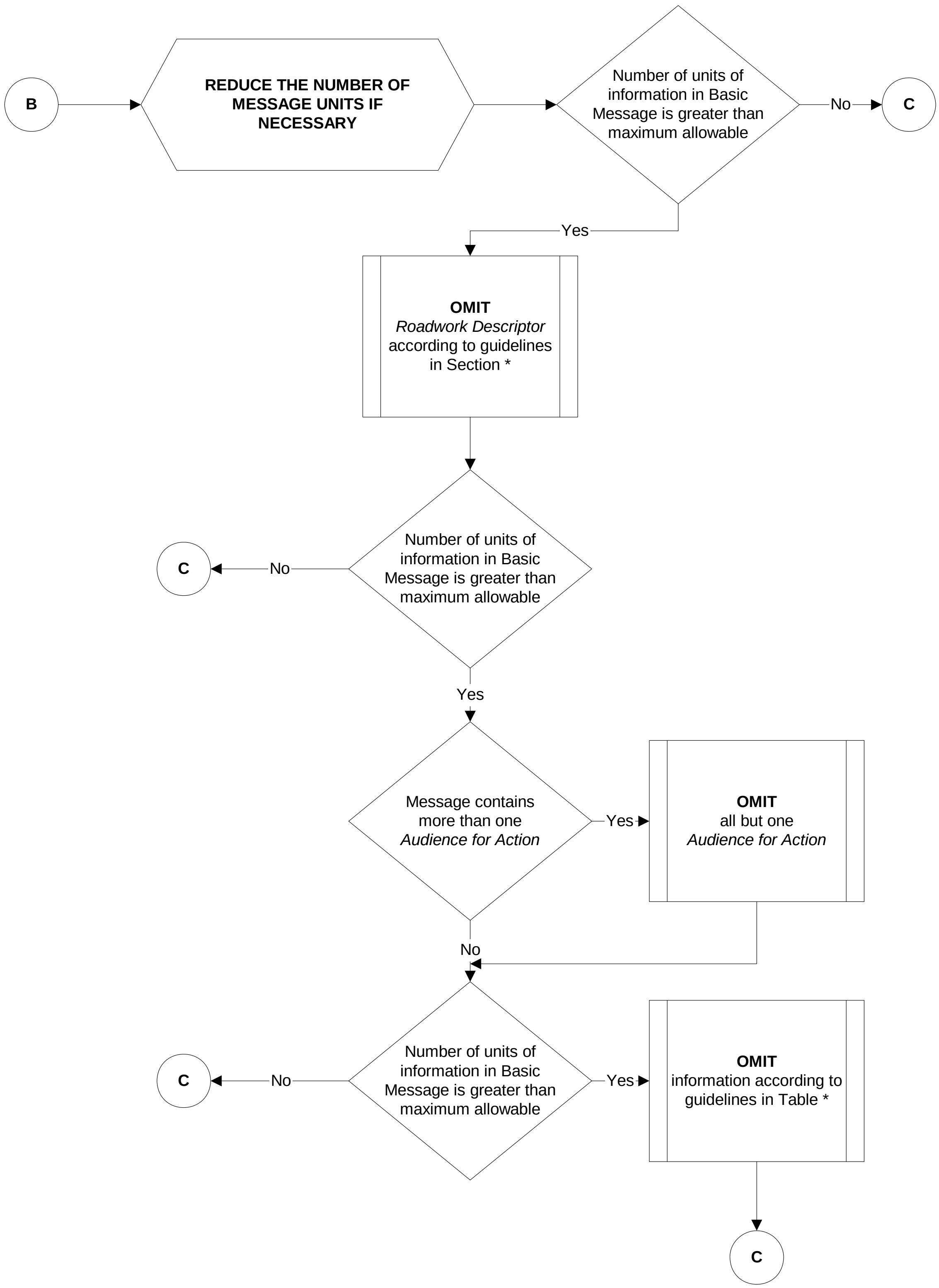
(a) Requiring Lane Closure(s)

Figure 3. DMS Message Design Flow Chart for Roadwork.



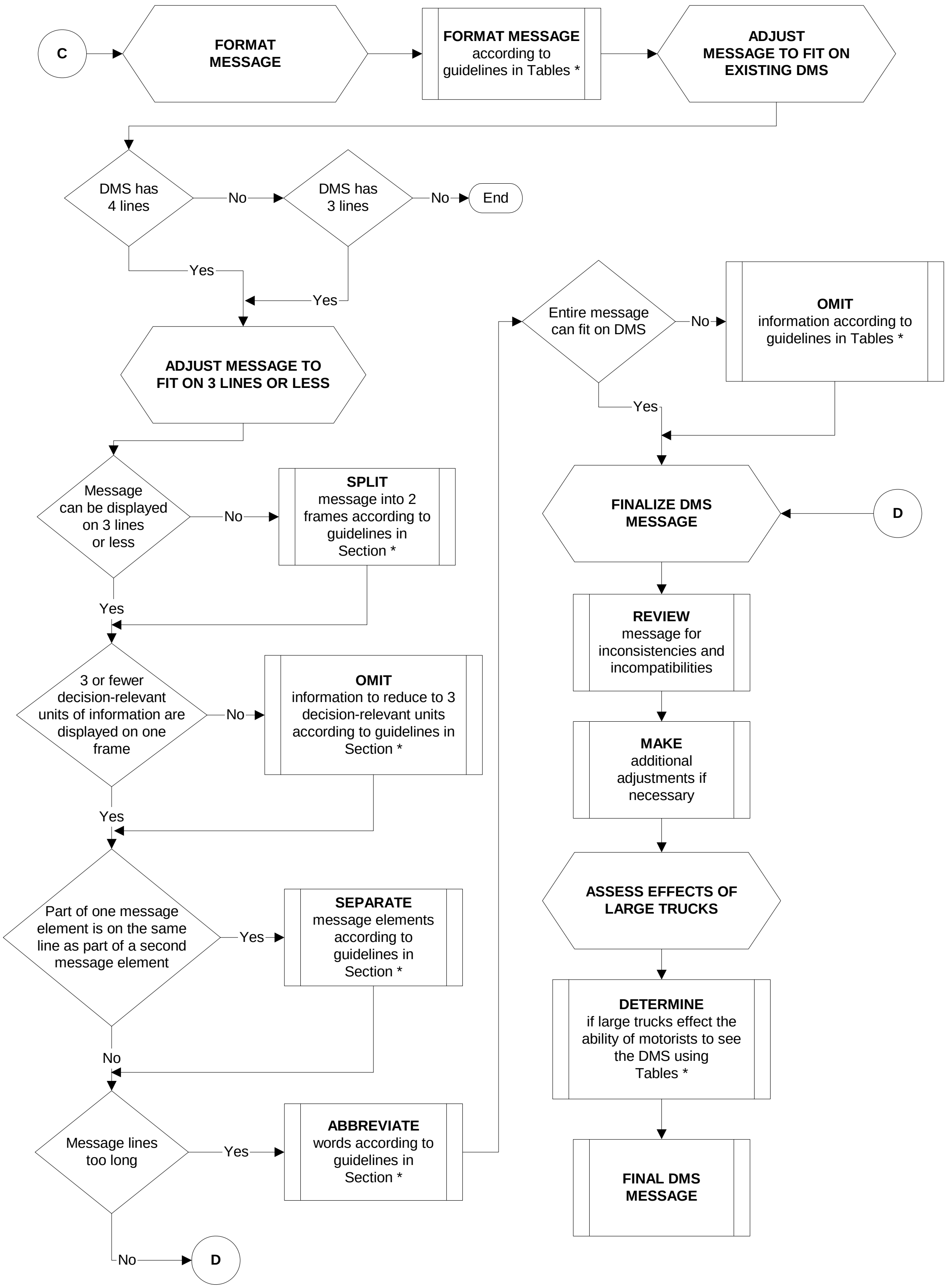
(a) Requiring Lane Closure(s)

Figure 3. DMS Message Design Flow Chart for Roadwork (Continued).



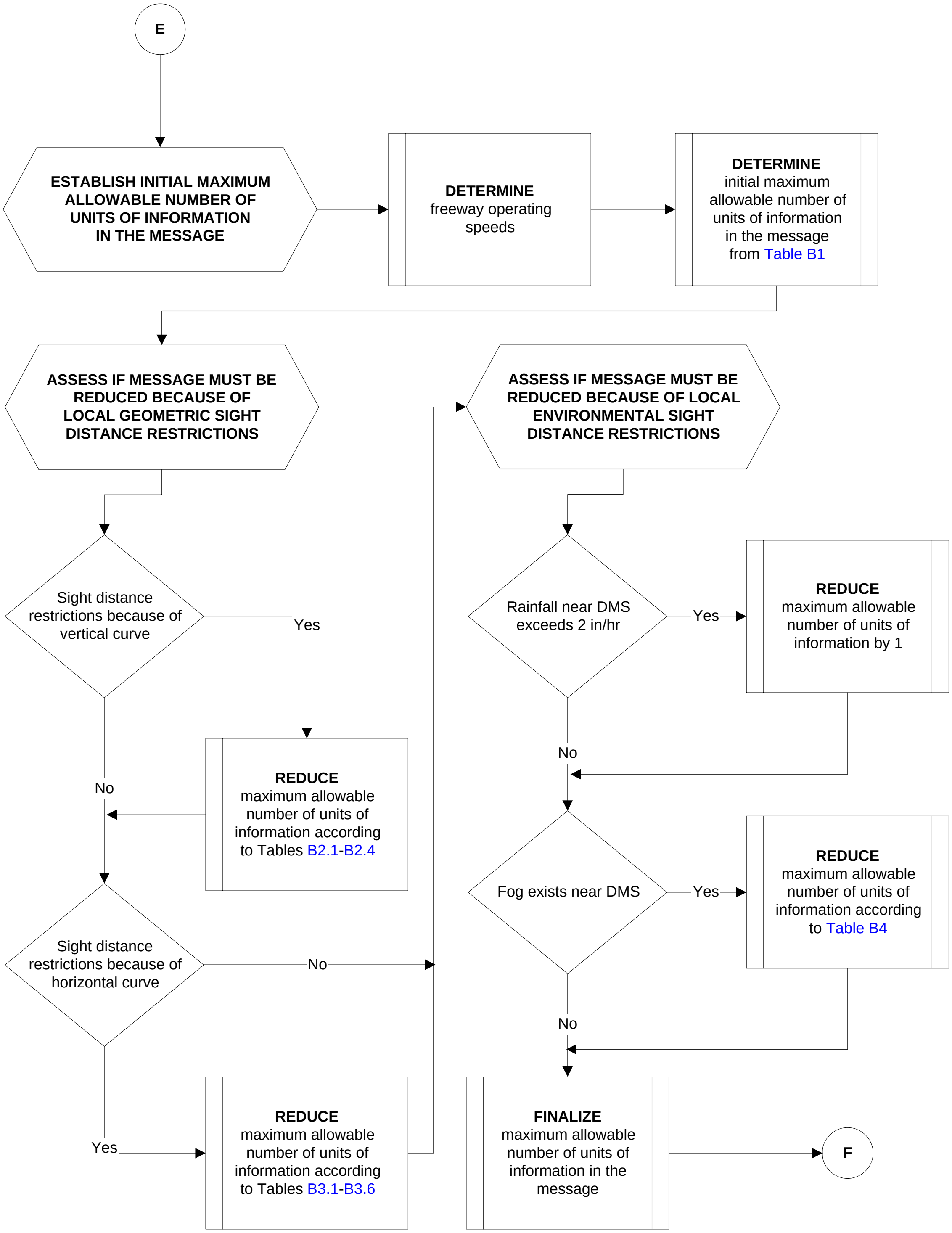
(a) Requiring Lane Closure(s)

Figure 3. DMS Message Design Flow Chart for Roadwork (Continued).



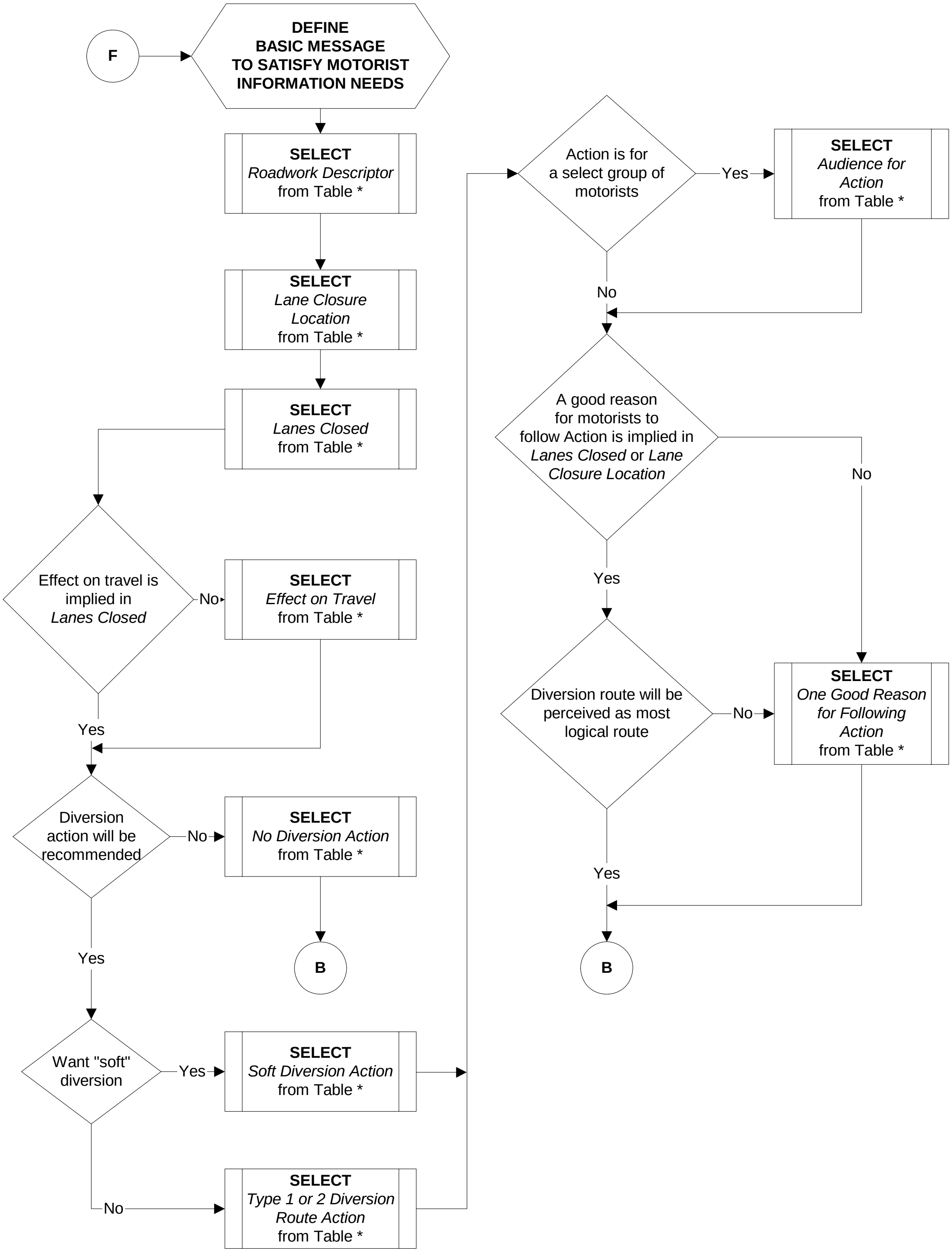
(a) Requiring Lane Closure(s)

Figure 3. DMS Message Design Flow Chart for Roadwork (Continued).



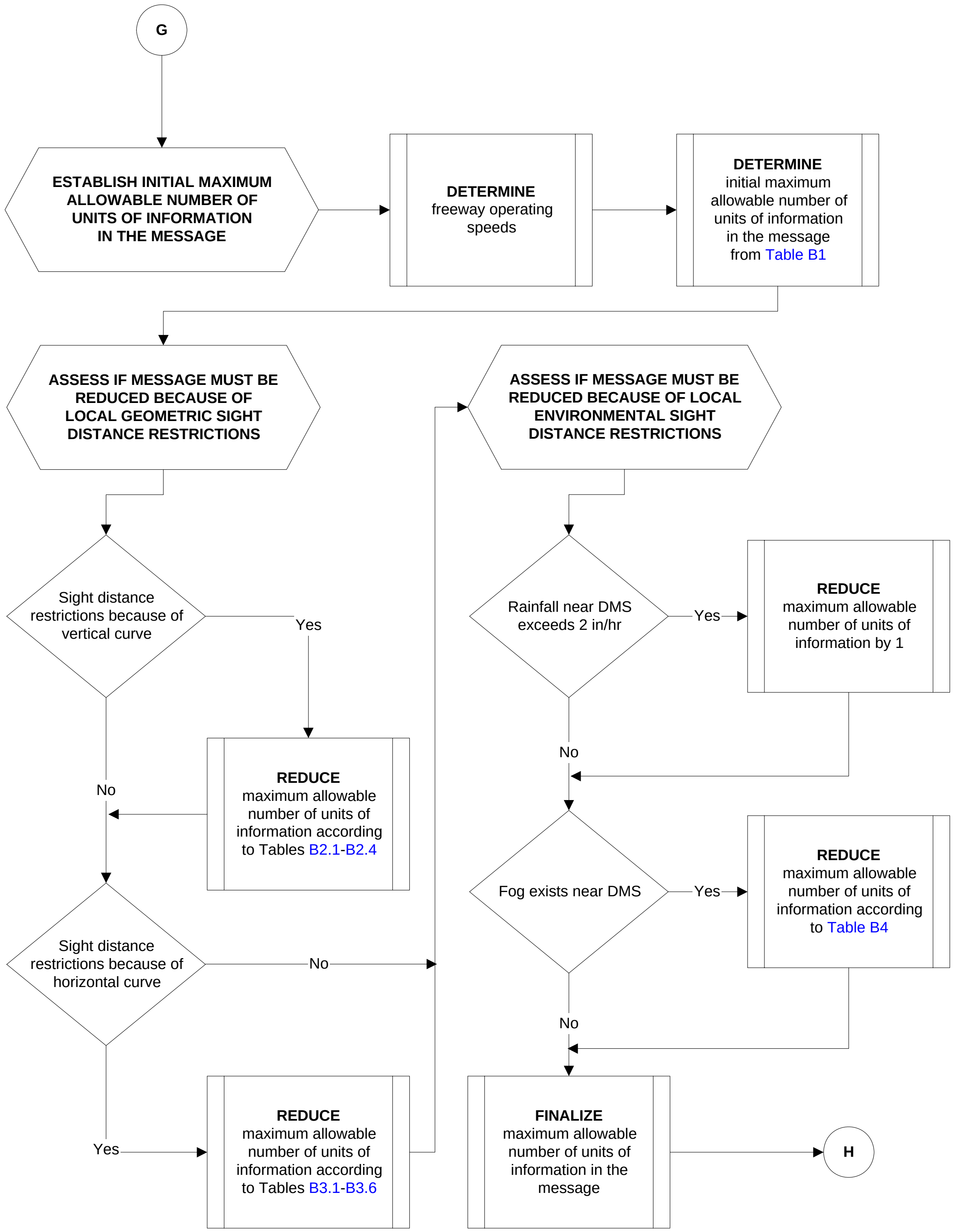
(a) Requiring Lane Closure(s)

Figure 3. DMS Message Design Flow Chart for Roadwork (Continued).



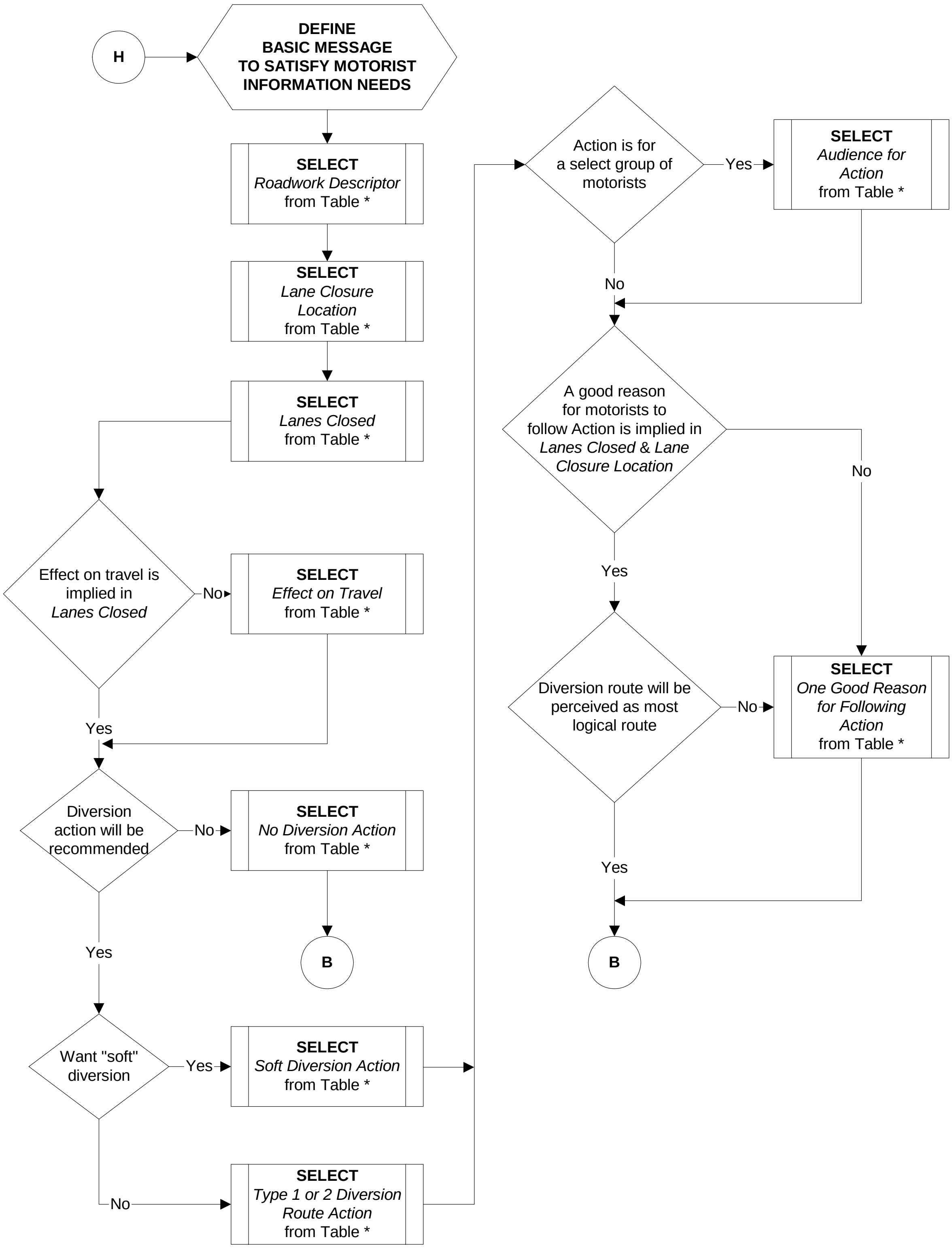
(a) Requiring Lane Closure(s)

Figure 3. DMS Message Design Flow Chart for Roadwork (Continued).



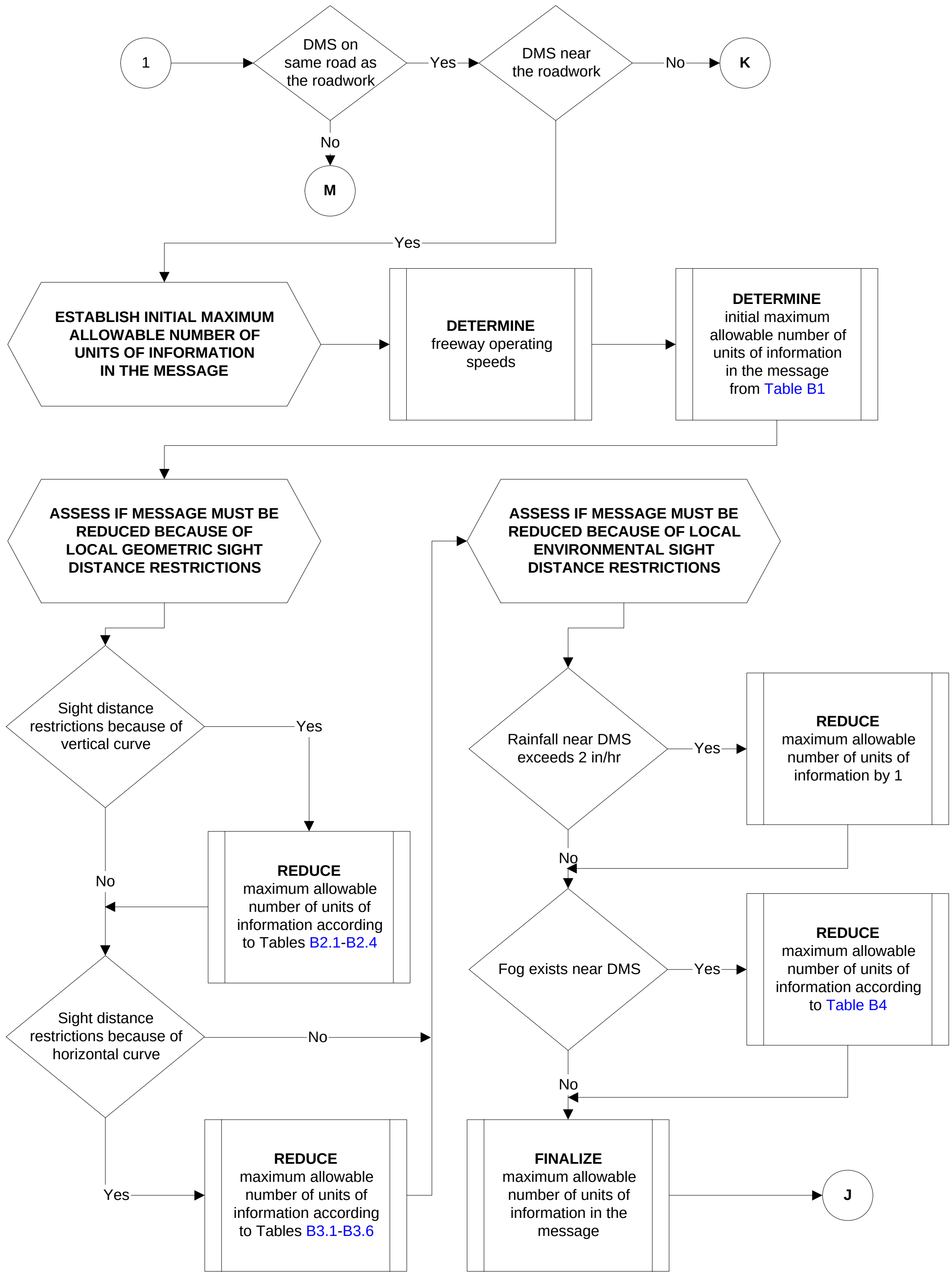
(a) Requiring Lane Closure(s)

Figure 3. DMS Message Design Flow Chart for Roadwork (Continued).



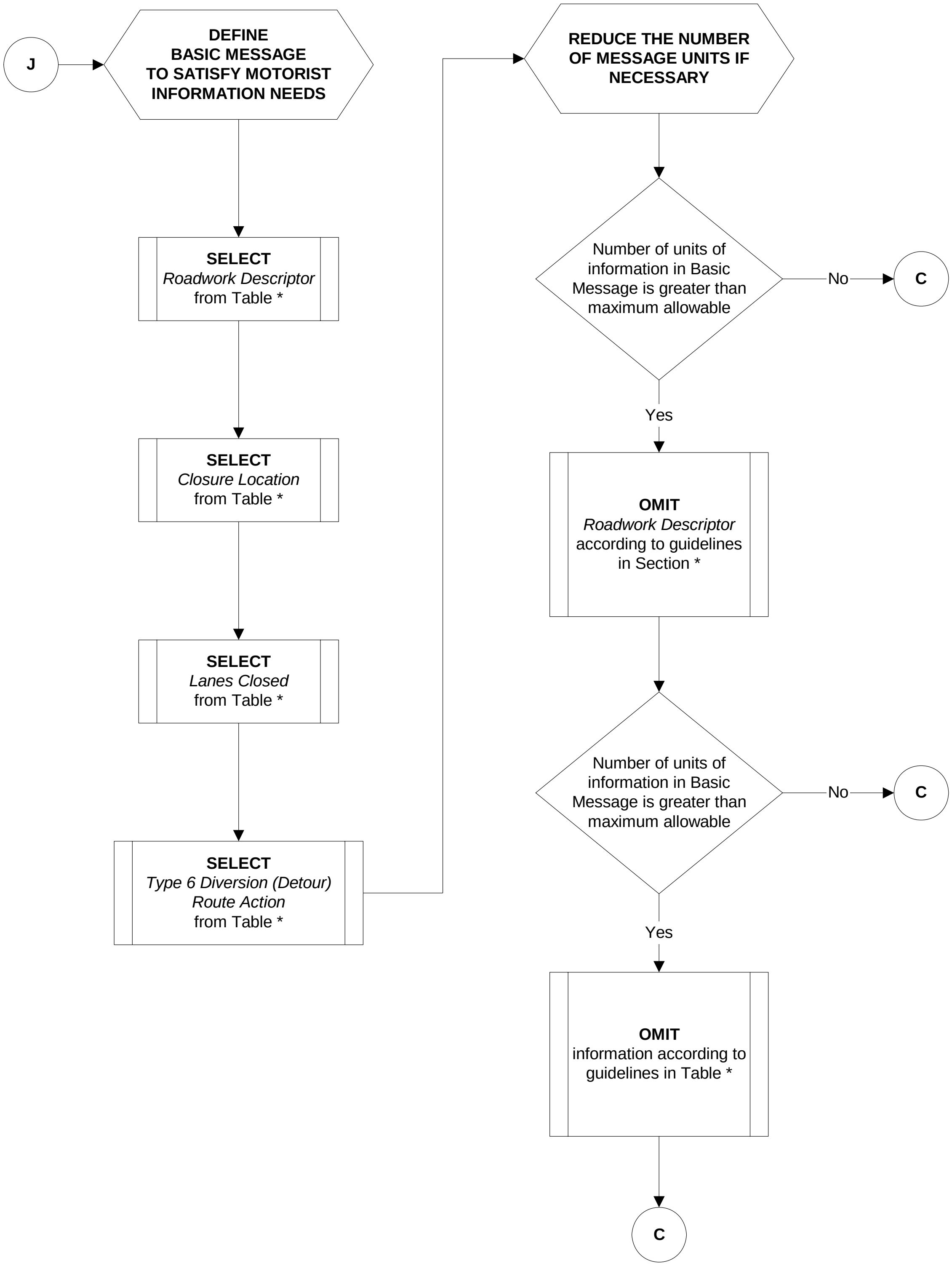
(a) Requiring Lane Closure(s)

Figure 3. DMS Message Design Flow Chart for Roadwork (Continued).



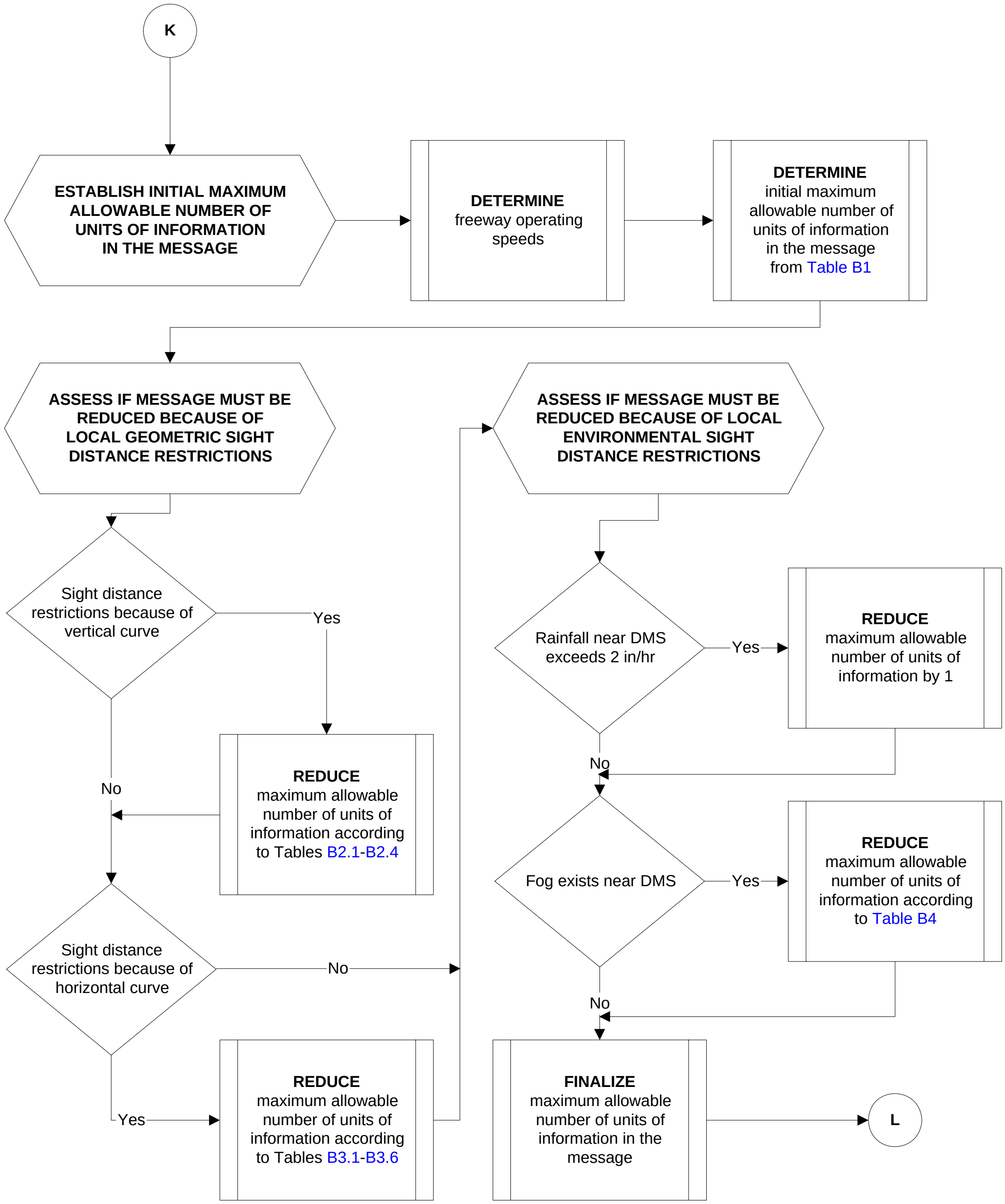
(b) Requiring Closure of Freeway

Figure 3. DMS Message Design Flow Chart for Roadwork (Continued).



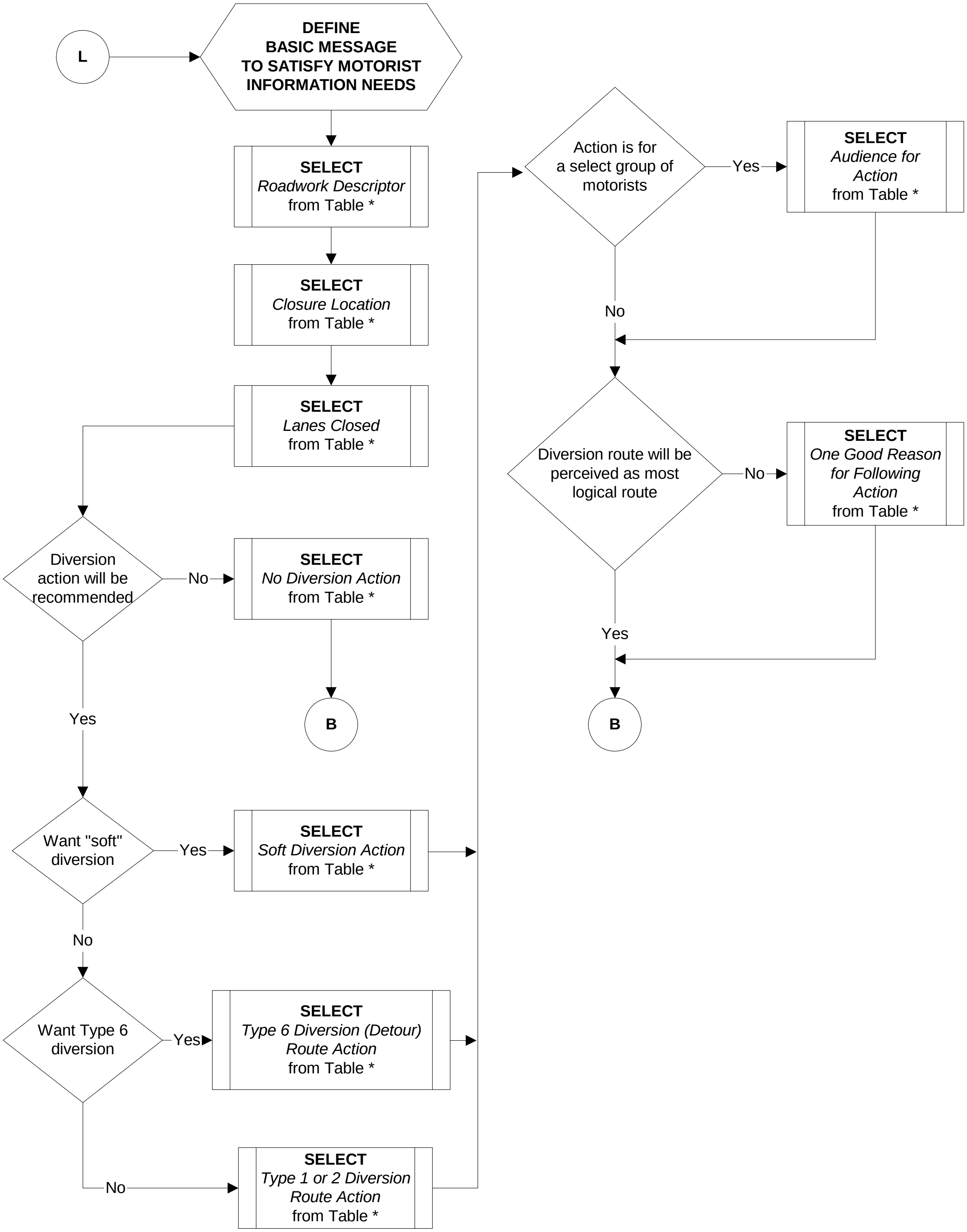
(b) Requiring Closure of Freeway

Figure 3. DMS Message Design Flow Chart for Roadwork (Continued).



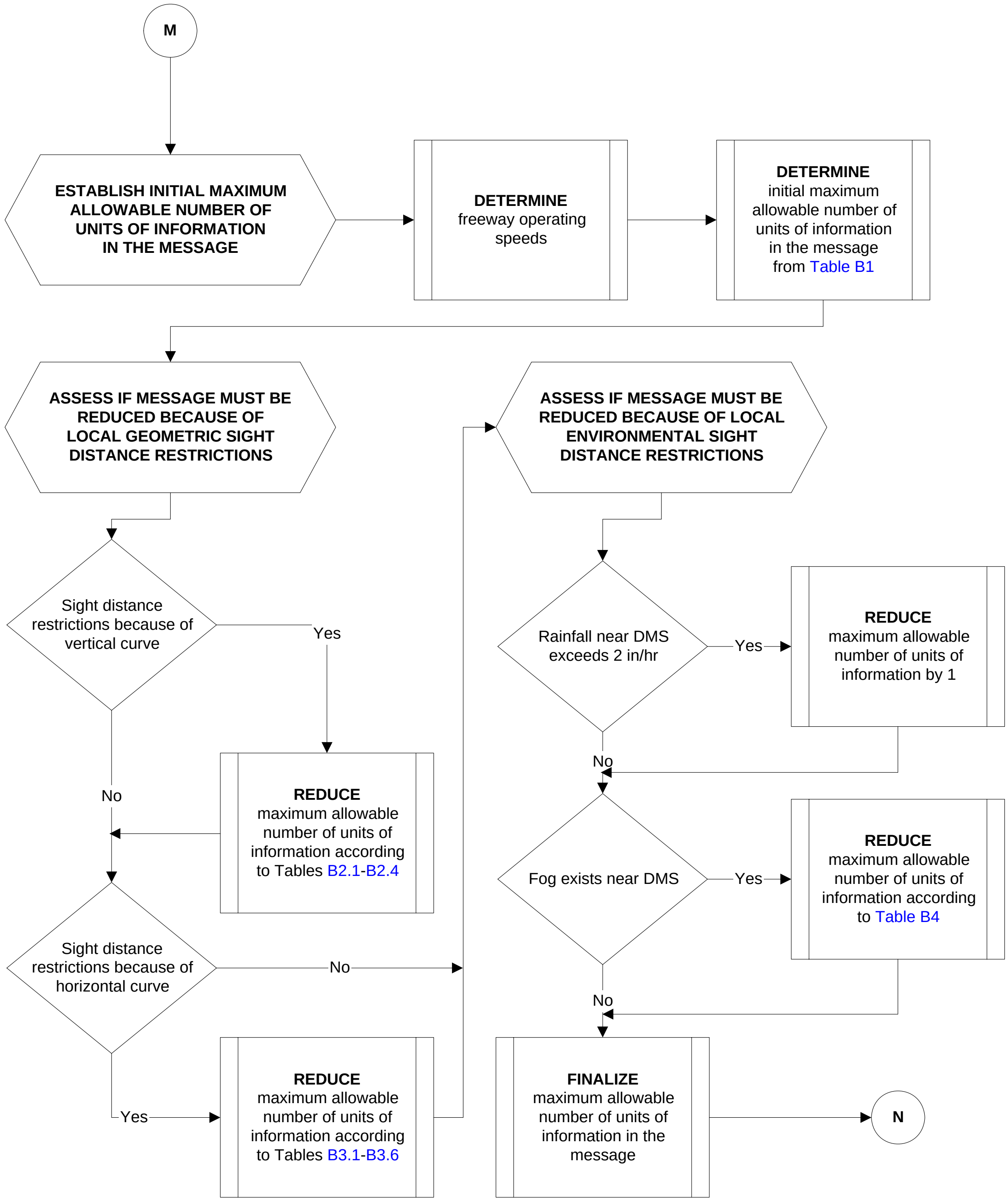
(b) Requiring Closure of Freeway

Figure 3. DMS Message Design Flow Chart for Roadwork (Continued).



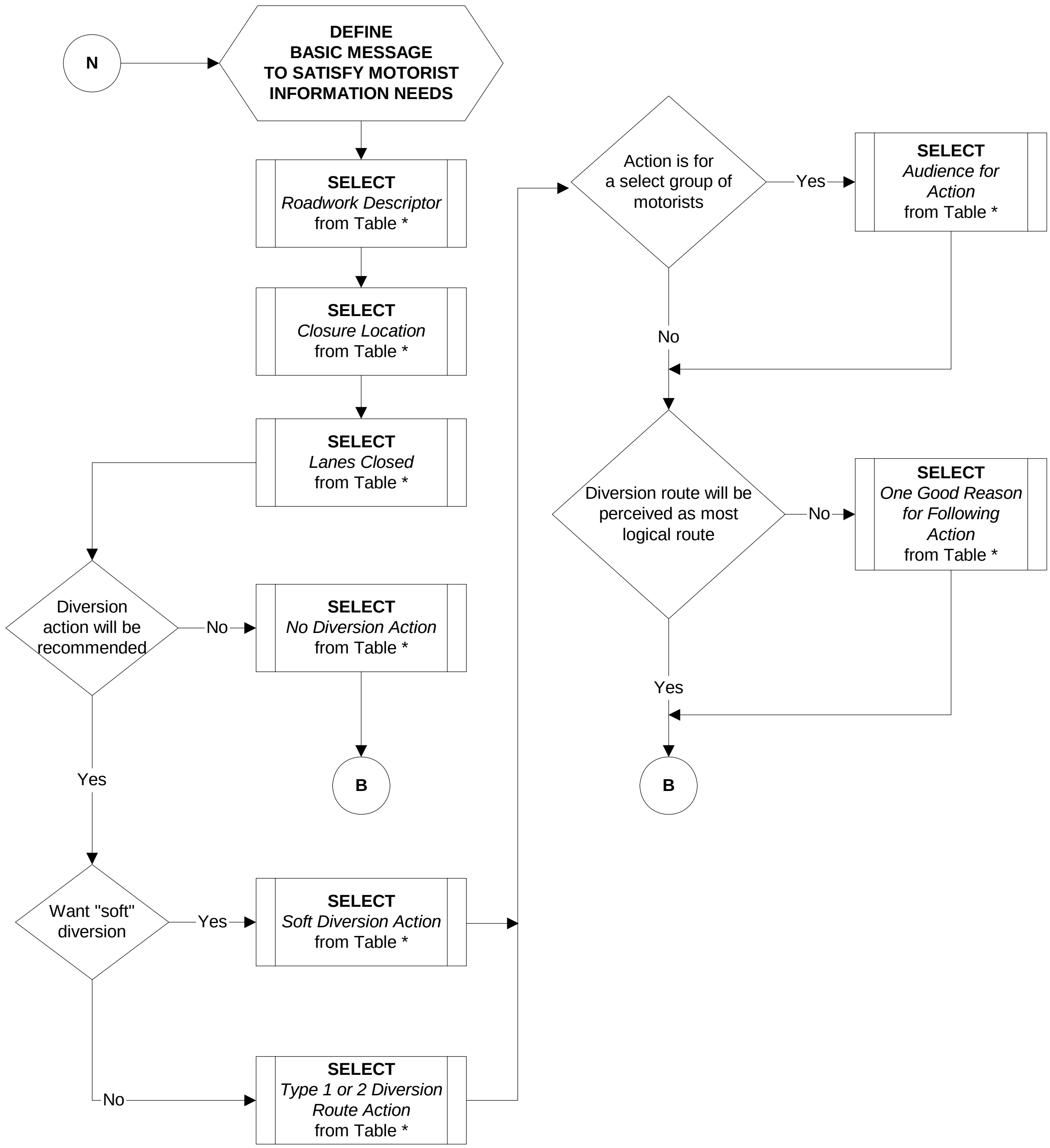
(b) Requiring Closure of Freeway

Figure 3. DMS Message Design Flow Chart for Roadwork (Continued).



(b) Requiring Closure of Freeway

Figure 3. DMS Message Design Flow Chart for Roadwork (Continued).



(b) Requiring Closure of Freeway

Figure 3. DMS Message Design Flow Chart for Roadwork (Continued).

APPENDIX B—FLOW CHART TABLES

Table B1. Maximum Number of Units of Information in DMS Message (Base Maximum Message Length).

Type of DMS	Speed Range	Condition			
		Mid-Day	Washout	Backlight	Nighttime
Light-Emitting Diode [A]	0-35 mi/h	5 units	5 units	4 units	4 units
	36-55 mi/h	4 units	4 units	4 units	4 units
	56-70 mi/h	4 units	4 units	3 units	3 units
Fiberoptic	0-35 mi/h	5 units	5 units	4 units	4 units
	36-55 mi/h	4 units	4 units	3 units	3 units
	56-70 mi/h	3 units	3 units	2 units	3 units
Incandescent Bulb	0-35 mi/h	5 units	5 units	4 units	4 units
	36-55 mi/h	4 units	4 units	3 units	3 units
	56-70 mi/h	3 units	3 units	2 units	3 units
Reflective Disk	0-35 mi/h	5 units	4 units	2 units	3 units
	36-55 mi/h	4 units	3 units	1 unit	2 units
	56-70 mi/h	3 units	2 units	1 unit	1 unit

[A] Valid only for the newer aluminum indium gallium phosphide (or equivalent) LEDs.

Table B2.1. Number of Units of Information that Must Be Subtracted from Number Given in Table B1 Due to Vertical Curve PERMANENT LED DMS [A] Mounting Height: 20 feet.

Condition	Vertical Curve Design Speed								
	Overhead			20-Foot Offset			60-Foot Offset		
	30 mi/h	35 mi/h	40 mi/h	30 mi/h	35 mi/h	40 mi/h	30 mi/h	35 mi/h	40 mi/h
Mid-Day	1 unit	0 unit	0 unit	2 units	0 unit	0 unit	5 units	3 units	1 unit
Washout	1 unit	0 unit	0 unit	2 units	0 unit	0 unit	5 units	3 units	1 unit
Backlight	0 unit	0 unit	0 unit	1 unit	0 unit	0 unit	4 units	3 units	1 unit
Nighttime	0 unit	0 unit	0 unit	1 unit	0 unit	0 unit	4 units	3 units	1 unit

[A] Valid only for the newer aluminum indium gallium phosphide (or equivalent) LEDs.

Table B2.2. Number of Units of Information that Must Be Subtracted from Number Given in Table B1 Due to Vertical Curve PERMANENT LED DMS [A] Mounting Height: 25 feet.

Condition	Vertical Curve Design Speed								
	Overhead			20-Foot Offset			60-Foot Offset		
	30 mi/h	35 mi/h	40 mi/h	30 mi/h	35 mi/h	40 mi/h	30 mi/h	35 mi/h	40 mi/h
Mid-Day	0 unit	0 unit	0 unit	2 units	1 unit	0 unit	5 units	4 units	1 unit
Washout	0 unit	0 unit	0 unit	2 units	1 unit	0 unit	5 units	4 units	1 unit
Backlight	0 unit	0 unit	0 unit	1 unit	0 unit	0 unit	4 units	3 units	1 unit
Nighttime	0 unit	0 unit	0 unit	1 unit	0 unit	0 unit	4 units	3 units	1 unit

[A] Valid only for the newer aluminum indium gallium phosphide (or equivalent) LEDs.

Table B2.3. Number of Units of Information that Must Be <u>Subtracted</u> from Number Given in Table B1 Due to Vertical Curve
PORTABLE LED DMS [A]
Mounting Height: 7 feet.

Condition	Vertical Curve Design Speed					
	20-Foot Offset			60-Foot Offset		
	30 mi/h	35 mi/h	40 mi/h	30 mi/h	35 mi/h	40 mi/h
Mid-Day	3 units	2 units	1 unit	5 units	5 units	3 units
Washout	3 units	2 units	1 unit	5 units	5 units	3 units
Backlight	2 units	1 unit	1 unit	4 units	4 units	2 units
Nighttime	2 units	1 unit	1 unit	4 units	4 units	2 units

[A] Valid only for the newer aluminum indium gallium phosphide (or equivalent) LEDs.

Table B2.4. Number of Units of Information that Must Be <u>Subtracted</u> from Number Given in Table B1 Due to Vertical Curve
PORTABLE LED DMS [A]
Mounting Height: 10 feet.

Condition	Vertical Curve Design Speed					
	20-Foot Offset			60-Foot Offset		
	30 mi/h	35 mi/h	40 mi/h	30 mi/h	35 mi/h	40 mi/h
Mid-Day	2 units	2 units	1 unit	5 units	4 units	3 units
Washout	2 units	2 units	1 unit	5 units	4 units	3 units
Backlight	1 unit	1 unit	0 unit	4 units	3 units	2 units
Nighttime	1 unit	1 unit	0 unit	4 units	3 units	2 units

[A] Valid only for the newer aluminum indium gallium phosphide (or equivalent) LEDs.

Table B3.1. Number of Units of Information that Must Be Subtracted from Number Given in Table B1 Due to Horizontal Curve
PORTABLE LED DMS [A]
Offset: 2 feet
Traffic Operating Speeds: 0-35 mi/h.

Curve Radii (ft)	Mid-Day and Washout — Offset of Sight Obstruction From Edge of Travel Lanes (ft)							Backlight and Nighttime — Offset of Sight Obstruction From Edge of Travel Lanes (ft)						
	10	20	50	100	150	200	250	10	20	50	100	150	200	250
250	4 units	4 units	2 units	1 unit	1 unit	1 unit		3 units	3 units	1 unit				
500	4 units	3 units	1 unit	1 unit				3 units	2 units					
750	4 units	2 units	1 unit	1 unit				3 units	2 units					
1000	3 units	2 units	1 unit					2 units	1 unit					
1250	3 units	2 units	1 unit					2 units	1 unit					
1500	3 units	1 unit	1 unit					2 units	1 unit					
1750	3 units	1 unit						2 units	1 unit					
2000	3 units	1 unit						2 units	1 unit					
2250	2 units	1 unit						1 unit						
2500	2 units	1 unit						1 unit						
2750	2 units	1 unit						1 unit						
3000	2 units	1 unit						1 unit						
4000	1 unit	1 unit												
5000	1 unit													
7500	1 unit													
10000	1 unit													

[A] Valid only for the newer aluminum indium gallium phosphide (or equivalent) LEDs.

Table B3.2. Number of Units of Information that Must Be Subtracted from Number Given in Table B1 Due to Horizontal Curve
PORTABLE LED DMS [A]
Offset: 2 feet
Traffic Operating Speeds: 36-55 mi/h.

Curve Radii (ft)	Mid-Day and Washout: Offset of Sight Obstruction From Edge of Travel Lanes (ft)							Backlight and Nighttime: Offset of Sight Obstruction From Edge of Travel Lanes (ft)						
	10	20	50	100	150	200	250	10	20	50	100	150	200	250
250	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
500	3 units	3 units	2 units	1 unit				3 units	3 units	2 units	1 unit			
750	3 units	3 units	1 unit					3 units	3 units	1 unit				
1000	3 units	2 units	1 unit					3 units	2 units	1 unit				
1250	3 units	2 units						3 units	2 units					
1500	3 units	2 units						3 units	2 units					
1750	3 units	2 units						3 units	2 units					
2000	3 units	1 unit						3 units	1 unit					
2250	3 units	1 unit						3 units	1 unit					
2500	2 units	1 unit						2 units	1 unit					
2750	2 units	1 unit						2 units	1 unit					
3000	2 units	1 unit						2 units	1 unit					
4000	2 units							2 units						
5000	2 units							2 units						
7500	1 unit							1 unit						
10000	1 unit													

[A] Valid only for the newer aluminum indium gallium phosphide (or equivalent) LEDs.
N/A Adequate sight distance not available for any message.

Table B3.3. Number of Units of Information that Must Be Subtracted from Number Given in Table B1 Due to Horizontal Curve
PORTABLE LED DMS [A]
Offset: 2 feet
Traffic Operating Speeds: 56-70 mi/h.

Curve Radii (ft)	Mid-Day and Washout: Offset of Sight Obstruction From Edge of Travel Lanes (ft)							Backlight and Nighttime: Offset of Sight Obstruction From Edge of Travel Lanes (ft)						
	10	**20**	**50**	**100**	**150**	**200**	**250**	**10**	**20**	**50**	**100**	**150**	**200**	**250**
250	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
500	N/A	N/A	N/A	N/A	N/A			N/A	N/A	N/A	N/A	N/A	N/A	N/A
750	3 units	3 units	2 units	1 unit				2 units	1 unit					
1000	3 units	3 units	2 units					1 unit	1 unit					
1250	3 units	3 units	1 unit					1 unit	1 unit					
1500	3 units	2 units	1 unit					1 unit						
1750	3 units	2 units	1 unit					1 unit						
2000	3 units	2 units						1 unit						
2250	3 units	2 units						1 unit						
2500	3 units	2 units						1 unit						
2750	3 units	2 units						1 unit						
3000	3 units	2 units						1 unit						
4000	2 units	1 unit												
5000	2 units													
7500	2 units													
10000	2 units													

[A] Valid only for the newer aluminum indium gallium phosphide (or equivalent) LEDs.
N/A Adequate sight distance not available for any message.

Table B3.4. Number of Units of Information that Must Be <u>Subtracted</u> from Number Given in Table B1 Due to Horizontal Curve
PORTABLE LED DMS [A]
Offset: 10 feet
Traffic Operating Speeds: 0-35 mi/h.

Curve Radii (ft)	Mid-Day and Washout							Backlight and Nighttime						
	Offset of Sight Obstruction From Edge of Travel Lanes (ft)							Offset of Sight Obstruction From Edge of Travel Lanes (ft)						
	10	**20**	**50**	**100**	**150**	**200**	**250**	**10**	**20**	**50**	**100**	**150**	**200**	**250**
250	5 units	4 units	2 units	1 unit	1 unit			4 units	3 units	1 unit				
500	5 units	3 units	1 unit					4 units	2 units					
750	5 units	3 units	1 unit					4 units	2 units					
1000	5 units	3 units	1 unit					4 units	2 units					
1250	5 units	2 units						4 units	1 unit					
1500	5 units	2 units						4 units	1 unit					
1750	5 units	2 units						4 units	1 unit					
2000	5 units	1 unit						4 units						
2250	5 units	1 unit						4 units						
2500	5 units	1 unit						4 units						
2750	5 units	1 unit						4 units						
3000	5 units	1 unit						4 units						
4000	5 units	1 unit						4 units						
5000	5 units							4 units						
7500	5 units							4 units						
10000	5 units							4 units						

[A] Valid only for the newer aluminum indium gallium phosphide (or equivalent) LEDs.

Table B3.5. Number of Units of Information that Must Be Subtracted from Number Given in Table B1 Due to Horizontal Curve
PORTABLE LED DMS [A]
Offset: 10 feet
Traffic Operating Speeds: 36-55 mi/h.

Curve Radii (ft)	**Mid-Day and Washout**							**Backlight and Nighttime**						
	Offset of Sight Obstruction From Edge of Travel Lanes (ft)							**Offset of Sight Obstruction From Edge of Travel Lanes (ft)**						
	10	**20**	**50**	**100**	**150**	**200**	**250**	**10**	**20**	**50**	**100**	**150**	**200**	**250**
250	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**N/A**
500	5 units	4 units	3 units	2 units	1 unit	1 unit		5 units	3 units	2 units	1 unit			
750	5 units	4 units	2 units	1 unit	1 unit			5 units	3 units					
1000	5 units	4 units	2 units	1 unit				5 units	3 units					
1250	5 units	3 units	1 unit					5 units	2 units					
1500	5 units	3 units	1 unit					5 units	2 units					
1750	5 units	3 units	1 unit					5 units	2 units					
2000	5 units	3 units	1 unit					5 units	2 units					
2250	5 units	3 units	1 unit					5 units	2 units					
2500	5 units	3 units	1 unit					5 units	2 units					
2750	5 units	2 units						5 units	1 unit					
3000	5 units	2 units						5 units	1 unit					
4000	5 units	2 units						5 units						
5000	5 units	1 unit						5 units						
7500	5 units	1 unit						5 units						
10000	5 units	1 unit						5 units						

[A] Valid only for the newer aluminum indium gallium phosphide (or equivalent) LEDs.
N/A Adequate sight distance not available for any message.

Table B3.6. Number of Units of Information that Must Be <u>Subtracted</u> from Number Given in Table B1 Due to Horizontal Curve
PORTABLE LED DMS [A]
Offset: 10 feet
Traffic Operating Speeds: 56-70 mi/h.

Curve Radii (ft)	Mid-Day and Washout							Backlight and Nighttime						
	Offset of Sight Obstruction From Edge of Travel Lanes (ft)							Offset of Sight Obstruction From Edge of Travel Lanes (ft)						
	10	20	50	100	150	200	250	10	20	50	100	150	200	250
250	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
500	N/A	N/A	N/A	N/A	N/A	1 unit		N/A	N/A	N/A	N/A	N/A	N/A	N/A
750	5 units	4 units	3 units	2 units	1 unit			4 units	3 units	2 units	1 unit			
1000	5 units	4 units	3 units	1 unit	1 unit			4 units	3 units	2 units				
1250	5 units	4 units	2 units	1 unit	1 unit			4 units	3 units	1 unit				
1500	5 units	4 units	2 units	1 unit				4 units	3 units	1 unit				
1750	5 units	4 units	2 units	1 unit				4 units	3 units	1 unit				
2000	5 units	3 units	1 unit	1 unit				4 units	2 units					
2250	5 units	3 units	1 unit					4 units	2 units					
2500	5 units	3 units	1 unit					4 units	2 units					
2750	5 units	3 units	1 unit					4 units	2 units					
3000	5 units	3 units	1 unit					4 units	2 units					
4000	5 units	3 units	1 unit					4 units	2 units					
5000	5 units	2 units						4 units	1 unit					
7500	5 units	2 units						4 units	1 unit					
10000	5 units	1 unit						4 units						

[A] Valid only for the newer aluminum indium gallium phosphide (or equivalent) LEDs.
N/A Adequate sight distance not available for any message.

Table B4. Number of Units of Information that Must Be Subtracted from Number Given in Table B1 Due to Effects of Fog in Daytime Conditions PORTABLE LED DMS. [A]

Visibility Range in Fog	Overhead			20-Ft Offset			60-Ft Offset		
	0-35 mi/h	36-55 mi/h	56-70 mi/h	0-35 mi/h	36-55 mi/h	56-70 mi/h	0-35 mi/h	36-55 mi/h	56-70 mi/h
1/2 mile	0 unit	0 unit	0 unit	0 unit	0 unit	0 unit	0 unit	0 unit	0 unit
1/4 mile	0 unit	0 unit	1 unit	0 unit	1 unit	1 unit	2 units	2 units	2 units
1/10 mile	2 units	2 units	2 units	3 units	3 units	3 units	N/A	N/A	N/A

[A] Valid only for the newer aluminum indium gallium phosphide (or equivalent) LEDs.

N/A Adequate sight distance not available for any message.