Texas Department of Transportation

**Product 0-5800-P1**
**Project 0-5800**

# Warrants for Major Traffic Generator Guide Signing

***September 2009***


***By***

**Fengxiang Qiao, Lei Yu, Hui Wang, Lijin Ma, Rong Zhang, and Yan Zeng**

Performed in cooperation with the Texas Department of Transportation and the Federal Highway Administration

Texas Southern University

| 1. Report No. | 2. Government Accession No. | 3. Recipient's Catalog No. |
|---|---|---|
| FHWA/TX-10/0-5800-P1 | | |

| 4. Title and Subtitle | 5. Report Date |
|---|---|
| Warrants for Major Traffic Generator Guide Signing | September 2009 |
| | 6. Performing Organization Code |

| 7. Author(s) | 8. Performing Organization Report No. |
|---|---|
| Fengxiang Qiao, Lei Yu, Hui Wang, Lijin Ma, Rong Zhang, and Yan Zeng | Product 0-5800-P1 |

| 9. Performing Organization Name and Address | 10. Work Unit No. (TRAIS) |
|---|---|
| Department of Transportation Studies<br>Texas Southern University<br>3100 Cleburne Avenue<br>Houston, Texas 77004 | 11. Contract or Grant No.<br>Project 0-5800 |

| 12. Sponsoring Agency Name and Address | 13. Type of Report and Period Covered |
|---|---|
| Texas Department of Transportation<br>Research and Technology Implementation Office<br>P.O. Box 5080<br>Austin, Texas 78763-5080 | Product<br>12/13/06-8/31/08 |
| | 14. Sponsoring Agency Code |

15. Supplementary Notes

Project performed in cooperation with the Texas Department of Transportation and the Federal Highway Administration.

16. Abstract

Major traffic generators (MTGs) are important regional attractions, events, or facilities that attract persons or groups from beyond a local community, city, or metropolitan area. MTGs are significant because of their unique educational, cultural, historical, or recreational experience and public appeal. The *Texas Manual on Uniform Traffic Control Devices* (TMUTCD) provides the definition of regular traffic generators based on four population types but not for MTGs. Minnesota, Missouri, North Carolina, and British Columbia in Canada have specific guidelines for MTGs in various forms, but these guidelines cannot be directly applied to Texas. It is imperative to establish MTG warrants that are suitable for the Texas environment. In this product, practices and manuals used in Texas and other states are scanned through a literature review, an engineer survey, and an MTG survey. The opinions of engineers and the needs of MTGs were obtained in terms of the criteria, types of symbols used, and location and size of symbols/signs. Practices in other states and the opinions of responding engineers are synthesized through proposed fuzzy logic–based algorithms. The preliminary recommendations of type of symbol and location and size of symbols/signs are identified based on the study of the literature and survey results, which are then tested in the driving simulator and computer slide show. Through all these efforts, warrants of guide signing for Texas MTGs are proposed.

| 17. Key Word | 18. Distribution Statement |
|---|---|
| major traffic generator, guide signing, symbol, warrant, driving simulator | |

| 19. Security Classif. (of this report) | 20. Security Classif. (of this page) | 21. No. of Pages | 22. Price |
|---|---|---|---|
| | | 51 | |

# Warrants for Major Traffic Generator Guide Signing

By
Fengxiang Qiao, Lei Yu, Hui Wang, Lijin Ma, Rong Zhang, and Yan Zeng

Product 0-5800-P1
Research Project Number 0-5800
Project Title: Symbols and Warrants for Major Traffic Generator Guide Signing

September 2009

Department of Transportation Studies
Texas Southern University
3100 Cleburne Avenue
Houston, Texas 77004

Performed in cooperation with the Texas Department of Transportation
and the Federal Highway Administration

## Disclaimer

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 Texas Department of Transportation. This report does not constitute a standard, specification, or regulation.

## Notice

The United States Government and the State of Texas do not endorse products or manufacturers. Trade or manufacturers' names appear herein solely because they are considered essential to the object of this report.

## Acknowledgments

The authors would like to express their sincere gratitude for the support and valuable comments that they received from project director Mr. Ismael Soto of the Texas Department of Transportation (TxDOT) through the course of conducting this project. The authors would like to thank the Project Monitoring Committee and other TxDOT personnel for any direct or indirect assistance that they provided.

The authors also express their sincere thanks to those who responded to the engineer survey, major traffic generator survey, and email survey on signing practices. The authors would like to thank research assistants in the Department of Transportation Studies at Texas Southern University (TSU) for sharing their ideas about this research. Also the authors would like to thank all the personnel at TSU who have directly or indirectly contributed to this project or have provided assistance.

## Credit for Sponsors

This research was performed in cooperation with the Texas Department of Transportation and the U.S. Department of Transportation, Federal Highway Administration.

# Table of Contents

Page

# LIST OF FIGURES

# LIST OF TABLES

**Page**

# CHAPTER 1
# INTRODUCTION

## *1.1 Definition of a Major Traffic Generator*

Major traffic generators (MTGs) are important regional attractions, events, or facilities that attract persons or groups from beyond a local community, city, or metropolitan area. MTGs are significant because of their unique educational, cultural, historical, or recreational experience and public appeal. MTGs usually require adequate signs or symbols to guide unfamiliar motorists from major corridors to the venues. One of the principles of good signing is to keep the message concise and use symbols that can provide effective messages when they are well recognized.

However, the signing space along these major corridors are normally very limited. In order to identify the suitable symbols or signs from beyond a local community, city, or metropolitan area to MTGs, it is important to identify the warrants of MTGs. This includes the identification of MTG eligibility criteria and the selection of symbols and/or signs for MTGs.

## *1.2 Traffic Generator Guide Signing in Texas*

The *Texas Manual of Uniform Traffic Control Devices* (TMUTCD) provides the definition of regular traffic generators (see Table 1); predominantly retail, business, or manufacturing centers are normally not eligible for guide signing. There is no specification of MTGs in the current TMUTCD. Therefore, it is necessary to identify the eligibility criteria and the design of symbols/signs of MTGs in Texas.

## Table 1 Type of Traffic Generators Defined in TMUTCD

| | **Population Range** | **More than 250,000** | **50,000-250,000** | **15,000-50,000** | **Less than 15,000** |
|---|---|---|---|---|---|
| Type of Generator | Specific Criteria | Major Metropolitan Areas | Urban Areas | Suburban and Rural Areas | Rural City |
| Airports (Publicly Owned) | Number of movements (one way) | 15 daily | 10 daily | 5 daily | 2 daily |
| | Maximum distance from intersecting highway | 5 miles | 8 miles | 10 miles | 10 miles |
| Airport TASP[1] | Maximum distance from intersecting highway | 5 miles | 10 miles | 15 miles | 20 miles |
| Colleges and Universities | Off-street parking (minimum) | 500 | 400 | 200 | 100 |
| | Mileage | 3 miles | 4 miles | 5 miles | 5 miles |
| Hospitals | See general service signs (TMUTCD 2D-45) | | | | |
| Recreational[2] and Cultural Interest Areas | Facilities open to general public. Minimum annual attendance. | 100,000[3] (300,000)[4] | 50,000[3] (250,000)[4] | 25,000[3] (100,000)[4] | 10,000[3] (50,000)[4] |
| | Maximum distance from highway | 5 miles | 5 miles | 5 miles | 5 miles |
| Government Facilities (Must Be Open for Public Access to Receive Service) | State or federal maximum distance from highway | 0.5 miles | 1 mile | 1 mile | 2 miles |
| Business Districts | A DOWNTOWN sign may be used if the marked route is within the city limits, or a "NEXT __ EXITS" sign may be used to provide guidance to an area with multiple exits. | (1) Largest core city of urban area of 25,000 population or more<br>(2) A distinct CBD must exist with an established multi-street system. Strip development business centers shall not qualify.<br>(3) Only one such supplemental sign will be permitted for each direction of travel for the best and most direct route serving the downtown core. It is not necessary that signs denoting DOWNTOWN for different directions of travel be confined to the same interchange.<br>(4) A downtown guide sign may include the core city's name, but other town or city names should not be used on the same sign as the text "Downtown." | | | |
| Parking, Park and Ride Terminal, and Rail Terminal Facilities | Facilities shall be directly related to the operation of a multimodal transportation system. This includes parking for carpooling, mass transit, and rail terminal access a maximum distance from highway. | 3 miles | 3 miles | 1 mile | 1 mile |
| | Minimum number of parking spaces | 200 | 100 | 100 | 100 |

Note: The traffic generator should be located on the street or roadway that intersects the highway.

1. Listed as approved in the Texas Airport System Plan (TASP).
2. State and national parks may be signed from the highway route nearest the park regardless of annual attendance. Refer to TMUTCD Chapter 2G, Tourist-Oriented Directional Signs, for additional information.
3. Applies to conventional roads.
4. Applies to freeways and expressways.

### *1.3 MTG Signing Practices in Other States*

In order to further identify the practices of MTG guide signing at the state level, an email survey was sent to state departments of transportation (DOTs) in 49 states in the United States (with the exception of Texas, where information has been collected through other channels) on November 13, 2007. One of the questions was "Do you have signing practices or standards for major traffic generators in your state or agency?" Twenty-two states effectively responded (a response rate of 44 percent). The survey responses show that Minnesota, Missouri, and North Carolina have specific guidelines for MTGs.

Each state has its own criteria for MTG guide signing, which are summarized in Table 2. Through the survey, it was found that:

- All responding states use the *Manual on Uniform Traffic Control Devices* (MUTCD) and *American Association of State Highway and Transportation Officials* (AASHTO) *Guidelines for the Selection of Supplemental Guide Signs for Traffic Generators Adjacent to Freeways.*
- All responding states have signing policies for some traffic generators.
- Minnesota, Missouri, and North Carolina have specific guidelines for MTGs.
- Rhode Island does not need to develop warrants and criteria for MTGs.
- Nevada decides MTG signing based on "common sense," which refers the issue to the director's office for review and confirmation via the minutes of each meeting.

**Table 2 Types of Traffic Generator Signing in Other States**

| State | Type of Traffic Generator Sign | | | |
|---|---|---|---|---|
| | Supplemental Guide Sign | Logo Sign | Tourist-Oriented Directional Sign | Recreational and Cultural Interest Area (RCIA) Sign |
| Alabama | X | | | |
| Alaska | | X | | X |
| Arkansas | | | | |
| Colorado | X | | X | X |
| Idaho | X | | | |
| Indiana | X | | | |
| Iowa | X | | | |
| Kansas | X | | | |
| Louisiana | X | | | |
| Maine | | X | | |
| Massachusetts | | X | | |
| Minnesota | X | | | |
| Mississippi | | | X | |
| Missouri | X | | | |
| Nevada | | X | X | |
| North Carolina | X | | | |
| North Dakota | | | | |
| Ohio | X | | | |
| Oregon | X | X | X | X |
| Rhode Island | | | | |
| Tennessee | X | | | |
| West Virginia | | X | | |

In the operational guidelines of the *Minnesota Traffic Engineering Manual*, the MTG eligibility criteria are set as: (1) parking for a minimum of 1,000 vehicles; (2) a minimum of 10 events per year, with average event attendance of at least 5,000 persons; (3) location not more than 16 km (10 miles) from the conventional highway interchange/intersection where signs are requested.

The Missouri Highways and Transportation Commission provides specific criteria for MTGs in the *Engineering Policy Guide*. The major traffic generator must meet the following criteria: (1) be fully operative and open to the traveling public for a minimum of 3 months each year; (2) be located along either the interchange crossroad or the freeway and within 6 miles of the major traffic generator in a rural area or within 2 miles in an urban or metropolitan area; and (3) meet the annual attendance requirements as provided in the definitions section of this rule.

The North Carolina Department of Transportation's Division of Highway, Traffic Engineering, and Safety Systems Branch provides standard practice for supplemental guide signs for MTGs as follows: (1) trip generations will be in amounts of 250,000 or more annually; (2) signs for qualifying traffic generators shall be limited to the closest freeway interchange, not to exceed 15 miles from the facility; and (3) the facility shall have adequate onsite parking during hours of operation for guests, tourists, and customers.

The Canadian province of British Columbia regulates the criteria for MTGs based on different land use types (rural/urban or suburban).

The manuals and practices of other states/provinces are valuable but cannot be directly applied to Texas due to its different geographical, demographic, and social features. It is imperative to establish the MTG warrants that are suitable for the Texas environment.

### *1.4 Outline of the Product*

In this product, relevant manuals and practices in Texas and other states will be analyzed, and necessary surveys (of engineers, MTGs, and motorists) and tests (in the driving simulator and through slide shows) will be described. Based on these, the warrants for Texas MTGs will be finally synthesized.

# CHAPTER 2
# SURVEY OF ENGINEERS AND MTGS

In order to identify the opinions of engineers and needs of MTGs regarding the warrants and design of MTG symbols and signs, two types of surveys were conducted: the engineer survey and the MTG survey. The engineer survey was distributed to relevant engineers in and outside of Texas, and the MTG survey was distributed to MTG executives and motorists who drove to MTGs.

## *2.1 Survey of Opinions of Engineers*

### 2.1.1 Purpose of Survey

The purpose of the engineer survey is to collect opinions from engineers in Texas and other states on their practical experiences in identifying symbols and warrants for MTGs, including eligibility criteria of MTGs, types of symbols, and signing location and size.

### 2.1.2 Survey Process

The engineer survey instrument, which was designed as an online survey, included two parts: MTG sign design and MTG criteria. The survey contents were revised several times through close and frequent communications between the research team and Project Monitoring Committee (PMC) members. The major questions in the survey are:

1. Can guide sign routing plaques effectively help unfamiliar motorists navigate a regional freeway system to its MTG?
2. What would be the most effective plaque design, i.e., symbol, text or combo, and color?

3. How many plaques could be attached to a parent sign without overloading the motorists' comprehension level?
4. What is the plaque size determination, i.e., the minimum text size?
5. How and where to place the trailblazing signs for MTGs through various routes.
6. What are the engineers' opinions and practices of eligibility criteria of MTGs?

The title of the survey is "Survey on Symbols and Warrants for Major Traffic Generator Guide Signing." The detailed questionnaires can be accessed at the website: http://itri.tsu.edu/TxDOT5800/survey5800.htm.

The survey was distributed to the following four sets of engineers:

1. A preliminary list of Texas engineers was prepared by searching the Texas Department of Transportation website name list and is named "Texas Engineers List." This list mainly includes the maintenance supervisors for each county of Texas.
2. A list of Texas engineers was recommended by the project director, Mr. Ismael Soto.
3. Based on the contacts with engineers in states other than Texas, the mailing list of engineers from other states was prepared. It covers almost all states in the United States (53 email addresses).
4. Transportation Research Board (TRB) committee AHB50 on traffic control devices.
5. American Association of State Highway and Transportation Officials (AASHTO) Subcommittee of Traffic Engineers.

### 2.1.3 Survey Feedback

The engineers' feedback was retrieved on May 27, 2008. A total of 17 engineers responded, with five from Texas and the rest from 11 other states: Minnesota, California, Tennessee, Illinois, Michigan, Colorado, Nevada, Massachusetts, Iowa, Mississippi, and Arizona.

Sign design focused on four subjects: (1) symbol sign practices, (2) symbol sign plaques, (3) trailblazing signs, and (4) MTG sign types.

All responding engineers have used symbol signs for traffic generators in their practice. The most employed symbols are standard symbols from the *Manual on Uniform Traffic Control Devices* and *Standard Highway Sign*s (SHS). All believe that symbol signs can effectively help unfamiliar motorists to navigate a regional freeway system to its MTG if these MTG signs are installed as guide sign routing plaques. Regarding appropriate types of MTG symbols, 53 percent of surveyed engineers prefer category-oriented symbols, 35 percent prefer specific symbols for each MTG, and 12 percent prefer a uniform symbol for all MTGs.

Fifty-nine percent of the engineers believe that 6 inches is the minimum text size for an MTG symbol sign plaque. Most engineers (71 percent) agree to place the MTG symbol sign on the top of the parent guide signs, like the airport and hospital guide sign routing plaques. The engineers have no obvious preference for blue, brown, or green. The majority (41 percent) agree that color as the background of a symbol and text plaque should be dependent on the category of MTG and should match the service. Most engineers (71 percent) believe that the trailblazing sign is necessary for MTGs. The engineers have different opinions on the maximum radius of an MTG that trailblazing signs should be provided for. Among the 12 engineers that responded to the relevant question, four of them prefer 5 miles, and three prefer 10 miles for placing trailblazing signs. In terms of MTG sign types, symbol sign plaques, supplemental guide signs, and specific service signs are preferred by the responding engineers and obtained the same number (11) of engineers' support.

## *2.2 Survey Needs of MTGs*

### 2.2.1 Purpose of Survey

The purpose of the MTG survey is to survey typical MTGs on their possible needs for symbol sign designs, including sign content, types, and locations. In addition to the survey of MTG executives, the motorists going to MTGs were also surveyed on their feelings and needs for freeway guide signs.

### 2.2.2 Survey of MTG Executives

The survey form for MTG executives was designed in a Microsoft Word file, containing 12 questions, including symbol sign design and the basic information relevant to MTG criteria. This instrument was emailed to 11 selected potential MTGs in Texas on June 17, 2008. The title of the survey is "Questions on Your Need for MTG Guide Signing."

### 2.2.3 Survey of Motorists Going to MTGs

Besides surveying the management sectors of potential MTGs in Texas, the opinions of motorists going to these MTGs are also very important. Two surveys were conducted of motorists driving to: (1) Robertson Stadium at the University of Houston (RSUH) on July 4, 2008; and (2) the Houston Toyota Center (TC) on July 22, 2008, and August 10, 2008.

### 2.2.4 Survey Feedback

Four MTGs responded to the survey: (1) Sam Houston Race Park, (2) Schlitterbahn Waterpark in New Braunfels, (3) Schlitterbahn Waterpark in South Padre Island, and (4) the Toyota Center. The response rate is 36 percent. There were 148 motorists responding to the survey at RSUH on July 4, 2008, and 104 responding at the TC on July 22, 2008, and August 10, 2008. The total surveyed motorists for these two MTGs were 252.

#### *2.2.4.1 Feedback from the Survey of MTG Executives*

From the MTG executives survey, all four MTGs would like to place guide signs for their facility to inform motorists along freeways. None of them want to pay all costs of their guide signs. If classifying MTGs, Schlitterbahn Waterpark in New Braunfels and Schlitterbahn Waterpark in South Padre Island claimed themselves as amusement parks, Sam Houston Race Park claimed itself as a horse track or concert venue, and the Toyota Center claimed itself as an arena. Regarding the background color of guide signs, Schlitterbahn Waterpark in New Braunfels and Schlitterbahn Waterpark in South Padre Island like blue and white, while Sam Houston Race Park and the Toyota Center prefer green.

Except for Sam Houston Race Park, three of the other responding MTGs would like to display a symbol on their guide signs. Regarding the form of symbols displayed in the guide signs, the two Schlitterbahn Waterparks and the Toyota Center would like to display specific symbols for their facilities. Schlitterbahn Waterpark in South Padre Island also would like to

display a category-oriented symbol based on the classification of the MTG. Sam Houston Race Park skipped this question. Except Sam Houston Race Park, three of the responding MTGs agreed that symbols will be helpful to direct motorists to their destinations.

Regarding the elements displayed on guide signs, all wanted to show the names of their facilities and the messages of their events. In addition, Schlitterbahn Waterpark in New Braunfels liked displaying the distance information and its logo. The Toyota Center wanted to display a symbol. Schlitterbahn Waterparks in New Braunfels and South Padre Island preferred to use two or three small guide signs at the freeway interchange approaching to their sites. This can be implemented by using MTG symbol plaques on top of the standard interchange signs. However, Sam Houston Race Park and the Toyota Center preferred one large guide sign, i.e., using an independent supplemental guide sign.

The Toyota Center liked installing its guide signs at the nearest freeway exit only in each direction. The other three MTGs wanted to install their guide signs not only at the nearest freeway exit but also in other places such as on other highways and on mile markers. This means these three MTGs preferred trailblazing signs. None of the responding MTGs provided additional comments on the guide signs for MTGs.

The MTG survey identified that: (1) Sam Houston Race Park and the Toyota Center have more than 1,300 parking spaces each, and the Schlitterbahn Waterparks in both New Braunfels and South Padre Island have more than 900 parking spaces; (2) there are more than 20 events per year at both Sam Houston Race Park and the Toyota Center, and more than 12 events per year at Schlitterbahn Waterparks in both New Braunfels and South Padre Island; (3) there are more than 450,000 attendees annually at both Sam Houston Race Park and the Toyota Center, and more than 250,000 annual attendees at Schlitterbahn Waterparks in both New Braunfels and South Padre Island; and (4) the distance from the nearest freeway exit is less than 2 miles for Sam Houston Race Park and the Toyota Center, the distance from the nearest freeway exit to Schlitterbahn Waterpark in New Braunfels is more than 10 miles, and the Schlitterbahn Waterpark in South Padre Island is located between 3 and 5 miles from the nearest freeway exit.

#### *2.2.4.2 Feedback from the Survey of MTG Motorists*

Based on the feedback from the survey of MTG motorists, 12 percent of responding motorists located their destinations based on the information provided by freeway guide signs

only. Thirty-one percent of motorists depended on an online map before travel. Forty-five percent mostly used their driving experience. Even for those who relied on online maps and/or their own experience, they still needed to follow the freeway guide signs. At least 43 percent of motorists rely on freeway signs.

Eighty-eight percent of responders felt that it was necessary to place specific signs for MTGs on freeways; only 10 percent held the opposite opinion. The most-needed information to be displayed on the specific signs for MTGs according to the responding motorists is the name of the destination (36 percent), action information such as "exit" (26 percent), and distance (13 percent). Nearly half (49 percent) of the responders preferred to use blue as the background color for specific signs for MTGs, 35 percent preferred green, and 5 percent preferred brown. The motorists cared more about the position (34 percent) and an adequate number of signs (32 percent) for the guide signs for MTGs, while they cared less about how the guide signs were designed (21 percent).

# CHAPTER 3
# INDENTIFICATION OF ELIGIBILITY CRITERIA FOR MTGS

## *3.1 Problem Statement*

Based on the practices in states that have established MTG criteria in their manuals, possible factors could include community population, site-generated traffic, parking, proximity to major corridors, attractions of MTGs, etc., which are normally based on engineers' experiences and opinions with no quantified and formulated way to synthesize such criteria.

Engineers' experiences and opinions are human knowledge, which is difficult to represent in crisp values in calculations. This motivates the need to develop a methodology that can synthesize the expert knowledge from engineers and existing practices in other states.

Fuzzy logic, which has been widely used in almost all aspects of transportation systems, is able to conduct a so-called "soft-computing" of human knowledge from experts and engineering practices and is thus an ideal tool to synthesize the MTG criteria for Texas, provided that the experts' knowledge and practices have been collected through necessary surveys and literature reviews.

## *3.2 Fuzzy Logic–Based Algorithms*

Figure 1 is an illustration of the proposed approach. The existing criteria of MTGs from other states are synthesized first, and then the survey results from engineers in and outside of Texas are also synthesized. Both are supported by the different strategies of fuzzy logic.

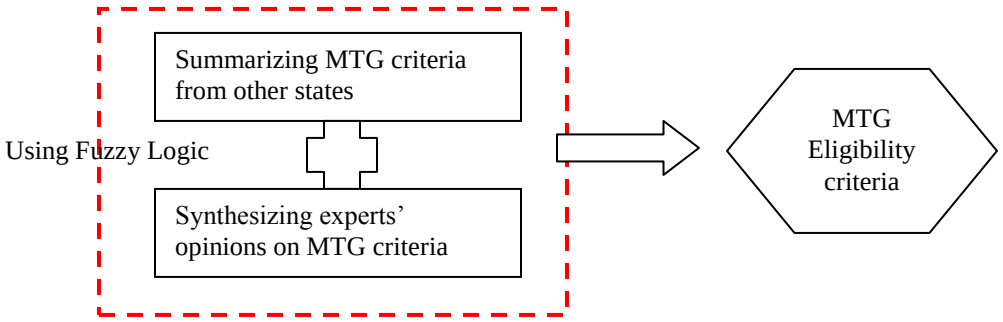



**Figure 1 Fuzzy Logic–Based Syntheses of MTG Criteria for Texas**

The proposed methodology is based on the following three steps:

- step 1: synthesize the MTG criteria based on existing MTG criteria from other states using fuzzy logic,
- step 2: synthesize MTG criteria based on an engineer survey using an algorithm developed by the fuzzy system, and
- step 3: finalize the MTG criteria generated in the previous steps.

For step 1 of the methodology, since there is only a very limited number of states providing MTG criteria, the way to synthesize those existing criteria was based on the fundamental concept of fuzzy logic.

Step 2 is based on the engineer survey results that have been reported in Task 2. Since there are 17 engineers who replied to the survey, a specific approach was developed to synthesize the knowledge from all responding engineers.

In the developed approach in step 2, any single expert survey response was represented by a pair of input-output data sets: $\left(x_1^p, x_2^p, x_3^p ..., x_n^p; y^p\right)$. The purpose is to design a fuzzy system $f(x)$ based on these N input-output pairs. The following is a procedure with six sub-steps.

*Sub-step 2-1: Define fuzzy sets to cover the input and output spaces.*

For any input data $x_i \in [\alpha_i, \beta_i]$, there exists fuzzy set $A_i^p$ such that its membership value $\mu_{A_i^p}(x_i) \neq 0$. For multiple inputs (such as for *N* inputs), there should be *N* sets of membership values defined.

*Sub-step 2-2: Calculate the number of inputs supporting the same fuzzy sets.*

Suppose there are $n_1$ experts supporting the fuzzy set $\alpha_1$, $n_2$ experts supporting the fuzzy set $(\alpha_1 + a_1)$, $n_3$ experts supporting the fuzzy set $(\alpha_1 + b_1)$, and $(N - n_1 - n_2 - n_3)$ experts supporting the fuzzy set $\beta_1$, and there are similar cases for $A_2$ and $A_3$. Then:

$$\begin{aligned} A_1 &= \{\alpha_1,\ \alpha_1 + a_2,\ \alpha_1 + b_1,\ \beta_1\} \\ A_2 &= \{\alpha_2,\ \alpha_2 + a_2,\ \alpha_2 + b_2,\ \beta_2\} \\ A_3 &= \{\alpha_3,\ \alpha_3 + a_3,\ \alpha_3 + b_3,\ \beta_3\} \end{aligned} \tag{1}$$

In this case, the fuzzy term "several" for $A_1$ is defined as:

$$A_1\, several = \frac{n_1}{\alpha_1} + n_2/(\alpha_1 + a_1) + n_3/(\alpha_1 + b_1) + (N - n_1 - n_2 - n_3)/\beta_1 \tag{2}$$

*Sub-step 2-3: Calculate the sum of weight values of the opinion with the same fuzzy set for different experts.*

Suppose the first $n_1$ experts' opinion has the same fuzzy set $\alpha_1$, the following $n_2$ experts' opinion has the same fuzzy set $(\alpha_1 + a_1)$, the next $n_3$ experts' opinion has the same fuzzy set $(\alpha_1 + b_1)$, and the last $(N - n_1 - n_2 - n_3)$ experts' opinion has the same fuzzy set $\beta_1$. Then, the sum of the weight value of inputs $x_1$ with different fuzzy set ranges should be:

$$W_{A_1[\alpha_1, \beta_1]} = W_{x_1^1} + W_{x_1^2} + W_{x_1^3} + \ldots + W_{x_1^p} = \sum_{i=1}^{N} W_{x_1^i} \tag{3}$$

*Sub-step 2-4: Define the membership function for different inputs.*

The support of a fuzzy set $A_i$ in the universe of discourse $U$ is a crisp set that contains all elements of $U$ that have nonzero membership values in $A_i$. That is:

$$supp(A_i) = \left\{ x \in U \middle| \mu_{A_i(x_i)} > 0 \right\} \tag{4}$$

where $supp(A_i)$ denotes the support of fuzzy set $A_i$ and $\mu_{A_i(x_i)}$ denotes the percentage of weight value for different fuzzy set ranges to the sum weight value and converts the maximum value of $\mu_{A_i(x_i)}$ to 1. The following equation indicates how to calculate $\mu_{A_1(x_1)}$:

$$\mu_{A_1(x_1)} = \left\{ \mu_{\alpha_1},\ \mu_{\alpha_1+a_1},\ \mu_{\alpha_1+b_1},\ \mu_{\beta_1} \right\} \tag{5}$$

*Sub-step 2-5: Create one rule for one input-output pair.*

If $x_1^p, x_2^p, x_3^p \ldots, x_n^p$ are all satisfied with a certain fuzzy set, then $y^p$ is in the given fuzzy set. The degree of this pair of data $\left(x_1^p, x_2^p, x_3^p \ldots, x_n^p; y^p\right)$ is defined as:

$$D(rule) = \prod_{i=1}^{n} \mu_{A_i}\left(x_i^p\right) * \mu_B\left(y^p\right) \tag{6}$$

*Sub-step 2-6: Locate the expert opinion with the maximum degree.*

The input-output pair with the maximum degree is selected as the most representative one for synthesizing the MTG criteria. The maximum degree is calculated in Equation (7).

$$D(final) = \max_{p \in [1,N]} \left[ \prod_{i=1}^{n} \mu_{A_i^p}\left(x_i^p\right) * \mu_B\left(y^p\right) \right] \tag{7}$$

### *3.3 Synthesizing Warrants for MTG Guide Signing*

#### 3.3.1 Synthesize MTG Criteria Based on Manuals Using Fuzzy Logic

Manuals on MTG criteria from Missouri, Minnesota, North Carolina, and British Columbia in Canada were synthesized based on the fundamental concept of fuzzy logic. The descriptions in these manuals were converted to fuzzy rules, which were then analyzed one by one and merged afterward.

Finally, the combined eligibility criteria of MTGs in Texas are identified (considering existing manuals from other states only) as follows:

1. parking: a minimum of 1,000 vehicles;
2. a location along either the interchange crossroad or the freeway and within 6 miles of the major traffic generator in rural areas or within 2 miles in urban, suburban, and metropolitan areas; and
3. at least 300,000 visitors per year in metropolitan areas, at least 250,000 visitors per year in urban and suburban areas, and at least 200,000 visitors per year in rural areas.

### 3.3.2 Synthesize MTG Criteria Based on Engineer Survey Using Proposed Fuzzy-Based Approach

In order to process the engineer survey, the following parameters are defined: $x_1$: minimum number of parking spaces of the MTG; $x_2$: maximum distance from the nearest highway to the MTG; $x_3$: minimum annual attendance of the MTG; $x_4$: minimum number of events per year; and $y$: the eligibility criteria of MTGs for Texas.

The engineer survey results suggest four different ranges of population, which are the same as the population divisions for conventional traffic generators in the TMUTCD.

Two types of engineers' knowledge were classified: knowledge from Texas engineers ($R_{\text{Texas}}$) and knowledge from non-Texas engineers ($R_{\text{Non-Texas}}$). Survey responses from these two types were analyzed separately following the algorithms proposed in Section 3.2.

The criteria of MTGs from engineers' knowledge are identified from both $R_{\text{Non-Texas}}$ and $R_{\text{Texas}}$ by the following equation:

$$R(final) = a(R_{Texas}) + b(R_{Non-Texas}) \tag{8}$$

By changing the values $a \in [0,1]$, $b \in [0,1]$ that satisfy $a + b = 1$, the preferences can be identified in terms of whether or not knowledge from Texas engineers is more important than that from other states. For example, in the case of $a$ = 1 and $b$ = 0, this means the final criteria are based on experiences from Texas engineers only, and $a$ = 0 and $b$ = 1 excludes all Texas engineers and only considers opinions from Non-Texas engineers. Table 3 describes the specific MTG criteria for each population range based on different values of $a$ and $b$.

**Table 3 MTG Criteria Generated by Different Values of *a* and *b* Based on Engineer Survey**

| | | Major Metropolitan Area | Urban Area | Suburban Area | Rural Area |
|---|---|---|---|---|---|
| **$D(R_{Non\text{-}Texas})$ ($a = 0$, $b = 1$)** | $x_1$ | 1,000 | 950 | 700 | 400 |
| | $x_2$ | 2 | 5 | 5 | 10 |
| | $x_3$ | 200,000 | 300,000 | 100,000 | 50,000 |
| | $x_4$ | 15 | 12 | 5 | 3 |
| **$D(R_{Texas})$ ($a = 1$, $b = 0$)** | $x_1$ | 1,000 | 1,000 | 700 | 400 |
| | $x_2$ | 2 | 2 | 3 | 8 |
| | $x_3$ | 325,000 | 300,000 | 200,000 | 80,000 |
| | $x_4$ | 15 | 10 | 8 | 6 |
| ***a = 0.125, b = 0.875*** | $x_1$ | 1,000 | 956.25 | 700 | 400 |
| | $x_2$ | 2 | 4.625 | 4.75 | 9.75 |
| | $x_3$ | 215,625 | 300,000 | 112,500 | 53,750 |
| | $x_4$ | 15 | 11.75 | 5.375 | 3.375 |
| ***a = 0.25, b = 0.75*** | $x_1$ | 1,000 | 962.5 | 700 | 400 |
| | $x_2$ | 2 | 4.25 | 4.5 | 9.5 |
| | $x_3$ | 231,250 | 300,000 | 125,000 | 57,500 |
| | $x_4$ | 15 | 11.5 | 5.75 | 3.75 |
| ***a = 0.375, b = 0.625*** | $x_1$ | 1,000 | 968.75 | 700 | 400 |
| | $x_2$ | 2 | 3.875 | 4.25 | 9.25 |
| | $x_3$ | 246,875 | 300,000 | 137,500 | 61,250 |
| | $x_4$ | 15 | 11.25 | 6.125 | 4.125 |
| ***a = 0.4, b = 0.6*** | $x_1$ | 1,000 | 970 | 700 | 400 |
| | $x_2$ | 2 | 3.8 | 4.2 | 9.2 |
| | $x_3$ | 250,000 | 300,000 | 140,000 | 62,000 |
| | $x_4$ | 15 | 11.2 | 6.2 | 4.2 |
| ***a = 0.5, b = 0.5*** | $x_1$ | 1,000 | 975 | 700 | 400 |
| | $x_2$ | 2 | 3.5 | 4 | 9 |
| | $x_3$ | 262,500 | 300,000 | 150,000 | 65,000 |
| | $x_4$ | 15 | 11 | 6.5 | 4.5 |
| ***a = 0.6, b = 0.4*** | $x_1$ | 1,000 | 980 | 700 | 400 |
| | $x_2$ | 2 | 3.2 | 3.8 | 8.8 |
| | $x_3$ | 275,000 | 300,000 | 160,000 | 68,000 |
| | $x_4$ | 15 | 10.8 | 6.8 | 4.8 |
| ***a = 0.625, b = 0.375*** | $x_1$ | 1,000 | 981.25 | 700 | 400 |
| | $x_2$ | 2 | 3.125 | 3.75 | 8.75 |
| | $x_3$ | 278,125 | 300,000 | 162,500 | 68,750 |
| | $x_4$ | 15 | 10.75 | 6.875 | 4.875 |
| ***a = 0. 75, b = 0.25*** | $x_1$ | 1,000 | 987.5 | 700 | 400 |
| | $x_2$ | 2 | 2.75 | 3.5 | 8.5 |
| | $x_3$ | 293,750 | 300,000 | 175,000 | 72,500 |
| | $x_4$ | 15 | 10.5 | 7.25 | 5.25 |
| ***a = 0.875, b = 0.125*** | $x_1$ | 1,000 | 993.75 | 700 | 400 |
| | $x_2$ | 2 | 2.375 | 3.25 | 8.25 |
| | $x_3$ | 309,375 | 300,000 | 187,500 | 76,250 |
| | $x_4$ | 15 | 10.25 | 7.625 | 6 |

### 3.3.3 Combine and Finalize MTG Criteria for Texas

While comparing the results calculated by different $a$ and $b$ with the MTG criteria generated from existing manuals in other states in Section 3.3.1, the following can be concluded:

1. In metropolitan areas, the results of $a = 0.75$, $a = 0.875$, and $a = 1$ ($b = 0$) are close to the criteria generated from the existing manual. Since the annual attendance in metropolitan areas should be larger than that in urban areas, the results of $a = 0.75$ are discarded.
2. In urban areas, the suitable result should be $a = 0.875$ or 1 and $b = 0.125$ or 0.
3. In suburban areas, the suitable result should be $a = 1$ and $b = 0$.
4. In rural areas, the suitable result should be $a = 1$ and $b = 0$.

This means the knowledge from Texas engineers (i.e., $a$ is equal to or is close to 1) is preferred more. So, based on the established rule base and analyses, if considering the opinions mostly from Texas engineers (i.e., $a = 1$ and $b = 0$), the MTG eligibility criteria in Texas are identified in the following:

1. parking: a minimum of 1,000 vehicles in metropolitan and urban areas, 700 in suburban areas, and 400 in rural areas;
2. a location along either the interchange crossroad or the freeway and within 8 miles of the major traffic generator in rural areas, within 3 miles in suburban areas, or within 2 miles in metropolitan and urban areas;
3. at least 325,000 visitors per year in metropolitan areas, at least 300,000 visitors per year in urban areas, at least 200,000 visitors per year in suburban areas, and at least 80,000 visitors per year in rural areas;
4. number of events per year: a minimum of 15 events in metropolitan areas, 10 in urban areas, 8 in suburban areas, and 6 in rural areas.

These are listed in Table 4.

## Table 4 Finalized Criteria for Texas MTGs

| Factors | MTG criteria | | | |
|---|---|---|---|---|
| | **Major Metropolitan Area** | **Urban Area** | **Suburban Area** | **Rural Area** |
| Parking Space ($x_1$) | 1,000 | 1,000 | 700 | 400 |
| Distance from Freeway ($x_2$) | 2 | 2 | 3 | 8 |
| Annual Attendance ($x_3$) | 325,000 | 300,000 | 200,000 | 80,000 |
| Number of Events per Year ($x_4$) | 15 | 10 | 8 | 6 |

# CHAPTER 4
# MTG GUIDE SIGNING

## *4.1 Types of Symbols/Signs for Texas MTGs*

### 4.1.1 Manuals and Current Practices

The type of symbols used for MTG signs is relevant to the types of MTG signs. In the following sections, the types of MTG signs and symbols are analyzed.

The MUTCD and TMUTCD allow the use of four types of signs for important traffic generators, including: (1) supplemental guide signs, (2) specific service signs, (3) tourist-oriented directional signs, and (4) recreational and cultural interest area signs.

Section 2E.32 in the MUTCD and TMUTCD guides that supplemental guide signs can be used to provide information regarding destinations accessible from an interchange, other than places shown on the standard interchange signing. The *AASHTO Guidelines for the Selection of Supplemental Guide Signs for Traffic Generators Adjacent to Freeways* provides a basis for development of individual state policies on the use of supplemental guide signs.

In Chapter 2F of the MUTCD, specific service (logo) signs shall be defined as guide signs that provide road users with business identification and directional information for services, including GAS, FOOD, LODGING, CAMPING, and ATTRACTION. The attraction services shall include only facilities that have the primary purpose of providing amusement, historical, cultural, or leisure activities to the public. However, ATTRACTION services are not contained in this signing program of the TMUTCD.

In Chapter 2G of the MUTCD and TMUTCD, tourist-oriented directional signs are guide signs with one or more panels that display the business identification of and directional information for business, service, and activity facilities. These businesses are involved with

seasonal agricultural products. When used, tourist-oriented directional signs shall be used only on rural conventional roads and shall not be used on conventional roads in urban areas nor at interchanges on freeways or expressways. Tourist-oriented directional signs may be used in conjunction with general service signs. The general service sign symbols (Section 2D.45) and the symbols for recreational and cultural interest area signs (Chapter 2H) may be used. Generic icons for specific businesses, services, and activities may also be used.

Section 2H.01 and Section 2H.09 of the MUTCD and TMUTCD also provide guidance on the use of RCIA signs that depict significant traffic generators on freeways and expressways where there is direct access to these areas. The signs show recreational or cultural interest area destinations on supplemental guide signs. RCIAs are attractions or traffic generators that are open to the general public for the purpose of play, amusement, or relaxation. In Chapter 2H, the TMUTCD establishes criteria in Section 2H.10 to justify which traffic generators should be depicted on supplemental guide signs that are not specified in the MUTCD.

As shown by the email survey of other states, each state has its own favorite categories of traffic generator signing, which has been summarized in Table 2.

According to the current guidance in the TMUTCD, logo signs and tourist-oriented directional signs are improper to display the MTG information. Unlike in the MUTCD, logo signs in the TMUTCD do not add to the category of attractions, which are the main candidates for MTGs. As guided in Chapter 2G of the TMUTCD, tourist-oriented directional signs shall be used only on rural conventional roads and shall not be used on conventional roads in urban areas nor at interchanges on freeways or expressways, which would be the primary location of MTG signing. As guided in Chapter 2H of the TMUTCD, RCIA signs show recreational or cultural interest area destinations on supplemental guide signs. In addition, three states (Minnesota, Missouri, and North Carolina) that have specific guidelines for MTGs use supplemental guide signs.

Therefore, the Texas MTG signs could be supplemental guide signs on freeways. However, such supplemental guide signs are limited to the available space. A symbol sign plaque on top of a parent guide sign is proposed by the research team. Based on the engineer survey, symbol sign plaques and supplemental guide signs are preferred and obtained the same number (11) of engineers' supports. In the MTG survey, Sam Houston Race Park and the Toyota Center

preferred one large guide sign, i.e., using an independent supplemental guide sign. However, Schlitterbahn Waterpark in New Braunfels and Schlitterbahn Waterpark in South Padre Island prefer to use two or three small guide signs at freeway interchanges approaching their sites. This can be implemented by using MTG symbol plaques on top of the standard interchange signs.

Symbol designs shall be essentially similar to those that are shown in the TMUTCD and in the book *Standard Highway Sign Designs for Texas*. New symbol designs shall be adopted by the Federal Highway Administration (FHWA) based on research evaluations to determine road user comprehension, sign conspicuity, and sign legibility. Table 2H-1 of the MUTCD and TMUTCD lists the symbols within each series category. Design details are found in *Standard Highway Sign Designs for Texas*. Figure 2H-5 of the MUTCD and TMUTCD shows RCIA symbol signs.

### 4.1.2 Preliminary Identification of Types of Symbols

According to the guidance in the manuals and current practices, symbols used in three types of signs for traffic generators (supplemental guide signs, tourist-oriented directional signs, and RCIA destination guide signs) are category oriented, while symbols used in logo signs are specific. Some states like Massachusetts use a general word "ATTRACTIONS" which is attached to a logo, trademark, or name.

Three types of symbols that are possibly used for MTG signs are therefore identified:

- a uniform symbol for all MTGs,
- a category-oriented symbol according to the classification of MTG, and
- a specific symbol for each MTG.

The identified three types of MTG symbols were shown to engineers in the engineer survey. The survey results show that 53 percent of surveyed engineers prefer category-oriented symbols, 35 percent prefer specific symbols for each MTG, and 12 percent prefer a uniform symbol for all MTGs.

MTG survey results show that three MTGs (Schlitterbahn Waterpark in New Braunfels, Schlitterbahn Waterpark in South Padre Island, and the Toyota Center) would like to display specific symbols for their facilities. Schlitterbahn Waterpark in South Padre Island also would

like to display a category-oriented symbol based on the classification of MTG. Sam Houston Race Park skipped this question.

### 4.1.3 Simulator Tests on Types of Symbols

Since a uniform symbol for all MTGs obtained the least preference from engineers and MTGs, in the simulator test the category-oriented symbols (CS) (including MUTCD symbols, non-MUTCD symbols, and self-designed symbols) and specified symbols (SS) for MTGs at freeway interchanges were examined. The simulation results show that the overall performance of category-oriented symbols was better than specified symbols through ratings by participants (4.05 versus 3.48, with the full score as 5). MUTCD symbols always performed the best. This is illustrated in Table 5, where drivers' evaluation of the performance of MTG symbols is listed in detail. Figure 2 illustrates the mean recognition distance and velocity for tested symbol groups.

**Table 5 Drivers' Evaluation of the Performance of MTG Symbols**

| Criteria | Conspicuity | Legibility | Representability | Understandability | Overall Performance |
|---|---|---|---|---|---|
| Category-Oriented Symbol | 4.18 | 4.27 | 3.82 | 3.91 | **4.05** |
| Specified Symbol | 3.36 | 3.27 | 3.91 | 3.45 | **3.48** |

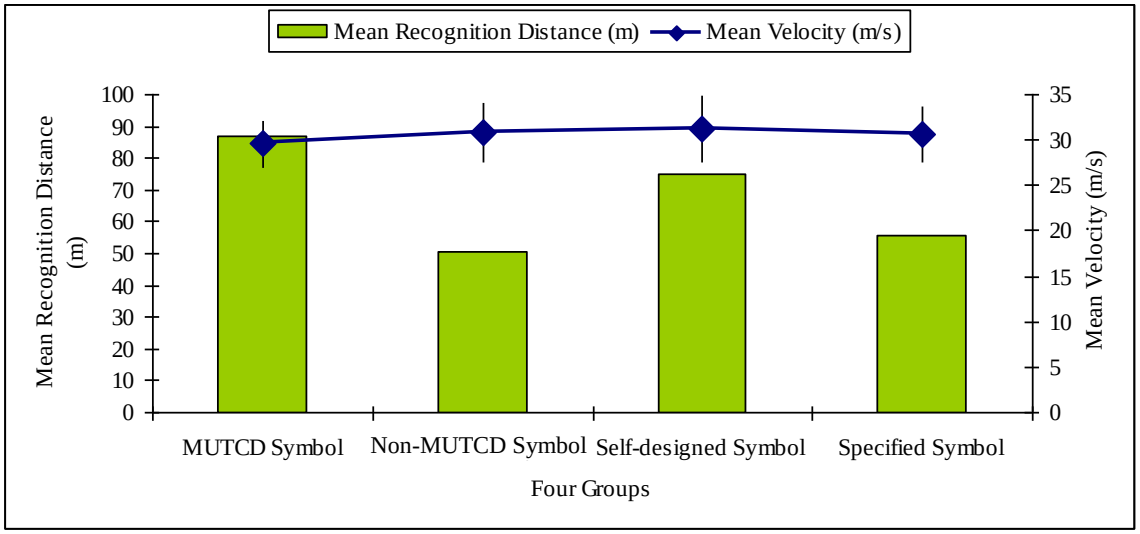



**Figure 2 Mean Recognition Distance and Velocity for Test Symbol Groups**

In Figure 2, the recognition distance for the four groups (MUTCD symbols, non-MUTCD symbols, self-designed symbols, and specified symbols) were 284.58 feet (86.74 m), 165.06 feet (50.31 m), 245.54 feet (74.84 m), and 183.4 feet (55.9 m), respectively. The comprehension

levels for MUTCD symbols, non-MUTCD symbols, self-designed symbols, and specified symbols were 91 percent, 64 percent, 68 percent, and 61 percent, respectively. Better performances are normally associated with simply designed symbols that drivers are familiar with. This suggests selecting and/or designing simpler and driver-acquainted symbols for MTG guide signing.

## *4.2 Location and Size of Symbols/Signs for Texas MTGs*

### 4.2.1 Manuals and Current Practices

The study of location and size of symbols/signs for Texas MTGs is focused on two types of MTG signs: supplemental guide signs and symbol sign plaques.

If sufficient space exists to accommodate the placement of the sign without interfering or conflicting with required signing, Texas MTG signs are installed as supplemental guide signs. In this case, the location and size of symbols/signs for Texas MTGs are in accordance with guidelines for other supplemental guide signs, which are addressed in Chapter 2E of the MUTCD, TMUTCD, and AASHTO guidelines.

The location of other supplemental guide signs is addressed in Section 2E.32 of the MUTCD and TMUTCD. Where two or more advance guide signs are used, the supplemental guide sign should be installed approximately midway between two of the advance guide signs. If only one advance guide sign is used, the supplemental guide sign should follow it by at least 800 feet (245 m). If the interchanges are numbered, the interchange number should be used for the action message.

Normally, supplemental guide signs for MTGs should not be installed at freeway-to-freeway interchanges. Signs for MTGs shall be located in advance of the interchanging road that provides the most direct route to the facility. Only one supplemental guide sign for an MTG may be used on each interchange approach. If used, it is normally installed as an independent guide assembly. A supplemental guide sign should not list more than two MTGs. When more than two MTGs meet the signing criteria, the MTG having the greatest need for signing should be shown.

AASHTO guidelines note that when the traffic generator is not located on the crossroad, written confirmation is required from the local government agency that it will install and maintain trailblazing signing for the logical direction of traffic to the facility.

Sign size is determined primarily in terms of the length of the message and the size of the lettering necessary for proper legibility. As guided by the MUTCD and Texas *Freeway Signing Handbook* (as listed in Table 2E-2.1 of the TMUTCD), the size and style of letters and signs, and the minimum numeral and letter sizes for freeway and expressway supplemental guide signs are summarized in Table 6.

**Table 6 Minimum Letter and Numeral Size for Supplemental Guide Signs**

| Supplemental Guide Signs | Minimum Size (Inches) |
|---|---|
| Exit Number Word | 10 |
| Exit Number Numeral and Letter | 15 |
| Place Name—Uppercase Letters | 13.3 |
| Place Name—Lowercase Letters | 10 |
| Action Message | 10 |

The legend of MTG supplemental signing shall be the same as other supplemental guide signs. As guided by Section 2E.32 of the MUTCD and TMUTCD, destination names should be followed by the interchange number (and suffix) or, if interchanges are not numbered, by the legend NEXT RIGHT or SECOND RIGHT, as appropriate.

As guided in Section 2E.04, guide signs on freeways and expressways, except as noted herein, shall have white letters, symbols, and borders on a green background. When a park or recreational or cultural interest area is signed as a significant destination for users of these roads, supplemental guide signs with a white legend and border on a brown background may be used on an expressway or freeway, as guided by AASHTO guidelines.

If the space is limited, MTG symbol sign plaques can be placed. The location of symbol sign plaques is instructed following the *Texas Freeway Signing Handbook*. Guide sign routing plaques provide supplemental information on travel routes for selected destinations or types of vehicles. Traffic Engineering Standard Sheet addresses the design and layout of guide sign routing plaques. Figure 3 shows the placement of guide sign routing plaques, which is the same as Figure 3-18 in the handbook and Figure 2D-11a in Section 2D.45, General Service Signs, of the TMUTCD.

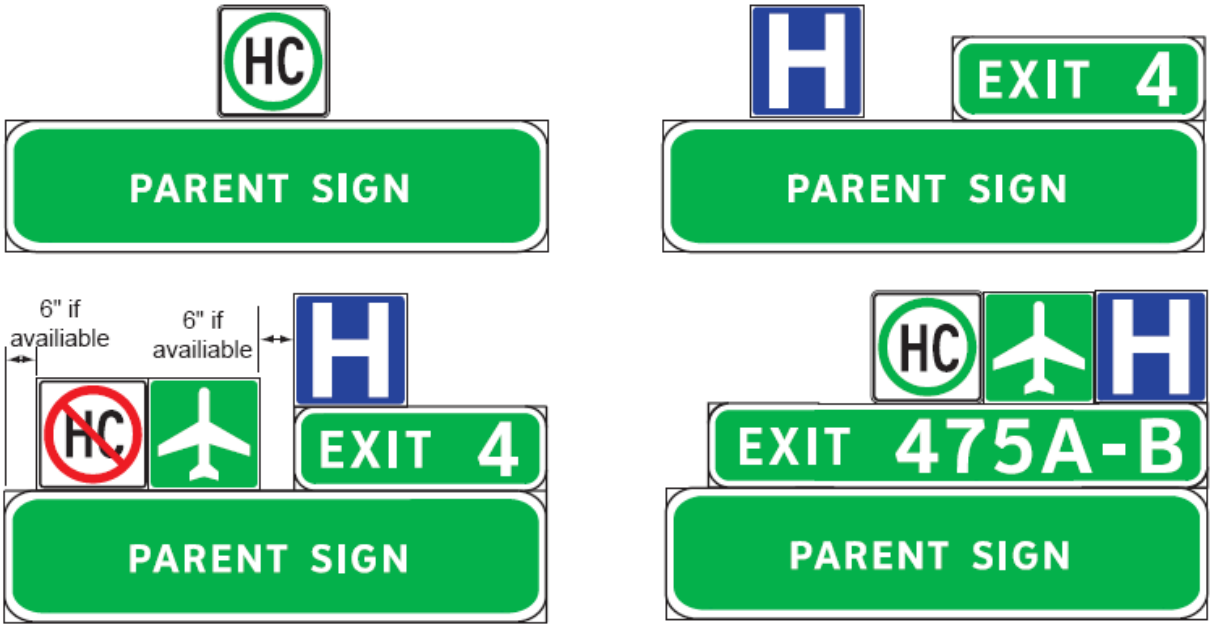



**Figure 3 Overhead Freeway Guide Sign and Routing Plaque Typical Assemblies**

The *Freeway Signing Handbook* further illustrates that plaques should be horizontally centered at the top of the parent guide sign. If the parent guide sign includes an exit number panel, the plaque (or plaques) should be centered between the exit number panel and the opposite sign edge. A spacing of 6 inches between the edge of the sign and the exit number panel is desired. If there is not enough space to place a routing plaque between the exit number panel and the sign edge, the plaque may be placed above the exit number panel.

The size of the symbols is mainly described in Chapter 2H of the TMUTCD. Recreational and cultural interest area symbol signs should be 24×24 inches. Where greater visibility or emphasis is needed, larger sizes should be used. Symbol sign enlargements should be in 6-inch increments. Recreational and cultural interest area symbol signs should be 30×30 inches when used on freeways or expressways, as guided in Section 2H.05, Symbol Sign Sizes.

Word messages in the legend of freeway and expressway guide signs shall be in letters at least 8 inches high. Larger lettering shall be used for major guide signs at or in advance of interchanges and for all overhead signs, as guided in Section 2E.13 of the TMUTCD.

### 4.2.2 Preliminary Identification of Location and Size of Symbols/Signs

Since there is standard guidance for location and size for supplemental guide signs, this section focuses only on the symbol sign plaques, which are a substitute for the supplemental guide signs.

In the engineer survey regarding the location of symbol sign plaques, most engineers (71 percent) agree to place the MTG symbol sign on the top of the parent guide signs like the airport and hospital guide sign routing plaques. Advance guide signs and exit direction signs are selected by most engineers (82 and 94 percent, respectively) to place the MTG symbol signs on. Only a Nevada engineer suggests also placing the MTG sign on exit gore signs. One Minnesota engineer prefers to install the MTG sign on a supplemental guide sign. He/she also likes placing the MTG signs on advance guide and exit direction signs. Based on the responses of the management sections of potential MTGs, the Toyota Center would like to install its guide signs at the nearest freeway exit only in each direction. The other three MTGs wanted to install their guide signs not only at the nearest freeway exit but also at other places such as on other highways and on mile markers. This means these three MTGs preferred trailblazing signs.

Most surveyed engineers (71 percent) believe that the trailblazing sign is necessary for MTGs. Of the 12 engineers who think the trailblazing sign is necessary, 42 percent of engineers think the maximum number of trailblazing signs provided for each MTG along one approach should depend on the location, distance, and how many turns to the MTG. Engineers have different opinions on the maximum radius of an MTG that trailblazing signs should be provided for. Four of them prefer 5 miles, and three prefer 10 miles.

Regarding the legends of MTG signs, 47 percent of surveyed engineers think that the most effective legend of MTG symbol plaques should contain a symbol and the associated text at the bottom, 29 percent prefer symbols only, and 24 percent prefer a symbol with text on top. No one considers text alone as an effective legend. If taking symbol and text into consideration as a legend of MTG signs, seven engineers think either the MTG category or the name of each MTG is the most effective text for MTG plaques. The MTG survey indicates that all MTG management sectors wanted to show the names of their facilities and the messages of their events. In addition, Schlitterbahn Waterpark in New Braunfels would like to display the distance information and its logo. The Toyota Center preferred to display a symbol. In the motorist survey on MTG signing,

the name of the destination (36.12 percent), the action information such as “exit” (26.18 percent), and the distance (13.22 percent) are most preferred by motorists to be display on the specific signs for MTGs.

Regarding symbol and text sizes in symbol sign plaques, 59 percent of engineers believe that 6 inches is the minimum text size of an MTG symbol sign plaque. Most engineers (94 percent) agree that the size of the MTG symbol plaque should be the same as that for airports and hospitals. Forty-one percent of engineers prefer the 30×30-inch size, and 41 percent prefer the 36×36-inch size as the minimum dimensions of a symbol sign plaque for MTGs on freeways. Figure 4 illustrates these two types of dimensions for symbol sign plaques.

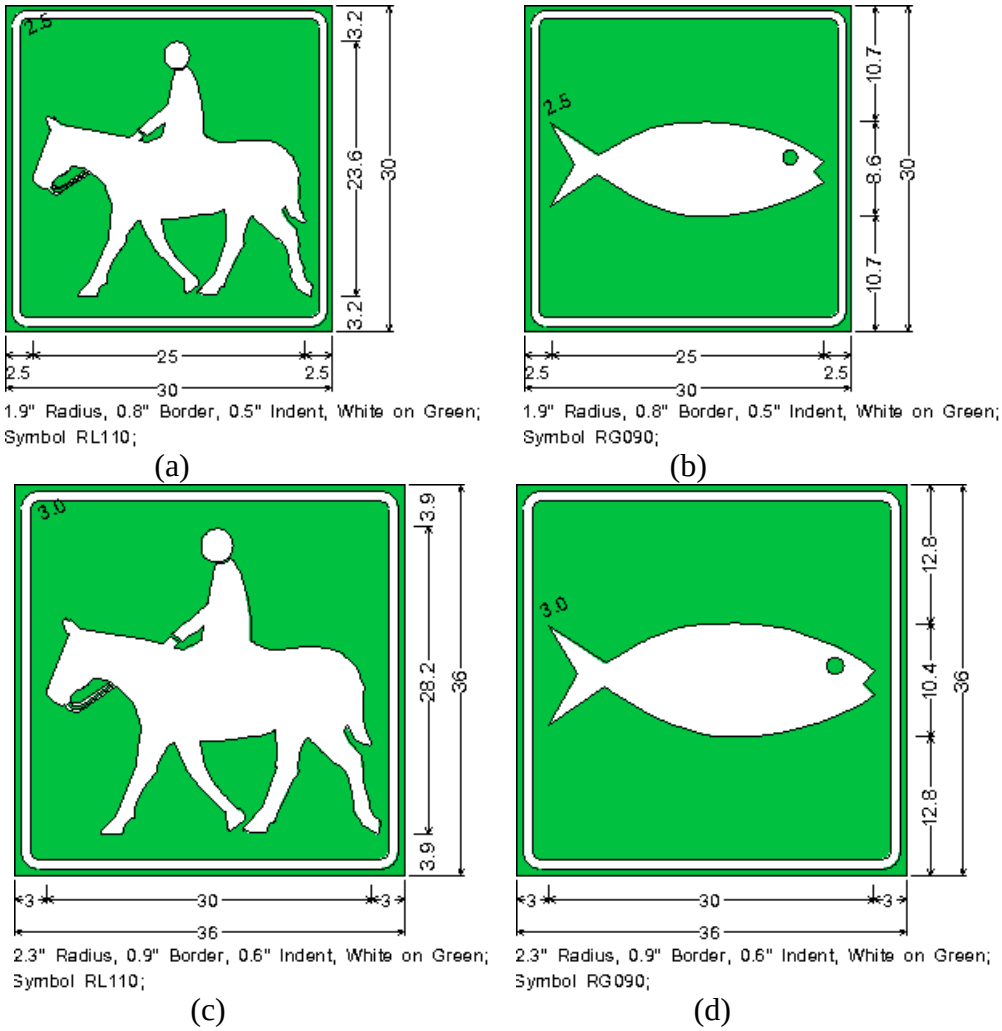


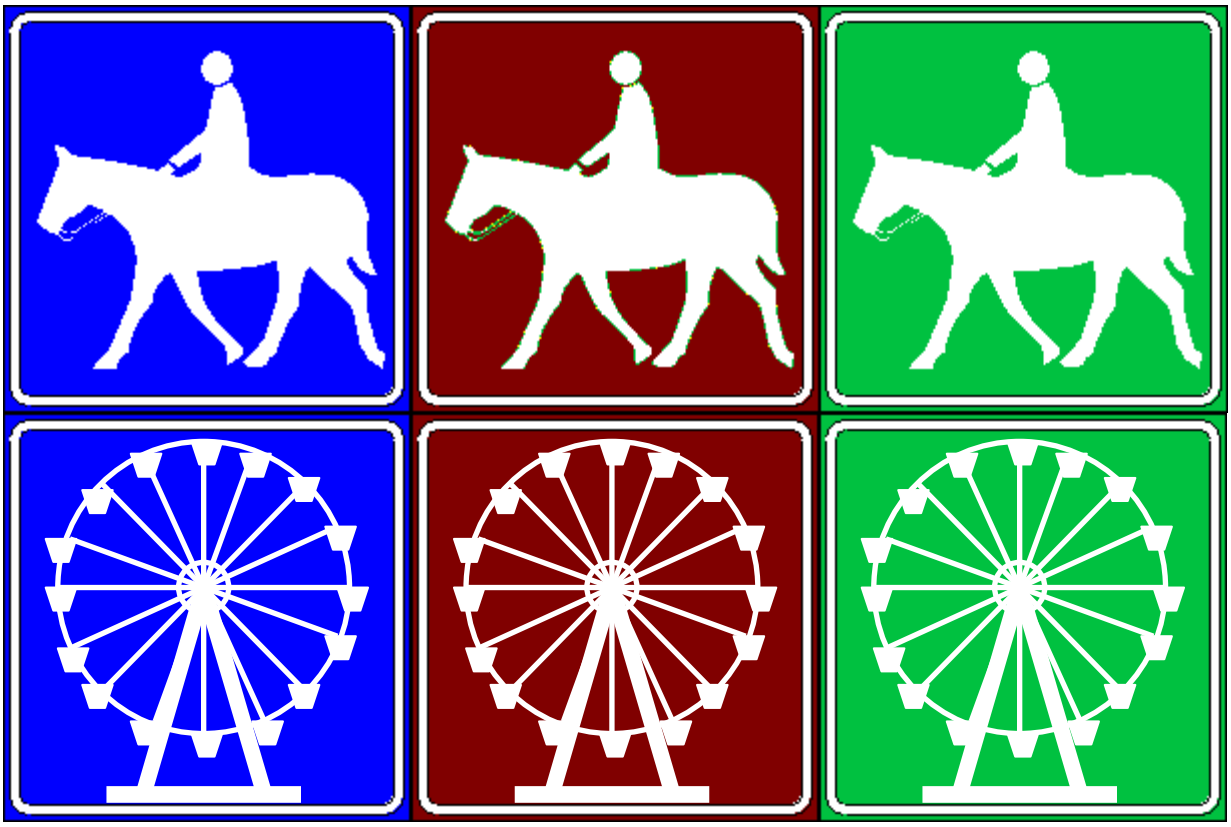

**Figure 4 Dimensions of Symbol Sign Plaques for MTGs on Freeways—Size 30×30 Inches in (a) and (b), and Size 36×36 Inches in (c) and (d)—Plotted Using SignCAD**

Regarding the number of symbol plaques, most engineers (65 percent) agree that a maximum of three plaques could be attached to an overhead freeway guide sign without overloading the motorists' comprehension level. If a parent sign includes an exit number panel, 53 percent of engineers still think three is the maximum number. One engineer from Minnesota and one from Massachusetts suggest no plaques on top of an overhead freeway guide sign. When the parent guide sign includes an exit number panel, two more engineers from Texas do not agree to put any plaque on it.

The surveyed engineers evaluated the priority on placing each type of routing plaque on top of overhead freeway guide signs, when considering the space availability and the workload of drivers. One engineer did not complete this question, and one engineer selected no priority by making decisions simply based on the application order. Through averaging the score of each plaque, the exit number panel receives the first priority, while the MTG symbol plaque receives the lowest.

Regarding the color of symbol plaques, the surveyed engineers have no obvious preference for blue, brown, or green. Representative symbol plaques with these three types of background colors are illustrated in Figure 5.

The majority (41 percent) agrees that the color of the background of a symbol and text plaque should be dependent on the category of MTG and should match the service. One Colorado engineer suggests that blue should be used on highways, while green can be used on interstate highways. Schlitterbahn Waterpark in New Braunfels and Schlitterbahn Waterpark in South Padre Island like blue and white, while Sam Houston Race Park and the Toyota Center prefer green. The motorist survey shows that nearly half (49 percent) of responders preferred to use blue as the background color for specific signs for MTGs; 35 percent prefer green, and 5 percent prefer brown.



(a) Blue (b) Brown (c) Green

**Figure 5 Illustration of Colors of Symbol Plaques Plotted in SignCAD**

### 4.2.3 Simulator Tests on Location and Size of Symbols/Signs

Simulations of symbol types, locations, and sizes were conducted in the driving simulator. Using position as a between-subjects variable, the one-way Analysis Of Variance (ANOVA) test indicated no effect on the position of the recognition distance under both right-lane and left-lane exits ($F_{2, 257} = 0.884$, $p = 0.414$ and $F_{2, 46} = 0.236$, $p = 0.79$). However, symbol signs positioned at the center and right were associated with greater recognition distances for both right-lane exits and left-lane exits. Figure 6 illustrates the recognition distance and mean velocity for right and left exits in the simulator test.

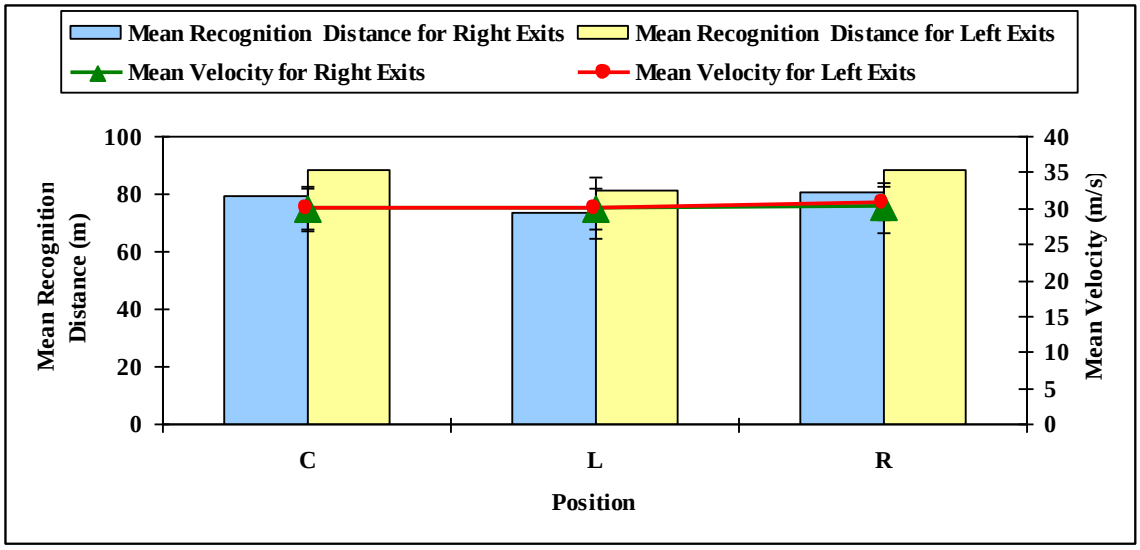
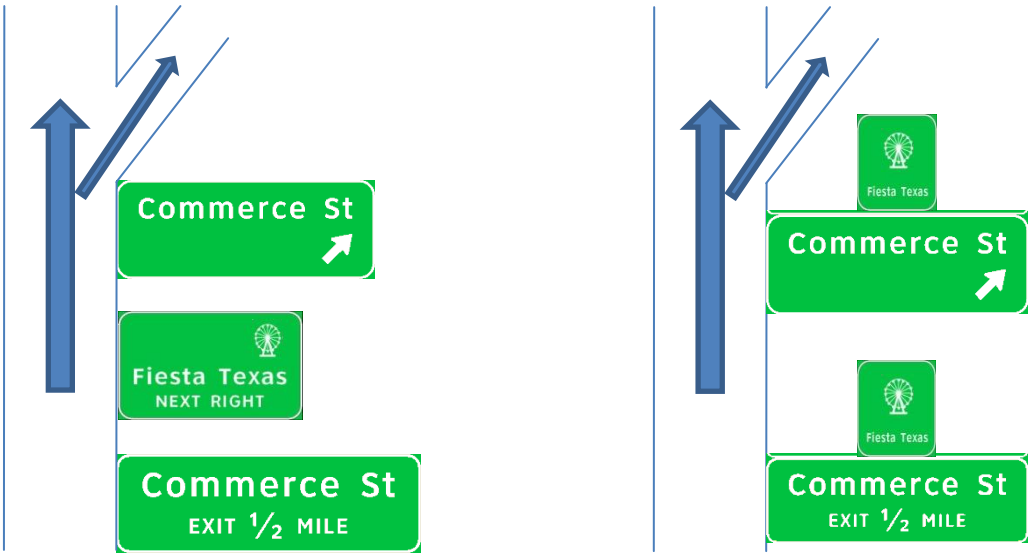



**Figure 6 Recognition Distance and Mean Velocity for Right and Left Exits in Simulator Test**

Figure 6 shows that for right-lane exits, symbol signs with center and right positions maintained a similar recognition distance ((79.45 m or 260.66 ft, and 80.37 m or 263.68 ft, respectively), both greater than that of the left position (73.55 m or 241.31 ft). For left-lane exits, symbol signs with center and right positions also maintained a similar recognition distance (88.56 m or 290.55 ft, and 88.28 m or 289.63 ft, respectively), both greater than that of the left position (80.99 m or 265.72 ft). Subjects preferred the right position for right-lane exits and the left position for left-lane exits. They also suggested that symbol signs should be placed on advance guide signs, exit direction signs, and even exit ramps. Symbol sizes significantly affected the recognition distance of symbols. The larger the size, the greater the recognition distance is.

The independent supplemental guide (SG) signs and dependent sign plaques (SP) test showed that the proposed sign plaques performed as well as supplemental guide signs in the case of single sign arrays.

Figure 7 illustrates the supplemental guide sign and symbol sign plaque with the symbol for Fiesta Texas.




(a) Supplemental guide sign (b) Symbol sign plaque

**Figure 7 Illustration of Supplemental Guide Sign and Symbol Sign Plaque**

A sign array refers to a set of individual sign panels that are installed together at a given point on the roadway, typically on the same sign-mounting structure or assembly. A single sign array includes a standard interchange sign with or without a sign plaque that represents less information workload in a driver scan. Table 7 lists the correct responses for MTG messages in the test.

In both 1.0-second and 2.5-second explore times, dependent SP signs performed worse than independent SG signs (56 percent versus 81 percent, and 78 percent versus 92 percent, respectively). In the 1.0-second explore time, dependent SP and independent SG signs had close correct response percentages (72 percent versus 80 percent) in the case of single sign arrays, and the difference between them was not significant. In the 2.5-explore time, dependent SP signs performed better than independent SG signs in the case of single sign arrays (97 percent versus 91 percent), although the difference was not very significant.

The dependent SP sign is comprehensible and would save not only space on freeways but also the cost of installation, management, and materials. Therefore, it is recommended that dependent SP signs be installed on top of advance guide (AG) and exit directional (ED) signs for critical MTGs when the signing space is limited at urban freeway interchanges.

**Table 7 Correct Responses for MTG Messages**

| Sign Type | Explore Time | Sign Array | MTG Messages | | | |
|---|---|---|---|---|---|---|
| | | | Correct Recall | Total Number | Correct Percentage | Z-Statistic |
| Dependent SP | All | All | 193 | 288 | 67% | –5.52 |
| Independent SG | | | 249 | 288 | 86% | |
| Dependent SP | All | Single | 162 | 192 | 84% | –0.29 |
| Independent SG | | | 164 | 192 | 85% | |
| Dependent SP | All | Multiple | 31 | 96 | 32% | –7.97 |
| Independent SG | | | 85 | 96 | 89% | |
| Dependent SP | 1.0 Second | All | 81 | 144 | 56% | –4.58 |
| Independent SG | | | 117 | 144 | 81% | |
| Dependent SP | | Single | 69 | 96 | 72% | –1.35 |
| Independent SG | | | 77 | 96 | 80% | |
| Dependent SP | | Multiple | 12 | 48 | 25% | –5.74 |
| Independent SG | | | 40 | 48 | 83% | |
| Dependent SP | 2.5 Seconds | All | 112 | 144 | 78% | –3.28 |
| Independent SG | | | 132 | 144 | 92% | |
| Dependent SP | | Single | 93 | 96 | 97% | 1.79 |
| Independent SG | | | 87 | 96 | 91% | |
| Dependent SP | | Multiple | 19 | 48 | 40% | –5.63 |
| Independent SG | | | 45 | 48 | 94% | |

According to the simulator tests and the associated posterior questionnaire survey, the symbol sign plaques performed as well as, or even better than, the supplemental guide signs. In the types of symbol sign plaques, the subjects preferred to display the information of MTG symbol and name. In the types of supplemental guide signs, the subjects preferred to display the information of MTG symbol and name, too. Supplemental guide signs with symbols and text performed better in all Measures of effectiveness (MOEs) including the recognition distance, maneuver distance, and correct exits.

# CHAPTER 5
# WARRANTS FOR MTG GUIDE SIGNING

Based on the surveyed opinions of engineers and needs of MTGs in Chapter 2, the identified MTG eligibility criteria for Texas in Chapter 3, and the types of symbols, location, and size of symbols/signs tested and identified in Chapter 4, the warrants for MTG guide signing in Texas are established and summarized in two parts: the eligibility criteria and the symbols for MTGs in Texas.

## *5.1 Eligibility Criteria for Major Traffic Generators*

The MTG eligibility criteria in Texas are identified in Chapter 3 and are summarized here. A traffic generator can be considered a major traffic generator if the following criteria are met:

1. parking for a minimum of 1,000 vehicles in metropolitan and urban areas, 700 vehicles in suburban areas, and 400 vehicles in rural areas;
2. a location along either the interchange crossroad or the freeway and within 8 miles of the major traffic generator in rural areas, within 3 miles in suburban areas, or within 2 miles in metropolitan areas and urban areas;
3. At least 325,000 visitors per year in metropolitan areas, at least 300,000 visitors per year in urban areas, at least 200,000 visitors per year in suburban areas, and at least 80,000 visitors per year in rural areas; and
4. a minimum of 15 events per year in metropolitan areas, 10 events in urban areas, 8 events in suburban areas, and 6 events in rural areas.

### *5.2 Symbols for MTG Guide Signing*

For the qualified MTGs, the type of guide signing could be a *supplemental guide sign* if there is sufficient space or a *symbol sign plaque* if available space is limited.

The type of symbols for Texas MTGs could be category-oriented symbols according to the MTG classification. Symbol designs shall be essentially like those shown in the TMUTCD and in *Standard Highway Sign Designs for Texas*. New symbol designs shall be adopted by the Texas Department of Transportation (TxDOT) based on research evaluations to determine road user comprehension, sign conspicuity, and sign legibility.

In MTG supplemental guide signs, the legend and size shall be the same as in the guidelines prescribed for other supplemental guide signs. Accepted MTG symbols may be included. The sign color shall be a white legend on a green or brown background in accordance with the TMUTCD. Only one supplemental guide sign for an MTG may be used on each interchange approach. If used, it is normally installed as an independent guide assembly. A supplemental guide sign should not list more than two MTGs. When more than two MTGs meet the signing criteria, the MTG with the greatest need for signing should be shown. If necessary, MTG trailblazing signs can be used depending on the location, distance, and how many turns to the MTG.

In MTG symbol sign plaques, the legend should contain the MTG symbol and associated word message at the bottom. The message should be either the MTG category or the name of the MTG. The size of the MTG symbol should be 30×30 inches when used on freeways or expressways. Where greater visibility or emphasis is needed, larger sizes should be used. Symbol sign enlargements should be in 6-inch increments. The word messages should be in letters at least 6 inches high. Where greater visibility or emphasis is needed, larger lettering shall be used, such as 8-inch letters. The color of the MTG symbol sign plaques shall be a white legend on a green, blue, or brown background, depending on the type of MTG service.

MTG symbol sign plaques may be placed on the top of advance guide and exit direction signs at freeway interchanges. Where necessary, MTG symbol sign plaques can be installed on freeway ramps, such as exit gore signs. The position of MTG symbol sign plaques on parent guide signs follows the guidelines in the *Guide Sign Routing Plaque in Freeway Signing Handbook*. Where necessary, trailblazing MTG symbol sign plaques shall be used, like airport

symbol signs. At most three symbol sign plaques could be placed at the top of a parent guide sign, whether or not there is an exit number panel. When there is a need for other guide sign routing plaques, the priority for other routing plaques should be higher than MTG symbol sign plaques.

Not all facilities that meet the MTG criteria should automatically display their informational signing. TxDOT shall retain the authority to deny requests for signing where other non-technical standards cannot be met. TxDOT should also retain the authority to specify the appropriate MTG sign types, message content, size of sign, sign location, color, etc., in accordance with standards for acceptable signing practice.

# CHAPTER 6
# CONCLUSION

In this report, the eligibility criteria of Texas MTGs are identified based on a fuzzy logic–based algorithm from the review of practices and manuals of other states, and from the engineer survey. The types of symbols, location, and size of symbols/signs are identified based on the literature review of practices of other states, engineer survey, MTG survey, and simulator and slide show tests. The recommended warrants are submitted to TxDOT as a reference for MTG guide signing in Texas.