TRANSGUIDE ITS DESIGN REPORT

NOTE TO READER:

THIS IS A LARGE DOCUMENT

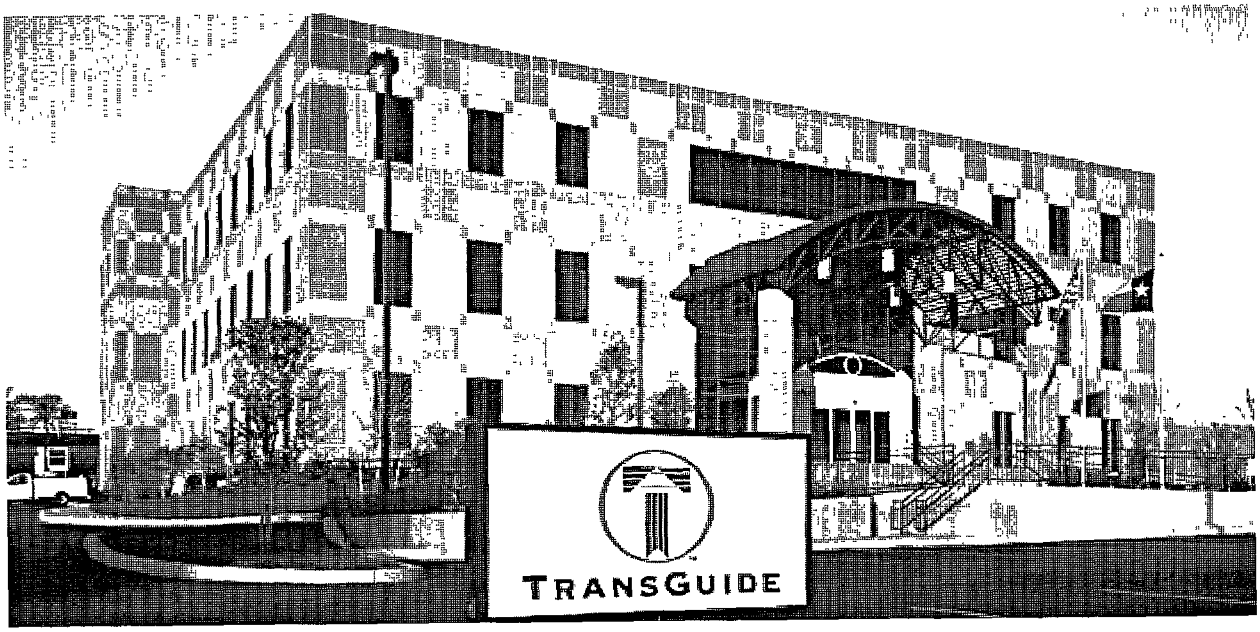
Due to its large size, this document has been segmented into multiple files. All files separate from this main document file are accessible from links (blue type) in the table of contents or the body of the document.

TransGuide
ITS
Design Report

TRANSGUIDE
TECHNOLOGY IN MOTION

Foreword

DRAFT



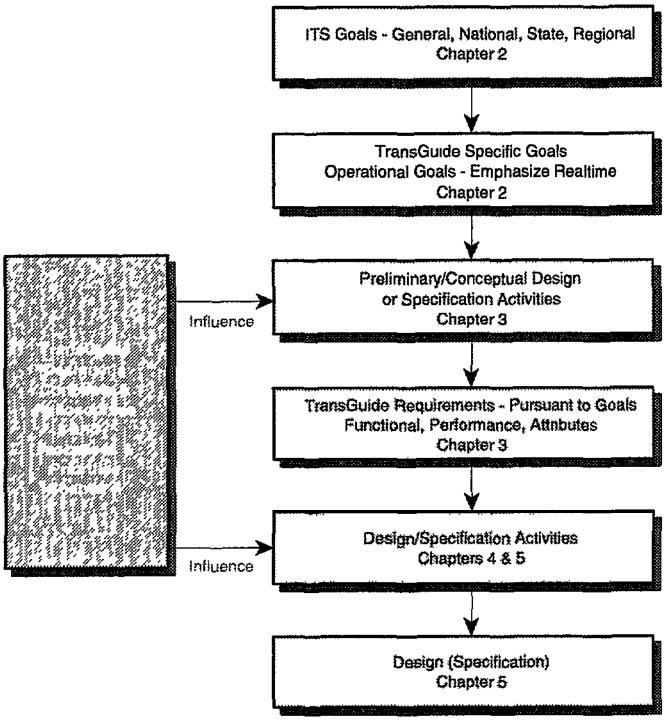
The TransGuide Operating Center in San Antonio, Texas

In reading and understanding the information reported herein, the reader can become cognizant of the important issues encountered during the TransGuide design experience, the methodology used in approaching those issues, and the results and trade-offs that are reflected in the system design,

The purpose of this document is to convey important facts and features about the TransGuide Intelligent Transportation System (ITS) design process. TransGuide goals, both general and specific, immediate and future, and performance and functional, are listed and discussed. Design concepts and philosophies employed to meet the various goals are described, with an emphasis on priorities and approaches. Important features of the completed system design are detailed and the design and selection criteria bearing on the ultimate design choices are explained. This report is offered to define the issues that were considered important in the design of TransGuide and to illustrate how the important design decisions were made.

Anyone wishing to know more about the TransGuide system design will find relevant information here. The document is aimed specifically at those individuals responsible for planning or developing a traffic management system that may be expanded to include other ITS functions and services. In reading and understanding the information reported here, the reader can become cognizant of the important issues encountered during the TransGuide design experience, the methodology used in approaching those issues, and the results and tradeoffs that are reflected in the system design.

This document is organized to reflect a goal-oriented design methodology as shown below.



TransGuide Design Methodology Diagram

The need for improved traffic mobility, safety, and productivity is reflected in the goals set forth in the national ITS initiatives. Those goals, and the more specific goals for the TransGuide system, are discussed in Chapters 1 and 2 of this report and are reflected in the functional and operational requirements for the TransGuide system as described in Chapter 3.

Chapter 4 focuses on two main themes. The first part of the chapter comments on the general approach and priorities used by the San Antonio District of the Texas Department of Transportation (TxDOT) in developing and documenting the TransGuide system design. A list of special specifications is included in this chapter of the report. The special specifications were the defining documents in the procurement contract let by TxDOT to AlliedSignal Technical Services Corporation (ATSC) for fabrication, test, and delivery of TransGuide. The second part of the chapter describes in detail the pre-engineered system responses to detected incidents, or solution scenarios, and the procedures and rationale used by the system designers in developing the solution scenario library.

Chapter 5 describes the TransGuide design in sufficient detail to allow a basic understanding of the structure and operation of the integrated system. Additional detail is included in the discussion of the system architecture and each major system component, to reflect the options considered in choosing the final architecture and components and the rationale leading to those design decisions. Graphical decision tables reflect the information in a-condensed and easy to understand format.

Throughout the report, generous use is made of photographs, tables, drawings, lists, and sketches to illustrate ideas and provide perspective as the reader is introduced to TransGuide. Quotes from TransGuide designers, other cognizant personnel, and related documents are included to enhance the reader's understanding of the reasoning behind design priorities and choices made duringTransGuide development.

As stated, the target audience for this report is traffic engineering personnel desiring to understand the approach and details of the TransGuide design experience. Themes were chosen to allow such readers to gain significant advantage from the experiences and lessons learned by the TransGuide design team. Much of the work accomplished during the TransGuide design experience will be applicable to other ITS implementations, and the information here should be valuable and time saving for a reader beginning to grapple with development of an ITS design. The reader is also directed to the general specification for the TransGuide system, developed by TxDOT, which includes many specifications for equipment required for the TransGuide traffic management functions.

The authors of this document feel that a full understanding of the goals and requirements established for TransGuide is necessary to understand the rationale for the system's structure. It is in this context that fundamental differences between TransGuide implementations and those best suited for a system that is being developed for another application will be found. For readers who are relatively new to automated traffic management concepts or for those dealing with different goals and requirements than TransGuide's, Chapters 2 and 3 may contain useful information. For applications of traffic management technologies that significantly differ from those found in TransGuide, a comparative analysis of the goals and requirements for both systems may be informative and beneficial. For experienced ITS developers or readers dealing with goals and requirements similar to those faced by the TransGuide design team, Chapters 4 and 5 will be of most interest, and the early chapters of the report might be viewed as reference material.

The authors wish to acknowledge the many helpful contributions made during development of this report by the TransGuide design team and operational personnel within TxDOT, and by the development team at ATSC.

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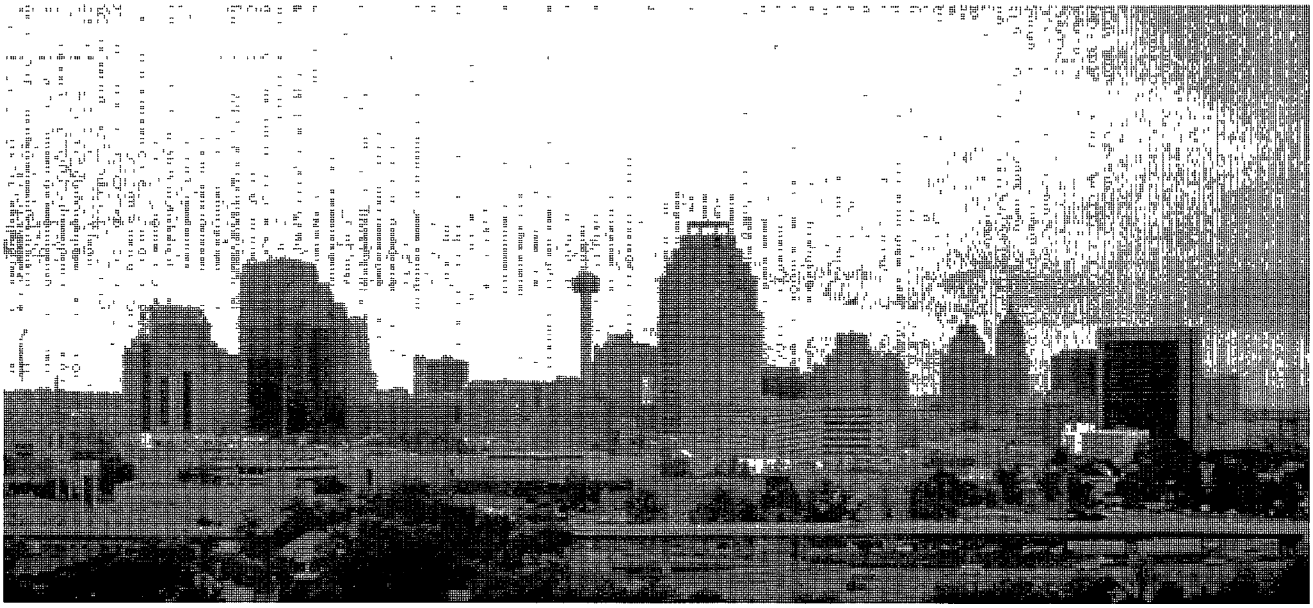
List of Acronyms

APTS	Advanced Public Transportation Systems
ATIS	Advanced Traveler Information Systems
ATMS	Advanced Traffic Management Systems
ATSC	AlliedSignal Technical Services Corporation
AVCS	Advanced Vehicle Control Systems
AWG	American Wire Gage
CCD	Charge Coupled Device
CCTV	Closed Circuit Television
CODEC	Coder Decoder (analog to digital conmverter)
CPU	Central Processing Unit
CRT	Cathode Ray Tube
DELNI	Digital Ethernet Local Network Interconnect
DLC	Digital Loop Carrier
DSO	Electrical voice grade communications channel operating at 64 Kbps
DSl	Electrical serial data communications channel operating at 1.544 Mbps
DS3	Electrical serial data communications channel operating at 44.736 Mbps
DSU	Data Service Unit
DTL	Detail Level of video camera
FHWA	Federal Highway Administration
FLD	Floor Lamp Display
FIT	Frame Interline Transfer
GUI	Graphical User Interface
I/O	Input/Output
IT	Interline Transfer
ITS	Intelligent Transportation System
IVHS	Intelligent Vehicle Highway System
kbps	Thousand Bits Per Second data communication rate
LAN	Local Area Network
LCS	Lane Control Signal
LCU	Local Control Unit
LED	Light Emitting Diode
LPTV	Low power television
Mbps	Million Bits Per Second data communications rate
MCU	Management Control Unit
NAFTA	North American Free Trade Agreement
NMS	Network Management System
NTSC	National Television System Committee
oc3	Fiber Optic communications channel operating at 44.736 Mbps
PBX	Private Branch Exchange
PC	Personal Computer
PCAMS II	Personal Computer Alarm Monitoring System
RAM	Random Access Memory
RS-232	Electronics Industry Association standard for serial data communication
RTU	Remote Terminal Unit
SONET	Synchronous Optical Network
Tl	Communications transmission channel operating at 1.544 Mbps

TCU	Telemetry Central Unit
TDU	Terminal Display Unit
TIU	Terminal Interface Unit
TMC	Traffic Management Center
TOC	TransGuide Operations Center
TRU	Telemetry Remote Unit
TxDOT	Texas Department of Transportation
UPS	Uninterruptible Power Supply
USDoT	United States Department of Transportation
VMS	Variable Message Sign

1.0 Introduction



San Antonio, Texas

"Practically immediate detection and effective response to incidents are required if controls are to aid in reducing congestion on busy free ways. "

Member of TxDOT's TransGuide Design Team

National initiative aimed at increasing the capacity and utility of the United States' surface transportation infrastructure by means other than building more miles of wider freeways has been actively promoted by government, commercial, academic, and private interests during recent years. The Intelligent Transportation Systems (ITS) thrust defined and supported by current and past national administrations is beginning to take shape as a visible solution to many of the nation's surface transportation concerns. Higher mobility, better safety, cleaner environments, enhanced energy efficiency, and increased productivity are all targets of the ITS initiative.

The United States Department of Transportation (USDOT) is the administrative arm charged with moving these important technology areas from concepts to solutions that provide real benefits to travelers and motorists in the U.S. The Joint ITS Program Office ~~of the~~ Federal Highway Administration (FHWA) has been designated to provide oversight and management of the various programs to effectively and responsibly attain progress and meet goals as broadly contained within the initiatives. The FHWA, working through national forums such as the Intelligent Transportation Society of America (ITS America), has developed ITS Strategic Plans which address national issues, concerns, functional planning, and broad implementation plans. The FHWA is also developing a National Program Plan to help the implementation of systems and services. Additional work is ongoing to establish a national ITS Architecture to ensure complete treatments and seamless integrations of the technologies developed or applied to address related challenges.

Working with the FHWA, the Texas Department of Transportation (TxDOT) has embraced the need to develop better approaches to traffic management as part of the ITS initiative. San Antonio, Texas, is home to what may be one of the most sophisticated Advanced Traffic Management Systems (ATMS) in the nation. The innovative concepts and technologies employed in San Antonio's "TransGuide ITS" can increase freeway capacity and safety through better traffic management, based on practical applications of available technologies. The goals of TransGuide are to provide:

>Incident detection with in minutes

>Traffic control changes within seconds

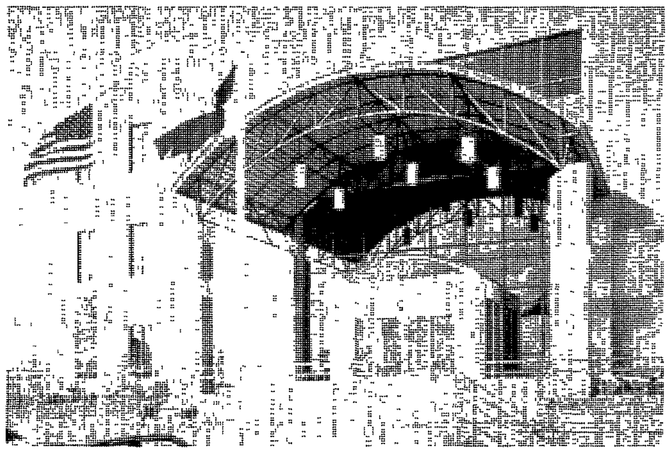
>Police, fire, and paramedic dispatch

>System reliability and expandability

>Support for transit dispatch operations

TransGuide's design incorporates flexibility and expandability to allow for the integration of future technologies and developments to further enhance public safety and the utility and efficiency of our freeways and public transportation systems, as the city grows and new technologies become available. The flexibility and expandability of the TransGuide system will be a key element in setting the stage for integration with user services such as Travel and Traffic Management, Public Transportation Management, Electronic Payment Services, Emergency Management, and Advanced Vehicle Safety Systems. The ITS user services also include existing development project areas widely known as Advanced Traveler Information Systems (ATIS), Advanced Public Transportation Systems (APTS), and Commercial Vehicle Operations (CVO).

Current traffic management systems, including the TransGuide system, depend on driver acceptance and compliance to be effective. This axiom is the basis of some of the highest priorities in the TransGuide requirements definition, design decisions, and implementation strategies. A high quality and functional system, as perceived by the driving public, will inspire confidence. If the system appears ineffective or appears to be doing more harm than good, drivers will be indifferent to the warning and control messages delivered to them. The utility and productivity of the operation is almost totally dependent on voluntary compliance by the driving public. Therefore, the first and highest priority goal in system design and conceptualization was that public acceptance and compliance must be won and preserved.



Entrance to TransGuide Operations Center

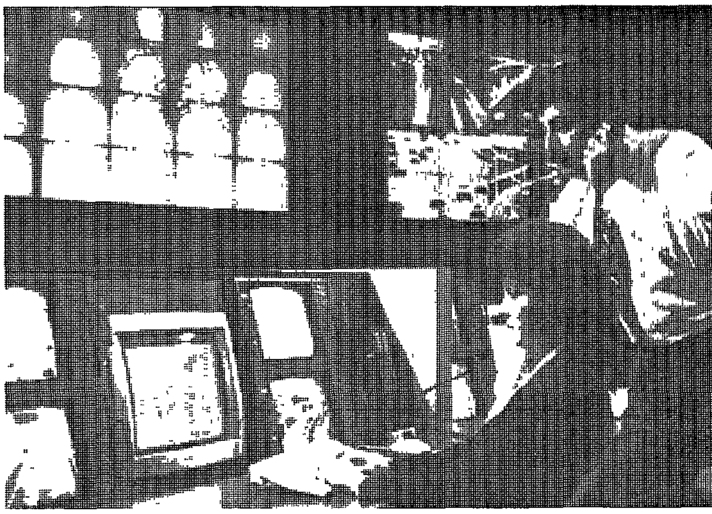
For TransGuide designers, high quality and meaningful functionality as perceived by motorists translates to REAL-TIME detection and assessment of, and response to traffic incidents, as well as the delivery of ACCURATE traffic management information so resulting congestion and delays can be reduced and dangerous situations dealt with in a timely manner. The goal of real-time detection and assessment of traffic incidents was specified, for this system, to mean that traffic incidents would be detected and assessed, and the appropriate response implemented, within minutes of an incident occurrence. The goal of providing accurate responses to traffic incidents was addressed by the implementation of pre-engineered reactions to detected traffic incidents. TransGuide allows an operator to quickly select the most appropriate SOLUTION SCENARIO from a library of thousands of pre-engineered responses to traffic incidents, with the confidence that the response has been individually developed, reviewed, and approved by traffic management experts for use in a particular situation. The consistence, confidence, and maturity of the traffic management function provided by the use of pre-engineered and approved responses was regarded by TransGuide designers as the most appropriate way to achieve quality performance and freedom from potential legal liabilities as the ATMS operates far into the future.

"At least half of the TransGuide design effort was focused on developing the estimated 128,000 solution scenarios that were needed for 191 miles of freeway in San Antonio."

Member of TxDOT's TransGuide Design Team

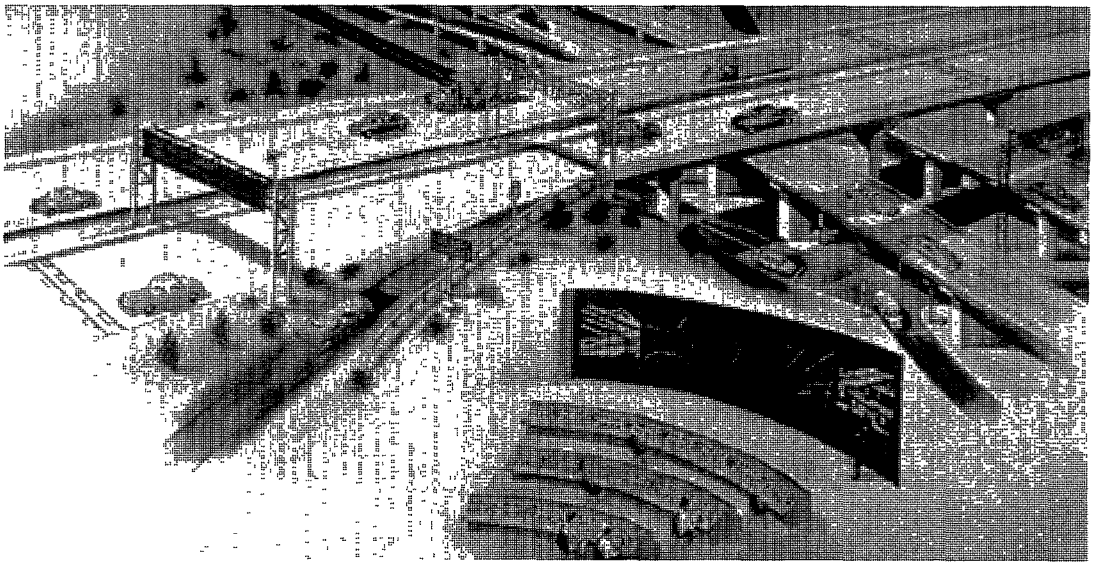
The TransGuide solution scenarios are comprehensive in scope, containing defining features for driver information and lane control systems as well as many other potential reactions such as alternative routing, signal light timing modifications, and distribution of system information to a variety of user services. The scenarios, which are individually identified by a unique location within a database, can be quickly communicated to emergency services such as police, fire, EMS, and other user services to inform them of existing freeway traffic incidents and the nature and impacts of those incidents as defined by the responses that have been implemented. The ease, speed, and accuracy of potential information exchange between traffic and emergency management systems was a design priority during TransGuide development.

TransGuide collects traffic information from multiple loop detectors in each lane of the freeway system at one-half mile intervals and from high quality, controllable video surveillance systems overlooking the freeways. A modern control center, with operators manning workstations and viewing freeway images on workstation video displays as well as large video wallboard displays, is at the heart of the system. A high performance, reliable conununications and information management network and a fault tolerant computing system are included in the implementation. These systems permit effective and automated approaches to detection and characterization of incidents and allow rapid implementation of solution scenarios by operating and management personnel focusing on traffic and safety issues. These support systems also provide for the expandability and flexibility that will be needed to allow the development, evaluation, and implementation of new technologies and enhancements as TransGuide's role expands.



Operator's Workstation Inside the TransGuide Operations Center

2.0 Intelligent Transportation System Goals



Artist's Concept of San Antonio's TransGuide's Advanced Traffic Management System

The ITS initiatives, and the ensuing research, development, implementation, and test efforts that are planned or in progress around the country and the world, are responses to problems and shortfalls that have been encountered in existing surface transportation systems. The application of resources to address these problems must be accomplished in a practical and effective manner, thus, the first step in the pursuit of answers and improvements was the definition of goals that, when achieved, would produce tangible and measurable results.

The ITS Strategic Plan encompasses evolutionary technology and implementation steps . . . over a 20-year period beginning in 1992. "

2.1 National Intelligent Transportation System Goals

The goals of the national initiative as reflected in the ITS Strategic Plan are focused in four areas: Improved Safety; Reduced Congestion and Improved Mobility; Enhanced Economic Productivity; and Energy Efficiency and Environmental Quality. The plan encompasses many areas of research and development, as well as more specific evolutionary plans for implementations in selected development project areas. The development project areas broadly addressed in the ITS Strategic Plan are:

>Advanced Traffic Management Systems (ATMS)

>Advanced Traveler Information Systems (ATIS)

>Advanced Vehicle Control Systems (AVCS)

>Commercial Vehicle Operations (CVO)

>Advanced Public Transportation Systems (APTS)

The plan includes an outline of functional pursuits in each of the development project areas and states logistical priorities and approaches for achieving progress in each area through strategic funding of projects and promoting cooperative efforts between government, industry and academia.

The ITS Strategic Plan encompasses evolutionary technology and implementation steps for each of the development project areas that are roughly divided into three major phases over a 20 year period beginning in 1992. The phases are described by planned time intervals during which the evolutionary technology steps for each of the development areas should occur. To promote general compliance with the progressive nature of the elements of the strategic plan, decisions and choices regarding funding for programs will be guided by the plan.

The USDOT is also producing a tactical implementation plan, the National Program Plan for Intelligent vehicle highway system which "provides a 'road map' describing how the interacting and potentially incompatible goals of industry government, and users will be addressed through development and deployment of services in a nationally compatible intermodal system." The plan is intended to clearly describe the program, ensure that intermodal aspects are considered, guide investment decisions, promote coordination, maintain a focus on deployment, assist in local policy decisions, and facilitate national program assessment.

The National ITS Program Plan includes an enhanced statement and reorganization of the various development project areas such as CVO, ATMS, etc. to include 28 specific planned improvement areas for user services. The user services referenced in the plan are organized in six user services groups Travel and Traffic Management, Public Transportation Management, Electronic Payment Services, Commercial Vehicle Operations, Emergency Management, and Advanced Vehicle Safety Systems.

2.2 Regional Goals for Intelligent Transportation Systems Implementation

The operational and functional goals for the TransGuide ATMS envision a major role for the system in the future application of ITS technologies to the entire South Texas region. TransGuide's goals include ATMS and ATIS functions, which will ultimately cover the 43,969 square-mile region and include 39 counties. These systems will also be established at 16 international bridge crossings along approximately 300 miles of the border between the United States and Mexico. This area supports international commerce that accounts for more than 60 percent of all imports and exports between the two countries and includes two proposed 150-mile automated corridors now being developed. One of these is anticipated to be the North American Free Trade Agreement (NAFTA) Highway.

2.3 TransGuide Intelligent Transportation System Goals for Freeway Operation Improvement

The general goals of TxDOT for improving freeway operations in and around San Antonio are in line with national goals. The stated goals for both the national initiatives and TransGuide are qualitative in nature and also are highly interactive and interdependent. TransGuide general goals as defined by the system designers are: 1) improved traveler safety on San Antonio's freeway system; 2) improved response by police and emergency services personnel and equipment in treating and transporting injured persons to hospitals, etc. and in assessing and clearing traffic incidents; 3) reduced traffic congestion and transit delays experienced by freeway travelers; and 4) increased effectiveness of user services and other related initiatives as identified in the ITS Strategic

Plan and the National Program Plan through integration with TransGuide.

2.4 TxDOT Self-Imposed Operational Priorities for TransGuide

A number of additional operational priorities for successful implementation and operation of an ITS have been identified by TransGuide designers. The high priority of several important features was dictated by the importance attached by the designers to public acceptance and long term viability of the system and was reflected in many design and implementation decisions made during TransGuide specification and development.

2.4.1 Accuracy and Credibility

TransGuide system designers regarded acceptance by the traveling public as extremely important. Compliance with the traffic management controls and recommendations that are to be delivered to the freeway users must be achieved for the system to **be effective.** Credibility and accuracy of the driver information and controls are paramount. Accurate and credible operation was also perceived by the TransGuide designers as the best way to minimize potential legal liabilities arising from ATMS operation.

2.4.2 Real-time Responses - More Than a Few Minutes is too Long!

One major goal of TransGuide is to minimize traffic congestion and delays **on the** freeway system. Accidents, breakdowns, or other unexpected incidents are a major cause of traffic congestion and often require responsive actions by public safety officials. It was determined that, for the system responses to freeway incidents to be perceived as accurate and credible by the driving public, the time lapse between an incident and resultant instructions to motorists must be as brief as possible. For example, if traffic management controls and recommendations are delivered to drivers only after a very long traffic queue has formed as a result of an incident on the freeway, the utility and credibility of the traffic management function will be suspect. The credibility of the system will also be compromised if traffic management controls delay or otherwise negatively impact the driving public's experience, and there is no visible incident or other apparent reason for the inconvenience.

"... the TransGuide system must rely on acceptance and compliance among the driving public to be effective."

Member of TxDOT's TransGuide Design Team

Real-time operation of the TransGuide system, and the public's perception of system accuracy and dependability, was therefore considered crucial to public acceptance of the system and pivotal in gaining voluntary motorist compliance with traffic management controls and recommendations. System designers specified that detection of an incident would be accomplished as quickly as was practical but no more than several minutes after the occurrence of the incident. They also specified that, when the TransGuide traffic management systems were commanded to operate in response to an incident, resulting changes in the entire system would occur as quickly as practical, but no more than a fraction of a minute after command issue.

"If you wait until a long queue exists before implementing controls, you've already lost the battle."

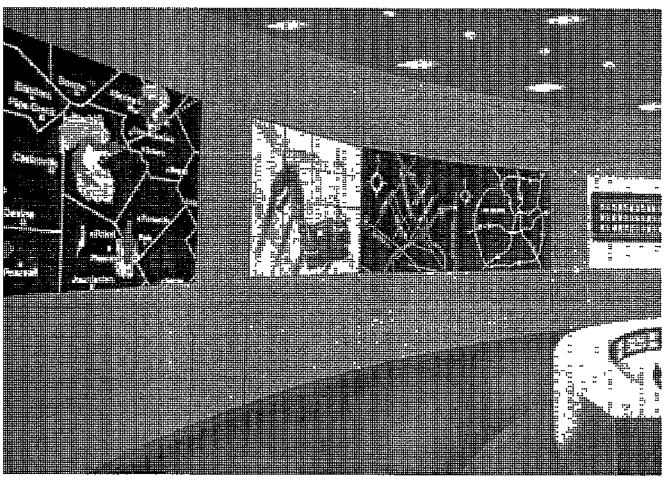
Member of TxDOT's TransGuide Design Team

2.4.3 Operations and Maintenance Cost Containment

TransGuide designers desired to minimize operational and maintenance costs while simultaneously attaining functional and performance goals. System costs will have a significant impact on the system's viability. It is often easier for state departments of transportation to gain funding for the initial costs of traffic control systems than for on-going operations and maintenance. TransGuide was designed to be an operational system, not just a test or experimental system; therefore, TransGuide designers had to adopt minimum operational and maintenance costs as a primary operational goal.

2.4.4 Positioning TransGuide for the Future

TransGuide represents a first step toward ITS in San Antonio it will ultimately change and expand in many directions. It was critical that the TransGuide **system** provide a basis for related systems, such as an ATIS. TransGuide will be expanded to control much of the freeway system in San Antonio and the surrounding region; it must therefore be capable of controlling or integrating with systems that control non-freeway traffic as well. Plans are already under way to add function**ality** to TransGuide to support and provide for integration for the public transportation system. TransGuide must also facilitate continued operations as the freeway system is expanded and modified in future years. These planned and potential changes demonstrate the need for a flexible, easily modified system.



Artist's Concept of TransGuide's Operations Center

2.5 Real-time Functional Goals for the TransGuide Intelligent Transportation System

TransGuide designers recognized certain core functions as time-sensitive and critical for the system to reach operational goals. The time sensitivity of these functions was based on the desire to minimize impacts on public safety and traveler transit delays that result from delayed detection and responses to freeway incidents. The core functions include incident detection, verification of the presence and nature of incidents, response to incidents with appropriate emergency services, employment of traffic control measures, and communication with public transportation systems and other user services.

2.5.1 Detect Incidents

Automatic detection of traffic incidents that cause sluggish or stopped traffic on freeway systems is a complex issue. Many variables can result in changes to the speed and density of traffic, including weather, rush hour demands, construction, and accidents. The problem becomes more complex when multiple lanes of traffic are involved. Much work has been done to understand these processes and to develop systems capable of automatically monitoring traffic flow patterns and recognizing when and where unusual or unplanned incidents have occurred.

An ATMS should provide the means to appropriately and automatically monitor traffic flow and conditions on all freeway systems within its scope of operations.

... significantly faster incident detection methods must be explored.

Some of the most successful systems for automatic traffic incident detection comprise multiple vehicle presence sensors in a traffic lane, coupled with data processing computers. Derivatives and adaptations of "California," "McMaster," or other traffic incident detection algorithms within the computers monitor traffic flow and attempt to distinguish normal traffic patterns from abnormal ones. When an abnormal pattern is detected, the system alerts an operator or supervisory system of the need for responsive action. Unfortunately, the time required to reliably distinguish between slowed traffic patterns resulting from real incidents or from other reasons can be exceedingly long. Elapsed times of tens of minutes have been experienced with these systems. The goal of real-time incident detection in TransGuide dictated that significantly faster incident detection methods be explored.

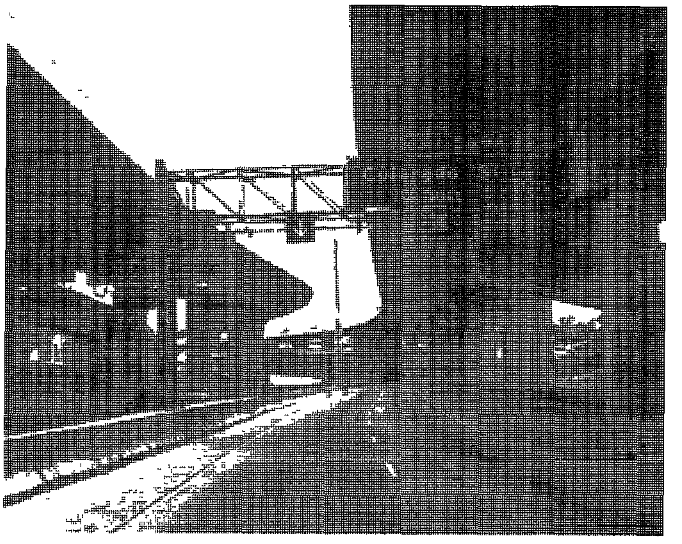
2.5.2 Verify Presence and Nature of Incidents

Once an abnormal traffic pattern is detected, it is important to characterize the cause of the abnormality quickly and accurately Traffic often slows or becomes congested for reasons other than accidents or disabled vehicles. System designers anticipated that some detected traffic abnormalities would not be associated with definable causes, at least in regard to freeway conditions, and would have to be dealt with as isolated transient abnormalities that would probably clear without further action (for instance, false alarms). Many traffic problems are attributable to general environmental or pre-determinable freeway conditions such as weather, construction, rush hour congestion, etc., which may or may not call for additional action to improve traffic conditions. Some abnormal traffic patterns, however, are the result of freeway or traffic incidents such as accidents, disabled vehicles, debris in the road, etc., that would require responses from TransGuide to enhance motorist safety and mitigate traffic delays and congestion that could result if quick action were not taken.

TransGuide designers recognized that real-time, accurate characterization of the presence and nature of definable causes for detected traffic delays and congestion was a prerequisite to the ability to make appropriate response decisions and initiate accurate, timely responsive actions.

2.5.3 Respond to Incidents with Emergency Services

Once an incident has been detected, TransGuide must be able to provide quick and effective response to any injured motorists. Automatic notification of police and quick dispatching of EMS ambulances to accident sites, when appropriate, is one of the first priorities in developing a response to a detected traffic abnormality that includes personal injuries. The average response time for police to reach an accident on San Antonio's freeways and call for emergency medical help now averages 18 minutes, but the decision support afforded by TransGuide to police could reduce that time drastically. Congestion can lead to



Typical TransGuide Lane Control Signals Showing Right Lane Closed

longer delays, and other factors at the scene of an accident can dictate which type of emergency service should be used. For example, if a serious accident with injuries occurs and access to the site is completely blocked by congested traffic, an early decision to use emergency medical helicopters to reach the accident scene more quickly may be made by police working with the operational personnel in the TransGuide Operations Center (TOC). Other emergency services, such as fire departments, police, hazardous material spill or debris removal response services, and tow trucks, may also be dispatched quickly by TransGuide personnel. A response within minutes by appropriate services will enhance the safety of motorists involved in an accident and will facilitate the rapid clearing of an incident.

2.5.4 Control Traffic to Reduce Congestion

Busy freeways can quickly become congested by an accident or other obstruction. Other conditions that contribute to freeway traffic delays include construction or other scheduled lane closures, inclement weather, traffic volume, secondary incidents, and the location of entrance and exit ramps relative to an incident. Many traffic control options can be implemented to mitigate or reduce the traffic delaying effects of freeway congestion resulting from one of these conditions. Appropriate traffic control measures may be as simple as routing traffic away from blocked lanes and onto unaffected lanes far enough upstream in traffic flow so that traffic runs smoothly around an incident. In severe cases, freeway systems may have to be closed and alternative routing provided. Detour controls far enough upstream in traffic flow, so motorists are made aware of the situation and are offered alternative routes that allow them to avoid the "parking lot," might be the most appropriate traffic control response. If traffic controls are delayed for a significant time, then congestion may saturate the available freeway system, removing any opportunity to reduce the traffic delay impacts of an incident.

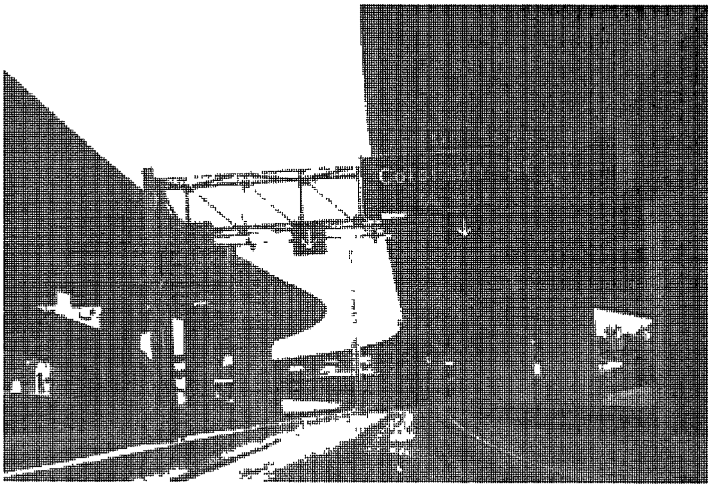
2.5.5 Support Public Transportation Operations and Other Intelligent Transportation System User Services

Public transportation services such as municipal bus systems are affected by congestion the same as private motorists are when freeway systems become jammed. The nature of public transportation operations, however, results in delays for more people per vehicle, as well as secondary delays from missing subsequent scheduled stops. Public transportation management has many options available to mitigate or compensate for the affects of congested freeways, such as using alternate routes to avoid congested areas or pressing additional vehicles into service to maintain later scheduled stops. However, current knowledge of traffic conditions usable in deciding whether to use these options is limited. With real-time freeway condition and traffic delay information available, operational enhancements that will result in a higher quality of service from public transportation systems can be put in place.

Improved transportation, both in private vehicles and in public transportation systems, is embodied by the national ITS initiatives and planned user services. Providing real-time freeway condition and traffic flow information to public transportation systems and to all other entities that could affect the public's driving choices and experiences is an important function of TransGuide. The ability to share timely and accurate information with other systems, such as the media, was therefore included in the goals and requirements established for real-time TransGuide system operations.

2.5.6 Detect and Respond to Changes In Incidents

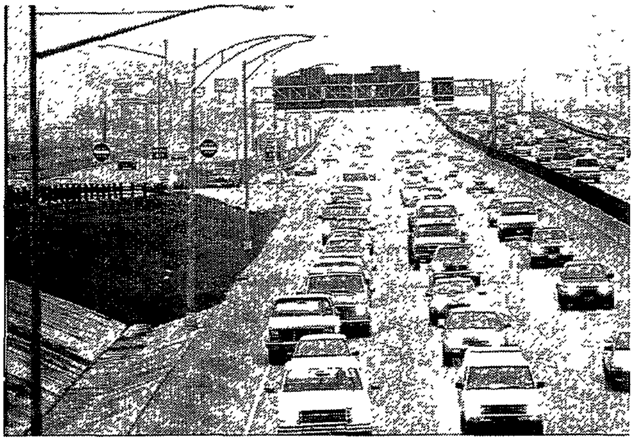
The presence and nature of freeway traffic incidents and appropriate responses to incidents are dynamic in nature. Worsening congestion resulting from incidents may prompt additional or different response strategies. Secondary incidents may occur that require their own response measures. Incidents that clear spontaneously or as a result of system responses are usually followed by improved traffic flow conditions. TransGuide designers built into the system timely and appropriate performance of all functional goals in the



Typical TransGuide Lane Control Signals Showing All Lanes Open

presence of dynamically changing freeway conditions because it is critical to the performance, viability, and public acceptance of the system.

3.0 TransGuide Intelligent Transportation System Requirements



Existing Traffic Congestion on San Antonio's Freeways

Timely and accurate operation of the system and the associated credibility and utility of the system as perceived by the driving public are the true performance requirements for TransGuide.

The TransGuide operational goals described in Chapter 2 are the basis for the system requirements. Operational, functional, and performance requirements, and other required attributes of the system, were developed based on the operational and functional goals. System designers used the requirements as a guide when selecting physical configuration options and potential component performance characteristics.

3.1 System Level Functional Requirements for TransGuide

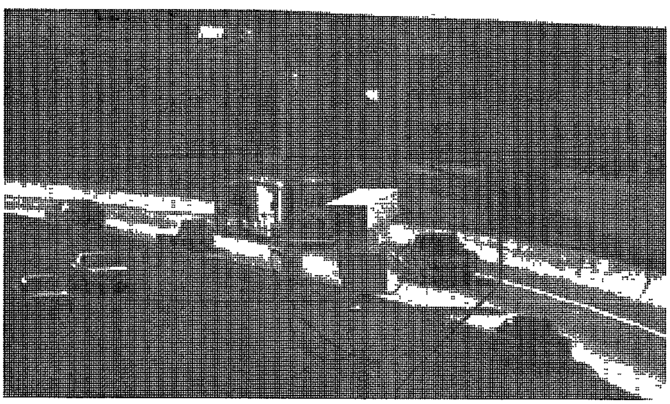
TransGuide was functionally organized to support operation of the system pursuant to established goals and requirements. The functional elements of system operation include several core capabilities required to meet the operational goals and requirements. Described in detail in this section, these capabilities provide TransGuide operators with an alert when incidents are detected, the means to assess the nature of the incident, the ability to confidently implement traffic control measures, and the means to effectively communicate traffic information to drivers, public transportation systems, and user services.

3.1.1 Alert TransGuide Operators to Abnormal Freeway Traffic Conditions

The TransGuide system shall provide the means to automatically produce an alarm indication when a predetermined threshold is reached for the traffic flow monitoring parameters used by the monitoring function. The thresholds used in the monitoring scheme shall be chosen to produce rapid detection of potential incidents while avoiding too many false alarms. The system shall also alert operators when detected abnormal traffic conditions have returned to normal.

3.1.2 Provide Surveillance of Suspected Incidents

TransGuide shall provide for effective surveillance of freeway areas that have been identified and associated with incident alarms. The surveillance characteristics shall be adequate to allow an operator to quickly and easily assess the presence and nature of the potential incident. The appropriate surveillance camera(s) shall be automatically selected and directed at the approximate location of the potential incident when an alarm is detected and presented for handling within the TOC.



TransGuide Surveillance Camera On the Job

3.1.3 *Control Traffic Lane Occupancy*

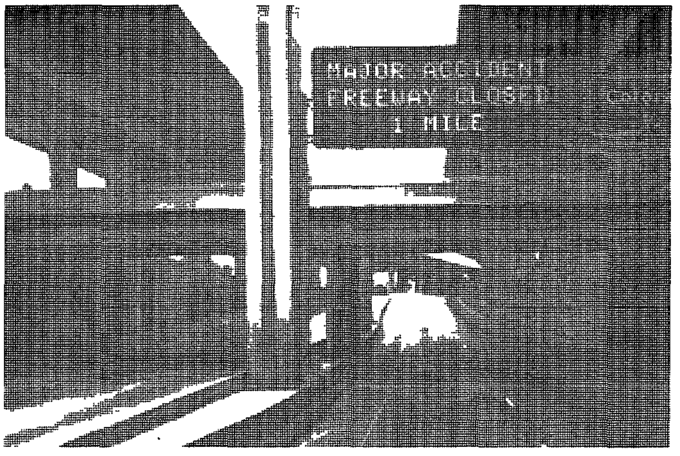
The TransGuide system shall provide a means for control of occupancy and use of individual freeway traffic lanes for the portion of the freeway system within the scope of operations. To establish a measure of traffic control in the vicinity of a freeway traffic incident, the system shall have the capability of diverting traffic to/from individual traffic lanes in a smooth and controllable fashion. This capability should decrease last-minute lane switching and the resultant traffic congestion that occurs when a freeway lane is blocked unexpectedly. The lane control function shall produce effects on traffic flow similar to those of a well-planned and controlled lane closure to ensure smooth-as-possible traffic flow and avoid the creation of safety hazards and the associated potential liability The lane closure function shall be operable for any individual lane, any combination of individual lanes, or for an entire freeway segment. The lane control function shall also provide a means for m-opening affected lanes for use by traffic downstream from an incident or when an incident has been cleared.

3.1.4 Control Access to Freeways

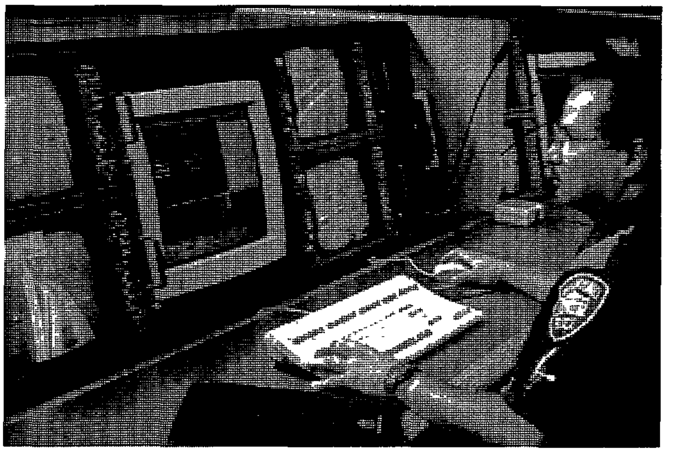
The TransGuide system shall provide a means for controlling access by motorists to freeway segments. Severely congested freeways may experience worsening conditions if additional traffic is injected onto the freeway system upstream of the congestion. In some cases, it may be necessary to reduce or remove existing traffic on congested freeway segments to enhance public safety and provide access to an incident by emergency services. The system's freeway access controls shall provide for limiting or stopping the influx of traffic from feeder streets to the freeway system when appropriate and shall provide for routing existing freeway traffic to frontage and feeder streets when required. The freeway access controls shall be applied to all freeway entrances and exits within the scope of TransGuide operations.

3.1.5 Communicate Traffic Information to Motorists

The TransGuide system shall provide a means for informing affected freeway users about traffic conditions. Motorists near to and upstream of a freeway incident shall be alerted to worsening traffic conditions with helpful information about the nature and severity of the incident and the estimated effects on traffic flow. Advance warning to motorists concerning safety related information, lane or freeway closures, and anticipated transit delays due to congested conditions will aid the motorist in decision making and will result in safer and more effective operation of the freeway system. Alerting drivers to unusual conditions



Typical TransGuide VMS Alerting Traffic to Trouble Ahead



San Antonio Police Working in the TOC

should be a significant contributing factor in gaining voluntary public compliance with traffic management controls and recommendations that are presented to drivers in response to freeway incidents.

3.1.6 *Communicate Traffic Information to Public Safety, Public Transit, and Other Intelligent Transportation Systems*

The TransGuide system shall provide a means to effectively and easily communicate information about what is happening on freeway systems to police, public transportation systems, and other transportation related services. Police notification of incidents requiring emergency handling shall fall within the real-time functions of TransGuide operations. The system shall allow interested external agencies access to information on traffic conditions, incidents, and related freeway control configurations. Enhancements to the management of external agencies and other related user services and initiatives will be facilitated by making the data available in a timely manner. The information shall be easily transmittable, complete, and current at all times, and it shall be organized such that each interested agency can readily extract information in a useable form. TransGuide shall provide supporting communications and documentation to appropriate external agencies that wish to use the freeway traffic information.

3.2 System Level Performance Requirements for TransGuide

Timely and accurate operation of the system and the associated credibility and utility of the system as perceived by the driving public are the true performance requirements for TransGuide. The physical configuration and implementation of the various system functions shall meet the general and design goals for real-time operation of the TransGuide core functions. System designers translated real-time operational goals for the core functions to practical minimum detection and response requirements through a series of analyses, tradeoffs, and tests. Some manually operated detection and response configurations of existing traffic management systems have been observed to yield relatively slow and unreliable detection performance and lengthy and inconsistent responses. The detection and response time requirements for TransGuide were established such that detection of incidents shall normally be accomplished within two minutes of occurrence and the resulting system outputs shall be accomplished within 15 seconds of an associated operational command.

3.3 Regional Functional and Performance Requirements for TransGuide

TransGuide's operational requirements include incident detection within two minutes and alteration of the traffic management system to the correct response within 15 seconds over the entire South Texas region. Although most metropolitan areas would not normally accept alteration of a traffic management system from another city,, TransGuide is the exception. The system's requirements support the ability of the separate metropolitan areas to design the system responses which will reside within the TransGuide response library When the response is implemented by

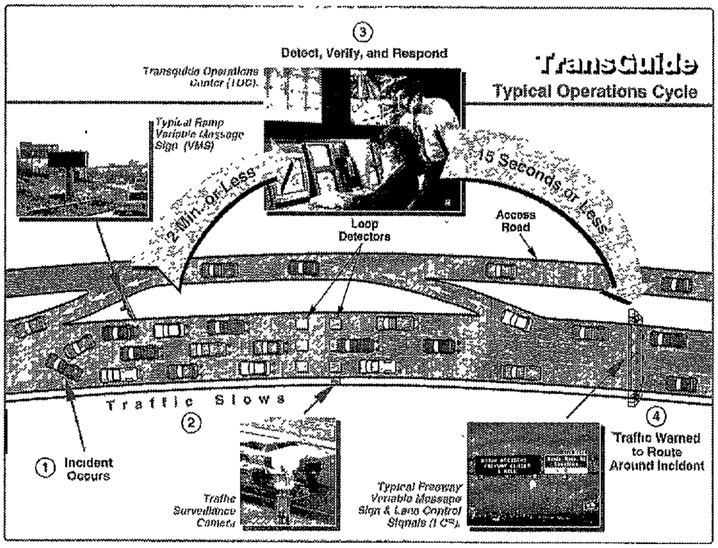


Illustration of* a *Typical TransGuide Operations Cycle

TransGuide, the plan will have already been accepted by the local area's responsible authorities. With these regional requirements in place, TransGuide is positioned to support the region in the same manner that the San Antonio metropolitan area will be supported.

In addition to the metropolitan areas of the region, TransGuide's requirements include the operation of several 150 mile corridors, including the NAFTA Highway. The requirements for these operations include full surveillance and incident detection for accidents or stalled vehicles. TransGuide is also required to support future ITS systems within these corridors as new systems are developed and deployed.

3.4 TransGuide Intelligent Transportation System Attribute Requirements

The specification for the physical configuration and implementation of TransGuide was developed pursuant to the primary goals for system operation described in Chapter 2. Additional features of the system design and implementation were considered to support general and operational requirements. Additional requirements for the system include attributes such as design life, cost priorities, manageability, expandability adaptability, availability reusability, and environmental capability. System attribute requirements were addressed during the planning stages and provided a rationale for the decisions made in the design and procurement process. Given the nature of modern information and control systems, system attribute characterizations often overlap and interact. Examples of the interdependence of system attributes include issues such as costs, which may be affected by flexibility requirements, and reliability, which may be affected by system complexity,, etc. The most significant TransGuide system attributes are listed and briefly discussed in this section.

3.4.1 TransGuide Design Life

The design life requirement for TransGuide was established to be 20 years. This requirement provided the rationale for equipment and architecture design decisions as well as criteria for design decisions regarding the balance of the system requirements. Predicted future growth of the San Antonio and South Texas freeway systems and the scope of the Transguide system were additional considerations.

3.4.2 Initial Costs

The TransGuide designers established a requirement for the system to meet aggressive traffic management and operational goals at practical initial costs. The use of mature technologies and commercially available equipment rather than new or proprietary devices was instrumental in containing initial costs of the system, as well as providing for cost effective maintenance infrastructures in the future.

Upon initial inspection, it appears that many of the basic functional elements reflected in the TransGuide goals and requirements could be individually addressed with components costing less than those chosen by the system designers. When system goals and requirements are integrated, however, to encompass low maintenance costs, expandability and adaptability to other ITS missions, environmental capability and reliability, and more, then the component specifications must reflect more than basic functional requirements.

"federal dollars pay for 80% of development and implementation costs . . . [We] designed for the most reliable, easy to maintain and operate system that would meet our budget and performance needs ... and accommodate growth and technical evolution in the future."

-Member of TxDOT's TransGuide Design Team

For example, the video camera/lens systems appear to be relatively expensive choices. However, the relative accuracy of incident characterizations, provided by these systems, will serve to increase TransGuide efficiency in dispatching appropriate emergency services to rapidly clear incidents and save lives. Lower quality video performance would result in less detail available to operators and police that may be called upon to make crucial judgements. Moreover, future implementations of additional ITS user services within TransGuide will make use of the high-quality video when technologies using vision systems, such as automated incident detection and characterization, vehicle identification, and even incident prevention techniques, are explored.

Similar examples exist for most of the functional requirements established for TransGuide. Communications and computation architectures, the central control infrastructure, and a distributed network of control features, such as signs and lights, were chosen not only to meet established functional requirements but also to address operational availability and cost containment goals for near-term operations as well as the system attribute requirements intended to position TransGuide as a modern, adaptable, expandable ITS asset in the future.

3.4.3 Maintainability and Maintenance Costs

TransGuide designers established a requirement for a highly maintainable system. The ability to quickly and effectively respond to failures and the facilities to promote and ensure effective preventative maintenance were regarded as important features. Funding policies established for TransGuide development and implementation created an environment where the practical minimization of routine operation and maintenance costs was often a higher priority for the designers than incremental minimization of initial costs. System designers considered tradeoffs, so the costs of operation and maintenance could be reduced by specifying appropriate and, if necessary and justifiable, more initially expensive implementations.

3.4.4 Operational Quality and Operational Costs

The TransGuide designers perceived that probably the single most prevalent threat to maintaining a high level of quality in system operation would be the variability in decision-making required for effective incident response implementations during routine day-to-day operations. TransGuide system operators were to be specially selected and trained personnel; however, experience has shown that significant variability can exist in similar control operations among different operators and over time with individual operators.

TransGuide's designers established an operational quality and cost minimization requirement such that demands on the system operators are minimal in the areas of training requirements and required operator inputs (opportunities for variability). This requirement was established to aid in producing consistent application of traffic management responses and to control system operating costs by de-emphasizing the required operator skill levels and training requirements.

3.4.5 Manageability

Vast amounts of information may be handled by the TransGuide system during routine operation, with the potential for much more information handling required as the scope of operations expands in the future. The information handling system will involve significant communications, networking, input/output, and information storage functions. Managing these functions so the system can perform the required real-time incident detection and response functions with reliability and security is a complex task.

"The use of a single communications network management system to manage all of the TOC networks became an important criteria . . . Multiple management systems are cumbersome and, in some cases, unavailable.. .[They can] leave gaps and overlaps that defeat the purpose of a management system. "

Member of TxDOT's TransGuide Design Team

A manageability requirement was established such that components and subsystems chosen for system implementation would integrate readily into a system with sufficient self-diagnostics, reporting, and system management infrastructures. This requirement was established to ensure adequate insight by systems management personnel into the status and operational integrity of all major system features and functions, especially where operational redundancy is provided. Systems management status reporting is to be available at all times to support problem and trend documentation and analysis.

The implementation structure for the information handling subsystem included a requirement for an offline testing and development function. An environment for evaluation of new concepts and ideas for preplanned responses to incidents, information display techniques, operational methodologies, detection algorithms and technologies, etc., was required. The development environment was configured so realistic operations through the traffic management system could be provided and results could be evaluated, but also so evaluation operations would not affect online system functionality.

The information system implementation was to support security requirements for access to controls and operation of the system and configuration control for potential software and hardware revisions. Specifically, secure release version control of operational software was required as a systems management function. The software is modular, well-documented, and annotated for effective management of changes and improvements. Hardware configuration documentation with configuration control was required. Supervisory circuits were also required in selected equipment, such as remote equipment housings, so unauthorized intrusion or tampering or inadequate power or environmental conditions can be reported and recorded.

3.4.6 Expandability

The scope of the TransGuide system is anticipated to expand over the coming years as a result of instrumenting and controlling more existing freeways, growth of the freeway system as the city grows, and the inclusion of other road systems or even other cities in the scope of TransGuide operations. Indeed, future plans for TransGuide include the potential development of a regional ATMS role housed within the current TOC. The expandability of the system to accommodate management of more miles of freeway was an important attribute required by system designers.

3.4.7 Adaptability

New technologies and methodologies that span the thrusts of the ITS strategic plan will evolve over time. TransGuide must be capable of integrating new devices and developments. The adaptability of the implementation is such that standardized formats for information interchange will be employed and sufficient excess capacity and communications bandwidth will be in place or can be integrated at a later date to allow for significant added functionality within the scope of operations.

There are many potential additional functions which could be integrated into the system structure and it is impossible to forecast a complete picture of future requirements. At a minimum, however, TransGuide designers recognized that future support of many of the currently planned ITS initiatives and user services as well as selected public safety and public transit functions would be required.

3.4.8 Availability

It was required that TransGuide be online and functioning for the vast majority of 24 hours per day and 365 days per year for the design life of the system.

> ***"Many traffic management systems suffer from very poor reliability, which impacts performance and acceptance by the driving public. TransGuide . . . will use reliable, proven, environmentally suited components, redundant systems, and online diagnostics to ensure San Antonio's drivers of a system that is working when they need it most."***
>
> *Member of TxDOT's TransGuide Design Team*

As the complexity and performance risks for system implementations increase, opportunities for system outages and other failures will also expand. System designers established a requirement that the percentage of time which the system would be fully operational would be 99.99 percent or more.

3.4.9 Reusability

The design and implementation of TransGuide reflects a departure from many existing approaches to ITS design. TransGuide's designers recognized that there may be a desire to use all or part of the implementation design in related implementations including other ITS facilities. Guidance criteria for selecting among potential choices for many component, subsystem, configuration, and software design alternatives were developed so that the design would be reusable, in part or in total. The system designers decided to use proven commercial hardware with broad applications and maintenance and support bases to enhance potential reusability of the system design. Components likely to become obsolete in the foreseeable future for technological, economic, or any other reasons were avoided. Complete design documentation allows reprocurements and reimplementations of TransGuide's systems or components to be straightforward. Software is portable, modular, and well-documented, so it can be as independent as practical of the hardware used in other applications.

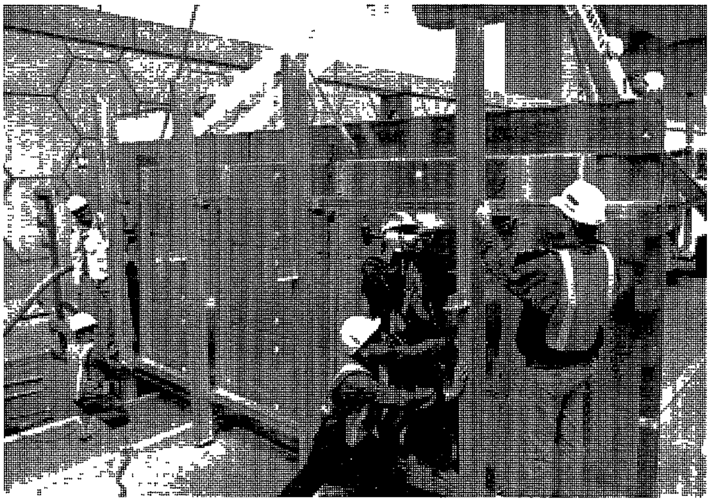
3.4.10 Environmental Capability

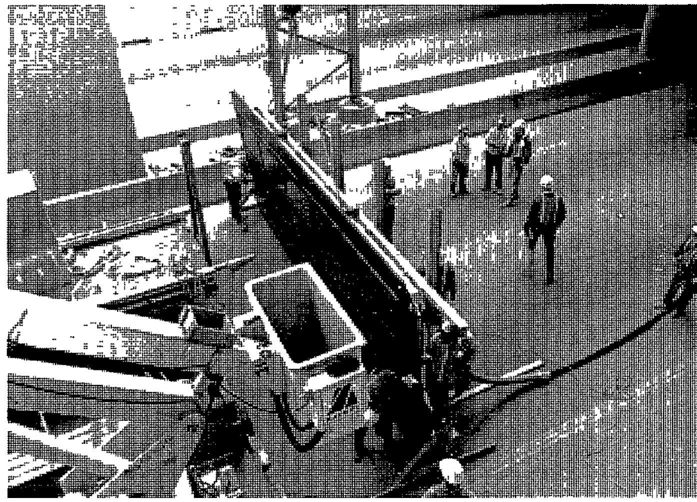
TransGuide must operate in all foreseeable weather conditions and atmospheric extremes. Traffic management systems are, by nature, distributed over many miles of roadway systems and involve the application of communications, surveillance, sensing, and information handling subsystems in potentially hostile environments. The TransGuide designers required component selection criteria to be based on intended or potential application environments. The environmental requirements for the components and subsystems were to be specified to ensure that system operational integrity would be maintained under worst-case environmental extremes and to ensure that system component operational life would not be degraded by exposure to unacceptable environmental stresses.

> ***"Some of the major architectural design decisions were driven by the availability of equipment that could withstand the field equipment environment."***
>
> *Member of TxDOT's TransGuide Design Team*

Maximum and minimum temperatures, sun loading, and other atmospheric extremes were considered in the specification for each major component or subsystem. Resistance to corrosion or the effects of corrosion was required for outdoor equipment. Adequate derating of operating parameters and other internal environmental modifiers in equipment assemblies was provided for, as was cooling and heating means for sensitive equipment in extreme environments.

4.0 TransGuide Intelligent Transportation System Designer's Processes and Priorities





TransGuide Construction Crews Installing a Variable Message Sign

The solution scenarios represent the body of knowledge and experience available to the designers in determining and implementing appropriate responses, controls, and driver communications in reaction to free way traffic congestion.

The TransGuide design reflects the integration of many new technological ideas and designs with established traffic control and DOT logistics processes and procedures. Basically, the design of the system satisfies the established goals and requirements for the system. The approach and priorities used in developing the TransGuide design are discussed in this Chapter. The development of a library of pm-engineered and pre-approved system responses to traffic incidents, called "solution scenarios," represents a special case with respect to the design approach and is also discussed herein.

4.1 TransGuide Intelligent Transportation System Design Approach and Priorities

The approach employed by TxDOT in accomplishing the TransGuide design included a number of distinguishing methods that merit discussion. TxDOT's design approach also addressed several logistical priorities, including dealing with TransGuide as an integrated system throughout design and development, accomplishing system design using internal resources, and planning a phased implementation of the system in regard to the amount of freeway miles that were in the scope of operations.

4.1.1 TransGuide Intelligent Transportation System Specification

The focus of the TransGuide design effort at TxDOT was the creation of detailed plans and specifications for the system and for selected critical major subsystems. The minimum requirements for the major subsystems or components were chosen to ensure that the integrated system would have the functionality and performance characteristics required. The specification was styled so the minimum specified requirements would be suitable for competitive procurement practices and so the lowest bidder could be chosen with confidence, as long as the minimum specified requirements were met. A comprehensive specification document was prepared that became the basis of the contract between TxDOT and the selected contractor for development and implementation of TransGuide. The specification was organized into approximately 50 detailed technical special specifications and produced in accordance with TxDOT standard specification practices. It included plans and requirements for the TransGuide building and contents, roadway specifications and modifications, signs and structures, communications and computing equipment, video surveillance and traffic control assets, software flow summaries, mechanical and electronic components, and more. A list of the special specifications dealing with equipment, subsystems, and structures within the design of the TransGuide system appears in the following table.

List of Special Technical Component and Subsystem Specifications

ITEM	TITLE
6240	Vehicle Loop Wire Sealant
6306	Surveillance Loop Detectors
6727	Electronic Components
6911	Prefabricated Pavement Markings
6966	Fiber Optic Changeable Message Sign System
6967	Portable Laptop Microcomputer
6969	Communication Cable
6970	Local Control Unit
6971	Preparation Of Existing Conduit
6973	Digital Multiplexer (OC3)
6974	Digital Loop Carrier System
6975	Communication System Switch
6976	Virtual Circuit Switch
6977	Digital Matrix Switch (DS3)
6978	Video CODEC (DS3)
6980	Video Monitoring Equipment
6981	Rear Screen Projection Equipment
6982	Freeway Traffic Management Mainframe
6983	Management Control Unit
6984	Local Control Unit Master
6985	Final Acceptance Plan
6986	Data Service Unit
6987	Lane Control System
6988	Communication Cabinet (Type 2)
6989	Fiber Hub
6990	CCTV Field Equipment
6992	Digital Loop Vehicle Detection Unit (Rack Mounted)
6993	Two Conductor Shielded Cable
6994	Rack Mounted Electronic Equipment Cabinet
6995	Digital Matrix Switch (DSl)
6996	Network Management System
6997	Incident Detection Software
7062	Central Control Center
7063	Multiscan Video Projection Equipment
7064	Fiber Optic Cable (Single Mode)

4.1.2 Integrated "Holistic" System Design Approach

TransGuide designers approached the development of ATMS design concepts as an integrated system that would satisfy the functional and operational goals and requirements for the system. The designers felt it was important to be opportunistic with regard to changes in technology and availability of new types of equipment to gain the best mix of additional capacity, performance margin, and design life. The design of the system was therefore approached as a flexible interconnection of many potential components and subsystems. The requirements for each component and subsystem were also considered flexible, such that tradeoffs could be conducted on the merits of available technologies and equipment that could be brought together as a system to collectively meet system goals and requirements. Components with fewer required features and functions than others were considered, if the required functions could be provided elsewhere in the system more effectively It was less important to end up with a design that included predetermined functional or physical partitions than it was to end up with an integrated system that met all the goals and requirements with as much excess capacity as feasible. The design of the TransGuide system, especially the technical components and operational features and functions, was continually updated by the designers as new ideas, technologies, or equipment became available, until the design specifications were frozen. Even in the frozen state, however, associated goals for flexibility, adaptability, etc. that leave the system relatively easy to change, improve, evolve, mature, and expand are included.

. . . [Designers were] careful to avoid the pitfalls of designing the pieces of a large highly integrated system before the true requirements.. . were known. This was done.. . recognizing that the impact of TransGuide 's presence on the motoring public will be much more than the sum of the impacts of the individual parts and subsystems contained within the system.

An 'alternative design approach that has been used in the development of systems similar to TransGuide could be classified as a "satellite" approach. In this process, relatively small and independent satellite traffic control facilities have been set up to improve traffic conditions in relatively small, circumscribed areas or trouble spots. Efforts to integrate existing satellite installations into larger systems capable of handling entire freeway subsystems have resulted in less than effective implementations of loosely coupled subsets of the functionality found in highly integrated systems.

Often, there was little attention paid to standardization or planning for future growth or integration when the satellites were formed. This was especially true if the satellites were constructed over a lengthy time span such that several generations of technology are represented between individual satellites or even within one satellite installation. In some cases, the satellites were designed with eventual integration in mind, but the level of integration and communications required to meet the demands of modern traffic systems and aggressive ITS initiatives may not have been foreseeable or affordable during development. TransGuide system designers were careful to avoid the pitfalls of designing the pieces of a large highly integrated system before the true requirements of the system were known. This was done by approaching the TransGuide system design holistically and recognizing that the impact of TransGuide's presence on the motoring public will be much more than the sum of the impacts of the individual parts and subsystems contained within the system.

4.1.3 User as Designer

Many agencies approach the design and development of specialized ATMS systems by making use of consultants or other temporary experts. The developers of TransGuide felt, however, that a potentially harmful disruption of continuity between the designers and users of the system could occur if outside consultants were relied on for details and decisions regarding system concepts and designs. It was felt that the optimum utility from TransGuide systems would come from having the same personnel that made crucial design and selection decisions (with all the attendant criteria and priorities involved in such a process) using, managing, evaluating, and planning improvements for the system as it matured in operation. For these reasons, the establishment of goals and requirements and the conceptual and early design of TransGuide were accomplished internally at TxDOT.

"The operating agency must know every component and every function of the network to effectively manage the system."

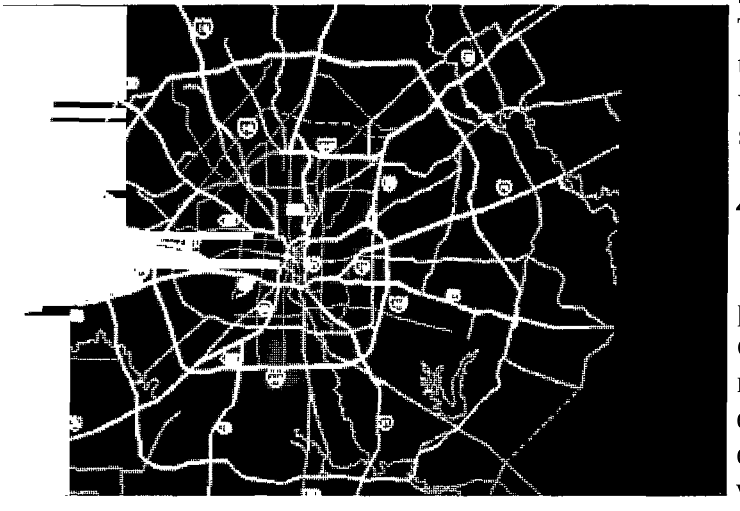
Member of TxDOT's TransGuide Design Team

It should be noted that many outside service and equipment providers were consulted on details of particular options and equipment during the design process. It should also be noted that numerous meetings and conversations between TransGuide designers and cognizant and helpful personnel at DOTS around the USA were held in the course of selecting the most appropriate required functions and features and the basic implementations needed to meet those requirements.

4.1.4 Build, Learn, Build More

The design and implementation of TransGuide was approached as a phased operation.

The basic infrastructure for the system and a limited scope of freeway systems was included in the first phase of development. The freeway systems involved comprise segments of several interstate highways that intersect to form an inner loop in or about downtown San Antonio and radiate out in several directions. The portions of the interstates involved in the first phase of construction for the system generally were confined to central city areas and did not reach the first outer loop that surrounds the inner city.



San Antonio's Freeway System – The TransGuide Guide Project *Phase One is Shown in Green. Phase Two is Shown in Yellow*

Twenty-six miles of IH 10, IH 35, IH 37, US 90, and US 281 were included in the first phase of implementation, as was the ATMS building, with the capacity to monitor and control all the freeways in San Antonio and much more. Fifty-nine video cameras, more than 800 inductive loop detectors, 359 lane control signals (LCS), 51 variable message signs (VMS) and some 70 miles of optical fiber cable were required to adequately instrument the 26-mile phase one freeway system.

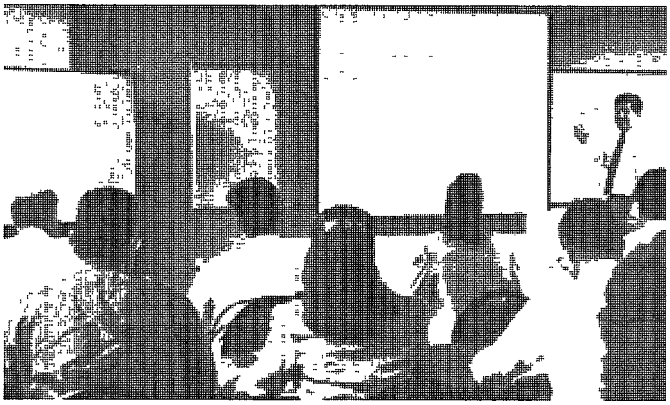
As planned, the scope of TransGuide will expand to cover the entire 191-mile freeway system in San Antonio. Additional traffic management functions in other regional districts such as Corpus Christi, Laredo, and Pharr are also being instrurnented. Control and monitoring of border-crossing activities at major points along the Texas / Mexico border are also developing within the scope of TransGuide operations. These and more urban and rural traffic management responsibilities are being met by TransGuide as part of the system's potential role as a regional traffic management system. Many other as yet unspecified related user services will eventually be supported by the system.

Phase one of TransGuide was embraced such that the operational and functional requirements for the system would be implemented and operated. As implementation and the operation of the system matured, important lessons were learned by the system designers, managers and operators. The lessons learned and improvements made in the maturation of the phase one implementation will be included in subsequent TransGuide expansions and improvements.

4.1.5 Training and Development Plan

TransGuide designers recognized the need for providing an effective training environment for operational personnel and the development of new and improved ATMS functions and processes. Additional workstations, computational equipment, and other operational assets were provided for these purposes. A video recording and processing studio function was specified to acquire actual traffic and traffic management footage for use in the ATMS training and development facilities. Care was taken by system designers to select a professional video format for these purposes, to take full advantage of the high quality provided by the TransGuide video and communications subsystems.

The functional traffic management components and subsystems planned for training and development uses are configurable into a simulation mode to provide realistic simulations of actual operational environments. In fact, real, recorded, or simulated data can be input to the systems and the resultant actions are the same as those occurring in the balance of the ATMS, with the exception that actual output to the traffic management controls and signs in the field is blocked. It was also planned that offline computational responses to real, recorded, or simulated input data could be accommodated external to the ATMS operations computers, and that the output of this development environment could be captured but similarly blocked from affecting actual traffic controls and signs.



An Operator Training Session Within TransGuide

41.6 Building Space Enters the Design Equation

The TransGuide system contains a large, sophisticated communications network with many functions distributed over a wide area. The distribution of components and interconnects will become much larger in the future as planned phases of growth are realized and the anticipated future expansion of TransGuide's role in regional ITS activities matures.

For some design decisions, the impact on floor space requirements for existing and future implementations was critical. For example, the video communications and switching required to meet TransGuide's functional requirements could be accomplished in multiple ways. Digitizing these signals in the field and routing them within the TransGuide Operations Center in digital rather than analog f&m resulted in a smaller floor space requirement for equipment, as well as significantly less equipment. Routing and managing video signals in analog form would have required many banks of signal conversion and switching equipment and consequently significantly more floor space.

"Building space designs must occur concurrently with the selection of potential technologies residing within the area over the life cycle of the project. Simple decisions in technology could have major impact on space allocation."

Member of TxDOT's *TransGuide Design* Team

4.2 The Solution Scenario – TransGuide's Traffic Management Expertise

The majority of the TransGuide implementation can be characterized as a platform from which critical ITS functions are conducted. The platform provides the means for incident detection, traffic surveillance, and implementation of traffic controls. The interaction that takes place within the system to integrate these functions is the heart of the traffic control operation. TransGuide designers worked to establish a broad, aggressive, and sophisticated platform with which to carry out the required functions. The solution scenarios represent the body of knowledge and experience available to the designers in determining and implementing appropriate responses, controls, and driver communications in reaction to freeway traffic congestion. The solution scenario approach reflects an enabling technology in the TransGuide design in that it allows rapid, consistent responses to detected incidents as opposed to the much slower and less predictable responses that may be observed in manually operated systems.

The solution scenario approach reflects an enabling technology in the TransGuide design in that it allows rapid, consistent responses to detected incidents . . .

Solution scenarios are stored sets of pre-engineered and pre-approved responses to abnormal traffic conditions on the freeways. Each solution scenario is uniquely identified within the database. Solution scenarios are automatically selected by the TransGuide software in response to detected traffic incidents and operator responses to incident characterization inquiries relative to the detected incidents. A solution scenario for each incident which is described through this process is presented to the operator that is handling the incident and is implemented within the system upon acceptance of the operator

It was estimated that approximately 128,000 solution scenarios would be needed for the TransGuide system to accommodate the total planned implementation of 191 miles of San Antonio free-

uide Design Team Reviewing Solution Scenarios

ways. At the end of development of the first phase, with 26 miles of freeway system under TransGuide's control, approximately 34,000 solution scenarios had been developed. Each solution scenario may include configuration data which controls up to 100 different pieces of field equipment through the network. It was also estimated that fully half of the investment in man-years of design effort required to develop and field the real-time operating system was focused on the development-of solution scenarios. It was concluded by TransGuide designers that the solution scenario development process should begin as early as possible in the planning of an ATMS, even before the placement of electronic field equipment was specified. Unfortunately, this was not the case for TransGuide. As is typical for most applications, the TransGuide solution scenarios were developed concurrently with the selection and development of technologies used in the system.

"People need to understand that the development of solution scenarios is a big part of the job . . . ideally, the solution scenarios should be developed before the free way electronic field equipment is designed."

Member of TxDOT's TransGuide Design Team

The processes and priorities used by the TransGuide designers in developing the library of solution scenarios for use within the system are discussed in the remainder of this chapter. Rules, procedures, examples and a comprehensive illustrated sample of a solution scenario is contained in the Appendix of this report.

"Two full time traffic experts required two years to develop 34,000 solution scenarios for the 26 miles of TransGuide, phase one."

Member of TxDOT's TransGuide Design Team

4.2.1 Scope of Solution Scenario Approach

Solution scenarios have been developed by the TransGuide designers for many potential incidents. Each possible combination of lane open/closed configuration for each section of freeway between detector installations is reflected in an appropriate response plan within a solution scenario.

"The solution scenarios enable the entire 191-mile network of freeway controls to be altered to the correct response within 15 seconds from the notification of an alarm."

Member of TxDOT's TransGuide Design Team

When a traffic flow alarm occurs in the system, it signals that traffic has slowed or lane occupancy has increased at a detector location. This indicates that an incident or other cause for congestion has occurred between the alarming detector location and the next detector location downstream in traffic flow. The freeway area between the alarming detector and the downstream detector is called an "incident space."

A "response configuration" was defined as the part of a solution scenario that determines which control assets will be used and what they will display A set of solution scenarios was developed for each incident space that provided a response configuration for e&h possible combination of lane closures that could exist at that location. The type of incident, the impact that the incident has on traffic flow, the location of entrance or exit ramps within the incident space, freeway lane configuration changes within the incident space, and many other criteria influenced the selected response configuration reflected in solution scenarios, and this resulted in multiple sets of solution scenarios for each incident space. The choice of which solution scenario to apply depends on the incident location (supplied automatically within TransGuide) and the incident characterization (supplied by the operator using the system information and surveillance systems).

4.2.2 Input Criteria for the Selection of a Solution Scenario

The general location of an incident that causes an alarm is provided by the information stored in the system, which identifies the incident space associated with each detector. The location of the incident is assumed to be between the alarming detector and the next detector downstream. The incident space involved with an alarm is the sole automatic criteria used for selection of a set of potential solution scenarios. Plans for the future of TransGuide include automation of more incident detection and handling functions. TransGuide may, when appropriate technologies are available in the future, support fully automatic traffic incident detection and handling.

4.2.2.1 Character of an Incident

Additional data regarding the characterof a detected incident are made available to operators as they select the most appropriate solution scenario from a set of solution scenarios indicated by incident space identification. This additional information is primarily acquired by the operator's use of TransGuide's video surveillance features. The operator is prompted by the system to classify the incident as fitting into one of the following six categories:

The operator is also prompted by the system to determine which freeway lanes are closed as a result of the incident and whether the existing traffic demand exceeds freeway capacity within the incident space and then to enter that data into the computers.

4.2.3 TransGuide Output Functions Affected by the Incident Response Configuration

The TransGuide system was designed to manage traffic flow in the presence of freeway incidents by controlling individual lane occupancy,

>Major accident

>Minor accident

>Construction

>Congestion

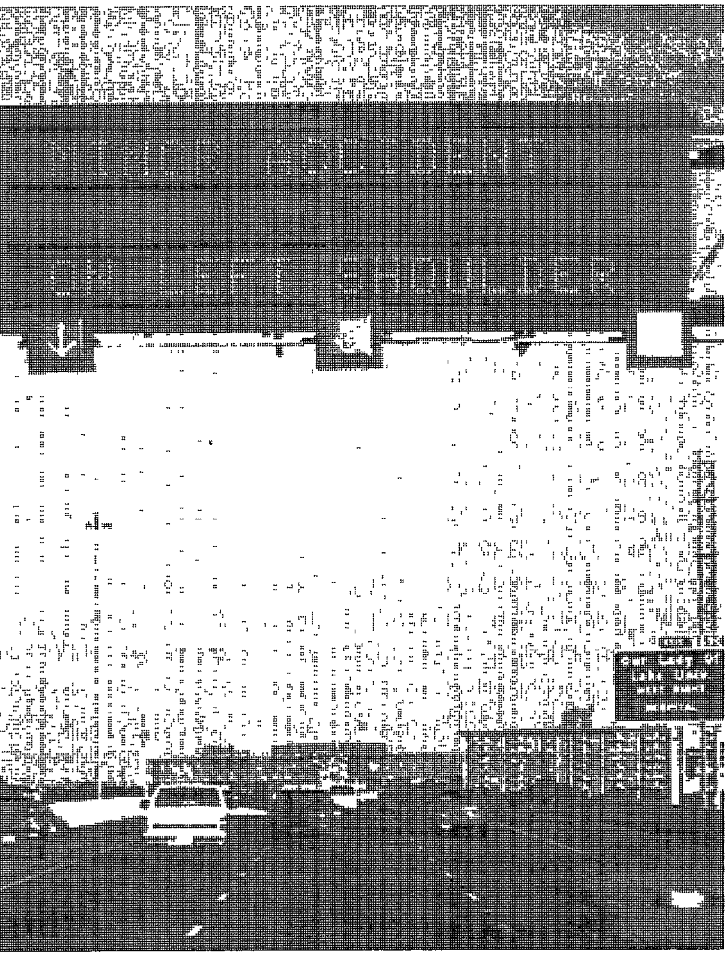
>Debris

>Weather condition

communicating information about incidents to drivers, controlling the use of freeway entrance and exit ramps in the vicinity of an incident, and controlling freeway cross-street traffic Light timing, if required, to effectively use access roads as additional freeway capacity.

Variable message signs were installed on approaches to major interchanges and upper / lower freeway splits to give drivers the option of exiting the freeway and using an alternate route before being committed to a closed or congested section of freeway. The VMSs can also be used to warn drivers of congestion or closures on an intersecting freeway, allowing them to detour or use an alternate route. On the detour routes, VMSs can be used to guide drivers back to their original route. Smaller types of VMSs were also located on continuous freeway access roads where there was an entrance ramp onto the freeway. These signs are used to warn drivers of accidents or complete freeway closures that would be encountered if they chose to enter the freeway system at that point and to help previously detoured drivers avoid reentering a congested freeway prematurely,

The LCSs are located on existing sign bridges on all freeway systems within the scope of TransGuide's operations at approximately one-mile intervals. The spacing of LCS locations was reduced to approximately one-quarter mile at points of diversion in the freeway lane configuration, so an LCS exists at the point of diversion and on the



Typical TransGuide VMS and LCS Combination

two previous sign bridges as encountered by a driver approaching the point of diversion. Signal locations and spacings are approximate, because the devices had to be installed on existing sign bridges.

The timing cycles of traffic control signal lights at certain freeway cross-streets were placed under the control of the TransGuide system for the purpose of increasing the mobility of traffic on the access roads when these roads are being used as additional freeway capacity. The signal lights chosen for the traffic management functions of the system are in areas where the access roads are continuous between freeway exit and entrance ramps and therefore suitable for use as additional freeway lanes when required.

4.2.4 Multiple Incidents

Each solution scenario was designed to address a single incident. There were no scenarios developed that specifically addressed multiple incidents. However, multiple single incident scenarios can be active at any time. TransGuide operators and managers will apply and, if necessary, modify scenarios as they manage alarms to accommodate multiple incidents. When a message is generated by a scenario for a specific sign that already has a message on it, the manager of the highway section containing the sign determines the priority of the messages. The highest priority messages are displayed and the rest of the messages are retained in system memory The queue function of the system stores, activates, and clears messages in the order they occur with one exception: messages related to major accident scenarios receive priority as long as those scenarios remain active. Messages in queue are cleared if the associated scenario is cleared. If a scenario that generated a message currently being displayed is canceled, a queued message takes its place. If there are still conflicts (multiple messages for the sign), the manager resolves the conflict as to which message will be displayed. Overall, multiple incidents are handled using combinations of standard or modified scenarios controlled by operators and managers.

"Solution scenarios were developed for single incidents only . . . there would be no limit to the task of developing responses for all possible combinations of accidents."

Member of TxDOT's TransGuide Design Team

4.2.5 Multiple Alarms from a Single Incident

Multiple alarms can be produced by single incidents. If congestion occurs as the result of an incident, separate alarms can also occur as the congestion queue lengthens to involve additional incident spaces. However, multiple alarms from added lane involvement within the same incident space are blocked after the initial alarm, pursuant to the assumption that the incident should already be under control and monitored by the ATMS. Each additional alarm is handled separately, and worsening congestion due to an incident is reflected in a scenario modification as initiated by an ATMS operator and approved by an ATMS manager. Multiple alarms arising from a single incident may also be handled by multiple solution scenarios being active at the same time. Traffic congestion resulting from an incident would be expected to improve as a result of the incident being cleared or congestion relief being provided by TransGuide operations. As congestion improves, any solution scenarios in effect are also cleared as the associated detectors and operator surveillance indicate more normal traffic flows, or as the incident is cleared from the freeway.

"Since every conceivable possible single accident scenario has been developed, multiple accidents are addressed by the use of multiple combinations of single incident scenarios. "

Member of TxDOT's TransGuide Design Team

4.3 Solution Scenario Development Process

TransGuide designers developed the solution scenarios by applying general rules and procedures to produce a draft response configuration for each incident configuration. The draft response configuration was then manually reviewed with regard to the specific freeway geometries associated with a subject incident space and changed as required to produce an acceptable response configuration. The response configurations were then reviewed by a peer review group and finally approved by the TransGuide management for use in the system as approved solution scenarios.

"Due to the complex nature of the scenarios and the need for consistency, it was necessary for the development process to consist of a small number of developers working over a long period of time. "

Member of TxDOT's TransGuide Design Team

4.3.1 Solution Scenario Identification System

Unique identification numbers were assigned to each of the incident spaces within the freeway systems included in the scope of operations for the TransGuide system. These numbers correspond to numbers assigned to the detectors at the beginning of each incident space. The numbers are based on the existing mile marker system used in the Interstate Highway System.

Each solution scenario file begins with the location identification number, so the incident space involved in any solution scenario may be determined by inspection of the mile marker numbering system. Further, each solution scenario occupies a unique location in the TransGuide data base, which is addressed by data automatically associated with an alarm and by inputs provided by TransGuide operators as they are handling an alarm. It is feasible, should it be determined to be desirable, to tag each solution scenario with a unique encoded identification number that could be distributed to public and private agencies when the scenarios are activated. This would provide the agencies with the opportunity to stay abreast of changing traffic conditions by extracting desired data from a list of active scenarios.

4.3.2 Draft Solution Scenario Design Issues

The solution scenario designers started by analyzing the incident space located at the terrninus of the scope of TransGuide operations for each included freeway system. The next consecutive incident space for a subject freeway was analyzed next, and the process continued in this fashion until the analysis was complete for all incident spaces for the subject freeway within the scope of the system. Solution scenario design for each incident space was initially approached by assuming that all lanes of a subject incident space would be closed due to an incident. Potential incident surveillance resources such as video camera systems were identified and recorded. Driver control and driver information resources such as LCSs and VMSs for the subject incident space and other affected freeway areas upstream of the incident space were determined and recorded. Other control assets, such as freeways or continuous access roads that could be used as detours or additional freeway capacity, entrance and exit ramps, and cross-street intersection control signals that could be used to enhance traffic flow, were identified and recorded. Driver control and information signs and signals on entrance ramps or adjacent freeways that could impact traffic flow at the subject incident space were also identified.

Appropriate variations in the characterization of an incident within the subject incident space were then analyzed. The possible incident characterizations were divided into four groups reflecting the possible combinations of major / minor and demand does / does not exceed capacity incident characterizations. For each of the four groups of potential incident characterizations, a five-step procedure was followed to arrive at the draft response configuration, as described in the following paragraphs.

4.3.2.1 Determine Which Control Assets to Use

A wide range of suitable response configurations was developed for incidents within the subject incident space for each of the four characterization groups. For each group, the set of possible incident characterizations was expanded to include all potential combinations of lane and shoulder closure configurations. Control assets identified and inventoried for the subject incident space for the worst case, complete closure, were reviewed for applicability for the subject incident characterizations. Each lane closure configuration was associated with appropriate LCS and VMS locations.

Variable message sign locations for a specific incident response configuration were chosen such that the VMS encountered by a driver immediately prior to an incident is used for incidents that are not creating sufficient congestion to reduce the freeway capacity below the current demand. If an incident is characterized such that the traffic demand exceeds freeway capacity, then the two VMS locations encountered prior to the incident are to be used. If a complete freeway closure is in progress, then the three VMS locations prior to the incident location are employed.

The application of LCS assets in the draft incident response configuration was similarly approached such that the number of LCS locations used depends on the severity of the incident. Generally, if an incident is characterized as any type other than a major accident and the existing traffic demand does not exceed freeway capacity, then two or less LCS locations encountered by a driver as he approaches an incident are used. If it is determined that traffic demand does exceed available freeway capacity, then two or more LCS locations prior to the incident location are used to alert drivers to the lane closures. For major accidents, where traffic demand does not exceed freeway capacity, at least two, but not more than three, LCS locations prior to the incident location will be used. For a major accident in which the freeway capacity is exceeded by traffic demand, at least three LCS locations immediately prior to the incident site are used.

4.3.2.2 Determine which Lanes to Close

If the subject incident characterization includes lanes that were closed or should have been closed to mitigate a danger to the driving public, then the LCSs identified for the draft incident space can be used as part of the system response configuration. Five possible steady (not flashing) LCS displays were chosen by the TransGuide designers:

>DOWN GREEN ARROW: Used over a lane that is open. This is the default LCS display, used when no solution scenarios are active for the associated incident space.

>RED X: Used over a lane that is closed.

>DOWN YELLOW ARROW: Used over a lane that has an accident on the shoulder that is adjacent to the lane. It could also be used in rare cases over a lane that will be closed ahead but where the freeway has an exit that reduces the number of lanes

>SLANT RIGHT YELLOW ARROW
Used over a lane that is closed ahead, prior to a RED X. This display is used to instruct a driver to move to the next right lane.

>SLANT LEFT YELLOW ARROW
Used over a lane that is closed ahead, prior to a RED X. This display is used to instruct a driver to move to the next left lane.

In the draft response configuration, when there are no lane closures, all LCSs identified with the subject incident space default to GREEN DOWN ARROWs. This is the same LCS default status used when there are no solution scenarios active for the associated incident space. When more than one LCS location in a given lane was employed in developing the draft response configuration, the general rules and procedures listed in the following were used:

>When two sets of LCSs are used, one RED X is used and it is preceded by one SLANT YELLOW ARROW (see note).

>When three sets ofLCSs are used, two RED Xs are used and they are preceded by one SLANT YELLOW ARROW.

>When four sets of LCSs are used, two RED Xs are used and they are preceded by two SLANT YELLOW ARROWs.

>When five sets ofLCSs are used, two RED Xs are used and they are preceded by three SLANT YELLOW ARROWS.

Note: The preferred LCS configurations involve two RED Xs prior to the location of an incident. It was felt by the TransGuide system designers that this approach yielded both consistency and redundancy in the application of LCSs for traffic control. The two-LCS configuration using one RED X and one SLANT YELLOW ARROW is typically encountered at the limits of the freeway systems operated under the scope of the system. Using more LCS locations is generally preferred, not only to give drivers more time and room to heed the directions, but also as a measure of operational redundancy for the system. If one of the two selected LCSs is malfunctioning, then a driver still has one LCS opportunity for direction prior to reaching an incident. Consideration was given to using YELLOW DOWN ARROWs in open lanes in the vicinity of an incident that is closing an adjacent shoulder, to signal to drivers that caution should be exercised. Experimentation by the TransGuide designers revealed, however, that the visual impact of this approach on drivers was significant the appearance of this LCS configuration was interpreted to mean that very little freeway capacity was available. GREEN DOWN ARROWs were therefore always used on open lanes and YELLOW ARROWs were only used in a slant configuration to precede lane closures, with one notable exception: a YELLOW DOWN ARROW was used in lanes adjacent to shoulders to promote caution by drivers occupying the outer lanes when approaching an incident where a disabled vehicle or accident investigation, etc., was occupying the shoulder.

4.3.2.3 Determine Changes to Cross-Street Signal Light Timing

The timing of cross-street signal lights in the scope of TransGuide operations was adjusted to provide higher traffic mobility on access roads when it was required to use them as extra freeway lanes. When draft incident response configurations included the routing of traffic to access roads to increase freeway capacity, signal light timing at the intersection of access roads and city cross-streets was modified to reduce traffic delays on the access roads. TransGuide designers concluded that the signal light timing modification should occur immediately on activation of the associated solution scenario; the signal light timing modification was therefore included in the draft incident response configuration. The cross-street timing controls continued to be operated by traffic demand as indicated by associated waiting traffic detectors (if applicable), but the maximum green light time for the access road traffic was increased to three minutes, while the maximum green light time for the cross-street traffic was limited to 10-15 seconds. The modification can be activated within 15 seconds of the changes to routing controls on the respective freeway. System designers intended that manual adjustments to cross-street signal light timing, to better accommodate cross-street traffic, could be made by TransGuide operators if indicated by freeway traffic conditions observed during the incident monitoring.

"Over 90% of all freeways in San Antonio have parallel access roads, therefore, TransGuide will utilize these roadways for additional capacity, not the already congested city street system."

Member of TxDOT's TransGuide Design Team

4.3.2.4 Determine What to Tell Affected Drivers

The appropriate message for each of the VMSs to be used in a response configuration was developed. These messages are based on the type of incident (one of six possible categories), whether traffic demand exceeds freeway capacity, which lanes are closed, and whether an exit ramp exists between the incident location and the closest VMS encountered by a driver prior to the incident location. The existence of lane drops and auxiliary lanes between the subject VMS and the incident location can also change the message content. It is possible that, for some freeway configurations, freeway lanes impacted by an incident do not exist at the location of the VMS used to inform drivers of the incident and any resultant traffic management instructions.

A library of possible VMS messages was developed according to the following general guidelines and examples.

4.3.2.4.1 Categorize the Incident Type Each incident characterization results in one of 12 possible incident message types:

>MAJOR ACCIDENT with DEMAND LESS THAN CAPACITY
>MAJOR ACCIDENT with DEMAND GREATERTHAN CAPACITY

>MINOR ACCIDENT with DEMAND LESS THAN CAPACITY
>MINOR ACCIDENT with DEMAND GREATER THAN CAPACITY

>CONSTRUCTION INCIDENT with DEMAND LESS THAN CAPACITY
>CONSTRUCTION INCIDENT with DEMAND GREATER THAN CAPACITY

>CONGESTION INCIDENT with DEMAND LESS THAN CAPACITY
*CONGESTION INCIDENT with DEMAND GREATER THAN CAPACITY

>DEBRIS INCIDENT with DEMAND LESS THAN CAPACITY
>DEBRIS INCIDENT with DEMAND GREATER THAN CAPACITY

>WEATHER INCIDENT with DEMAND LESS THAN CAPACITY
>WEATHER INCIDENT with DEMAND GREATER THAN CAPACITY.

Note: Selected terms as used in the incident type categories are defined as follows:

>MINOR ACCIDENT or MINOR INCIDENT: Anticipated lane closure of 15 minutes or less.

>MAJOR ACCIDENT or MAJOR INCIDENT: Anticipated lane closure of more than 15 minutes

>CAPACITY: "Maximum rate of flow that can be accommodated by a given traffic facility under prevailing conditions." 1985 Highway Capacity Manual, Special Report 209.

4.3.2.4.2 Two Incident Severity Categories -Minor and Other Messages for all types of incidents except minor accidents were handled as major incidents in the development of a draft response configuration. This was done because TransGuide system designers anticipated that the majority of all incident types other than minor accidents would require more than 15 minutes to clear.

4.3.2.4.3 Is There an Exit Before the Incident? Messages were based on two possible situations for a driver when approaching one or more lanes closed because of an incident:

When AN EXIT(s) exists, the messages are expanded to include the different types of conditions the driver will be encountering:

*There are NO EXITS between the driver and the location of the incident.

*There is AN EXIT(s) between the driver and the location of the incident.

>CITY CROSS STREET No continuous access road parallel to the main lanes

>CONTINUOUS ACCESS ROAD Traffic can move parallel to the main lanes

>CONNECTOR Freeway-to-Freeway ramp

4.3.2.4.4 Spacing **of** *Messages* Messages were created to alert and instruct drivers at the following distances prior to an incident:

>0 MILE (the incident is less than 1/2 mile ahead)

>1/2MILE

>1 MILE

>1 1/2 MILES

>2 MILES

>2 1/2 MILES

>3 MILES

In some cases, even greater distances are used, especially if alternative routing onto different freeway systems is advised in the message content.

4.3.2.4.5 Different Messages for Each Situation The incident messages are based on a combination of the messages in Sections 4.3.2.4.1 through 4.3.2.4.4. For example, a MINOR ACCIDENT with DEMAND GREATER THAN CAPACITY and NO EXIT ramp between the driver and the closed lane results in a different message than the message associated with a MINOR ACCIDENT with DEMAND GREATER THAN CAPACITY when an EXIT RAMP does exist between the driver and the closed lane(s).

4.3.2.4.6 VMS Message Intent-The designers of the TransGuide system attempted to style VMS message content to achieve several levels of impact on drivers encountering the messages, according to the severity of the traffic delays and freeway conditions involved. Generally, VMS messages were designed to tell the driver:

>What type of incident they are approaching (incident category)

>Which lanes are closed

>How far away the incident is (miles)

>What action (if any) they should take

The basic difference between a message for a DEMAND LESS THAN CAPACITY incident characterization, a message for DEMAND GREATER THAN CAPACITY situation, and a COMPLETE FREEWAY CLOSURE is:

>DEMAND LESS THAN CAPACITY: The message is positive, informing a driver of which maneuvers or slight modifications to his driving plans will help him minimize the delaying effects of a relatively insignificant (to traffic flow) incident ahead. Alternative routing recommendations or suggestions for evasive actions (other than possible lane changes) are avoided.

> DEMAND GREATER THAN CAPACITY The message is styled to create a more profound impact on drivers, prompting drivers to seek alternatives to routes experiencing significant problems The message is structured to communicate to drivers that serious delays are ahead unless appropriate evasive actions are taken as advised in the message. The message tells the driver which lane(s) is closed and what to do and will suggest that the driver take an ALTERNATE ROUTE or USE THE ACCESS ROAD if there is an exit ramp available.

>COMPLETE FREEWAY CLOSURE: The message states that the freeway is closed "ahead" (or gives the distance) and instructs all traffic to exit at a particular exit number or numbers, or to exit at the NEXT EXIT or NEXT EXITS providing there is an exit between the driver and the freeway closure.

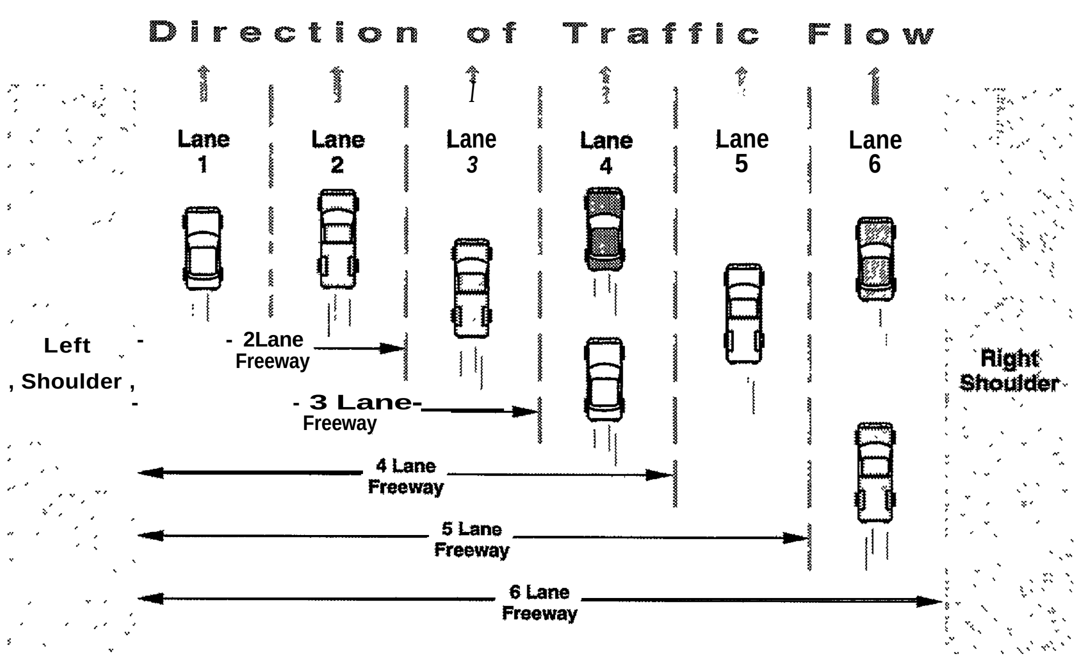
4.3.2.4.7 Street Names and Numbers - When an exit ramp is referenced in a VMS message, exit numbers are generally used rather than street names. This was done to address all drivers, not just those familiar with city street names, so that local drivers as well as tourists or other transient users of the freeway systems will receive effective directions. The numbering of exits is consistent with the Interstate Highway Numbering system, and exit ramps are generally identified with the nearest mile marker number. In some cases, however, multiple exits exist in close proximity and the use of exit numbers only could be confusing to drivers. This is especially true in non interstate and freeway areas with upper and lower level splits, where an exit is accessible from only one of the levels, or where exits with the same number exist on both levels. In these cases, street names are used to identify exits rather than exit numbers. Care was taken in the formulation of VMS messages to coordinate street names or exit numbers used in the messages with existing freeway guide signs to minimize confusion.

4.3.2.4.8 Lane Labeling Conventions – For the purposes of developing draft incident response configurations and the associated VMS message contents, TransGuide designers adopted a freeway lane numbering convention. The left most lane of a road with respect to the direction of traffic flow is always labeled as lane #l, with ascending lane numbers assigned to lanes from left to right. The left shoulder and right shoulder of the road are also labeled according to the direction of traffic flow. This arrangement is presented graphically in Figure 4.1. It should be noted that, in the development of VMS message contents, the designer was required to think through any changes in the road lane configuration that might occur between the respective VMS location and the actual incident. The use of a lane numbering system was critical to planning and developing appropriate incident response configurations but was not used in developing VMS messages, because lane number assignments changed each time an outer lane was dropped or added. Lanes are referenced in the VMS messages as LEFT, CENTER, or RIGHT lane or lanes, often with a number such as 2 LEFT LANES, in order to communicate which lanes will be closed when a driver reaches an actual incident location. Figure 4.1 illustrates the lane numbering convention used in TransGuide solution scenarios development.

4.3.2.4.9 VMS Message Terms and Phrases, Definitions, and Usage Conventions – A list of appropriate terminology and phrase usage conventions was developed by TransGuide designers for use in compiling VMS messages in the development of draft incident response configurations. The key phrases used to develop the appropriate VMS messages and a brief description of their meaning and usage within the TransGuide context are listed in the Appendix.

4.3.3 Review Specifics and Implement Changes

There were many exceptions to the general rules and processes used to develop the draft incident response configurations. The draft response configurations were individually reviewed in detail by TransGuide designers with respect to the actual freeway geometries, signage, potential safety hazards, LCS and VMS visibility, and



lane Labeling Convention Used in TransGuide Solution Scenarios "friendliness" of the control schemes and message contents for each situation. In the majority of cases, changes were made to the draft response configurations during the detailed review process. Most changes made during the review process dealt with increasing the number of VMS and LCS locations involved in a response and adjustment of the message content of the involved VMSs.

4.3.3.1 Changes in Lane Configurations

The vast majority of changes to draft response configurations were reactions to changes in the freeway lane configurations between incident spaces and the locations of the LCSs and VMSs. The locations of entrance and exit ramps, freeway merges and diversions, and any other lane configuration changes in the affected road prompted a fine tuning of the control schemes in the interest of mobility, safety, and friendliness. The types of exits encountered in an incident space during the detailed review also had an impact on the revised message contents, for instance, lane drop-type exits were treated differently than slip-type exits.

4.3.3.2 Probabilities, Estimates, and Judgements

Decisions on response configuration changes were often made during the review process based on estimated probabilities of the locations of incidents within an incident space. Judgements were made about the possible location of the incidents and the ability of affected traffic to execute meaningful maneuvers pursuant to traffic controls generated by TransGuide. When most of an incident space included distances after an entrance or exit ramp, for instance, the entire incident space was treated as if the lane configuration after the ramp prevailed for the entire length of the incident space. In this case, TransGuide designers judged that developing special response configurations for the relatively small area prior to the ramp would be useless, because drivers would be very close to the incident as they entered the incident space and would not have adequate time or room to take action. Also, in this case, the review process often yielded changes to LCS and VMS deployments for the response configurations for incidents in the outer lanes affected by the presence of the ramp. The changes were designed to produce beneficial driver controls transparent to the potential confusion related to lane configuration changes early in the incident space.

Many other types of potentially confusing changes in road geometry within an incident space were encountered during the review process, and all were dealt with individually and in a similar manner.

4.3.3.3 Experience and Interest Was Crucial

During the review process, it was necessary to depend on the application of classical traffic control principles. The ability to analyze traffic situations and foresee potential safety hazards and mobility enhancements was crucial. The sensitivity and experience to predict how drivers would perceive and react to the necessarily short messages on the VMSs and directions delivered by the LCSs was very important. Familiarity and experience with tried and true traffic management operations, roadway construction features and how they interact with driver safety, and fixed freeway sign methodologies was also a significant prerequisite. TransGuide designers included experienced and interested traffic management personnel in the design effort in the early stages, and all solution scenario development and reviews were conducted by these individuals.

4.3.4 Peer Review and Management Approval

To ensure the effectiveness and suitability of the TransGuide ITS solution scenarios, an independent review and approval process was set up within TxDOT. TransGuide designers concluded that potential legal liability arising from operation of the ATMS could best be handled by including a peer review and management approval process in the development of the traffic management responses. Data in the incident response configurations were coupled with identification, location, and housekeeping information and placed in a standard solution scenario electronic file format to form the recommended final solution scenario. The file was reviewed by an independent panel, which included experienced traffic management personnel that had not been previously involved in the development of solution scenarios. The review panel also included members of management at TxDOT with approval authority for implementation of the solution scenarios. As a result of the review and approval process, response configurations received final adjustments as required and final approval to become approved solution scenarios.

4.3.5 Solution Scenario Documentation

Solution scenario details were recorded in individual written files for each incident space for freeways included in the scope of TransGuide operations. These files included drawings of the associated freeway roads and structures and placement of the available control assets. The individual solution scenario files were the basis for review and approval of the system reactions to incidents as stored in the electronic database to be used during TransGuide operations. A complete example solution scenario file is included in the Appendix for reference purposes.