APPENDIX VA

IMPLEMENTATION PLAN

for the

TEXAS DEPARTMENT OF TRANSPORTATION

AUSTIN DISTRICT

FREEWAY TRAFFIC MANAGEMENT SYSTEM

Transportation Operations
Brian D. Burk, P.E.

Table of Contents

List of Figures

List of Tables

INTRODUCTIONIntroductionIntroduction

This implementation plan is intended to describe how traffic management systems will be implemented by the Texas Department of Transportation (TxDOT) Austin District. The information provided in this plan is intended to illustrate that traffic management systems are designed, built, operated, and maintained in the most efficient manner possible, considering performance, cost, and schedule.

This implementation plan is an evolving document. Revisions and updates are anticipated at regular intervals as deemed necessary by the TxDOT Austin District Transportation Operations. Priorities and initiatives for the TxDOT Austin District reflect local public concern. As public concern changes, so will this implementation plan.

LEGISLATION

We are all governed by laws passed by legislative bodies. At the Federal and State level congressional bodies debate and pass laws regulating a variety of activities relating to traffic management systems. Generally, these laws are codified, or systematically grouped, in specific areas. These codes define the law. Often the code does not prescribe how the law is executed. Agencies must develop administrative procedures for executing the requirements of the law. These procedures are often codified as administrative code. Codified laws and procedures generally do not get codified in more than one code. Therefore, it is sometimes necessary to review several codes when investigating a subject.

This plan can not possibly review and assess each and every legislative action which may affect a freeway traffic management system. The plan described in this document requires no additional legislation at this time to implement. However, any law at any level of government involving transportation or communications will have an effect on this plan. This section is intended to demonstrate a cognizance of legislation, policy, procedure, and where information can be found so it can be monitored for change.

Federal

Federal legislation influences the Austin District implementation plan. Many projects providing equipment and materials involve Federal assistance. Federal assistance is facilitated through the passage of Congressional bills. Currently, assistance in the area of transportation is provided by the Transportation Equity Act for the 21st Century (TEA-21) of 1998.

This Act authorizes funds to be made available to the States through particular categories of work on the transportation system. Generally, these categories provide assistance for preliminary engineering, design, and construction. Historically, categories dedicated for operation and maintenance have been limited. Generally, states must finance the maintenance and operation of the system once it is constructed. As more complex and technologically advanced traffic management systems are constructed, the need for maintenance and operational assistance can be expected to grow.

TEA-21 continues the enhanced role of the local metropolitan planning organization (MPO) on project planning and development enacted in previous legislation. The Austin Transportation Study (ATS) is the MPO providing guidance in the Austin area. ATS may develop criteria required to develop traffic management projects in addition to State and Federal codes. Generally, the Federal Highway Administration (FHWA) administers federal highway funds while the Federal Transit Administration (FTA) administers federal transit funds contained in the Act.

Procedures for utilizing federal assistance are documented in the Code of Federal Regulations (CFR). For example, this implementation plan has been prepared in accordance with Title 23, Part 655.409 of the Code of Federal Regulations (23 CFR 655.409).

State

Legislation at the State level also affects this implementation plan. The General Appropriations Act (HB1) contains directives regarding procedures for and limitations on state agency spending.

HB1 identifies strategies in the areas of design, construction, maintenance, and operations. These strategies are largely funded through a legislated state motor fuel tax. Revenues from this tax are dedicated to highway purposes. Revenue made available through federal assistance closely follows the motor fuel tax.

Regulatory laws may be found in Vernon's Texas Civil Statues (VTCS). These civil statutes define the law. Most statutes relating to traffic management systems have been codified in the Transportation Code.

Two laws, codified in the Transportation Code (TRC), directly relate to traffic management. TRC 472.012 authorizes TxDOT to remove personal property from the right of way or roadway if it determines that the property blocks the roadway or endangers the public safety. TRC 550.022 (b) states that the operator of a vehicle involved in an accident on certain portions of a freeway shall move the vehicle as soon as possible under certain conditions to minimize interference with freeway traffic. This law has often been referred to as the "Move It" law in Texas.

Procedures described in the General Appropriations Act, other legislative bills, and official agency policy are incorporated into the Texas Administrative Code (TAC). The TAC describes how an agency will fullfill the obligation of laws. Title 43, Part I of the TAC (43 TAC Part I) involves TxDOT. The TAC describes specific policies and procedures dealing with local ITS steering committees, multiple use of highway right of way, freeway corridor management systems, and removal and storage of spilled cargo and personal property. For instance 43 TAC 25.7 describes how TxDOT complies with TRC 472.012

TxDOT Policy and Procedure

The Transportation Code establishes a three member Texas Transportation Commission. The members are appointed by the Governor. An executive director is selected by this commission as the administrative head of TxDOT. Together, the Texas Transportation Commission and the Executive Director of TxDOT, have broad authority to establish policy and procedure in the design, construction, maintenance, and operation of highways in Texas.

TxDOT Executive Order 1-89 explains the various types of policy and procedure affecting TxDOT. This executive order explains the existence of rules, commission policy, administrative policy, operating procedures, and technical procedures.

Other Legislation

As traffic management systems become more complex, there may be a need to investigate legislation by other governmental bodies. At this time, other country, county, or city legislation is not known to significantly impact this plan.

SYSTEM DESIGN

The initial traffic management system design involves only freeway traffic management. In the future, additional systems could and should be a part of the overall system. The Austin area early deployment plan indicated favorable early benefits from incident management. Therefore, the initial system design is primarily concerned with freeway incident management. This design is influenced by many factors.

System Designer

TxDOT has been aggressively developing signal and freeway traffic management systems with in-house expertise since the early 1970's. TxDOT Division personnel have long been able to support local District staff with useful advice.

Austin District staff has been learning as other TxDOT Districts have been implementing freeway traffic management systems. This in-house expertise has been fostered and increased through technology sharing meetings with other TxDOT Districts as advanced freeway traffic management systems have begun operation in Texas.

As the freeway traffic management system evolves and is integrated with other components of an intelligent transportation system (ITS) infrastructure, consultants may be necessary to perform complex integrations. Successful design, construction, maintenance, and operations can be achieved in the near term with in-house Austin District and TxDOT Division personnel.

System Design Life

Many urban areas in the United States have systems that are still in operation 20 years after initially constructed. However, given today's technological advances, these systems are felt to be sorely out of date. For this reason, a maximum design life of 10 years appears reasonable without consideration of any upgrades. Ideally, equipment should be considered for staggered replacement every five years.

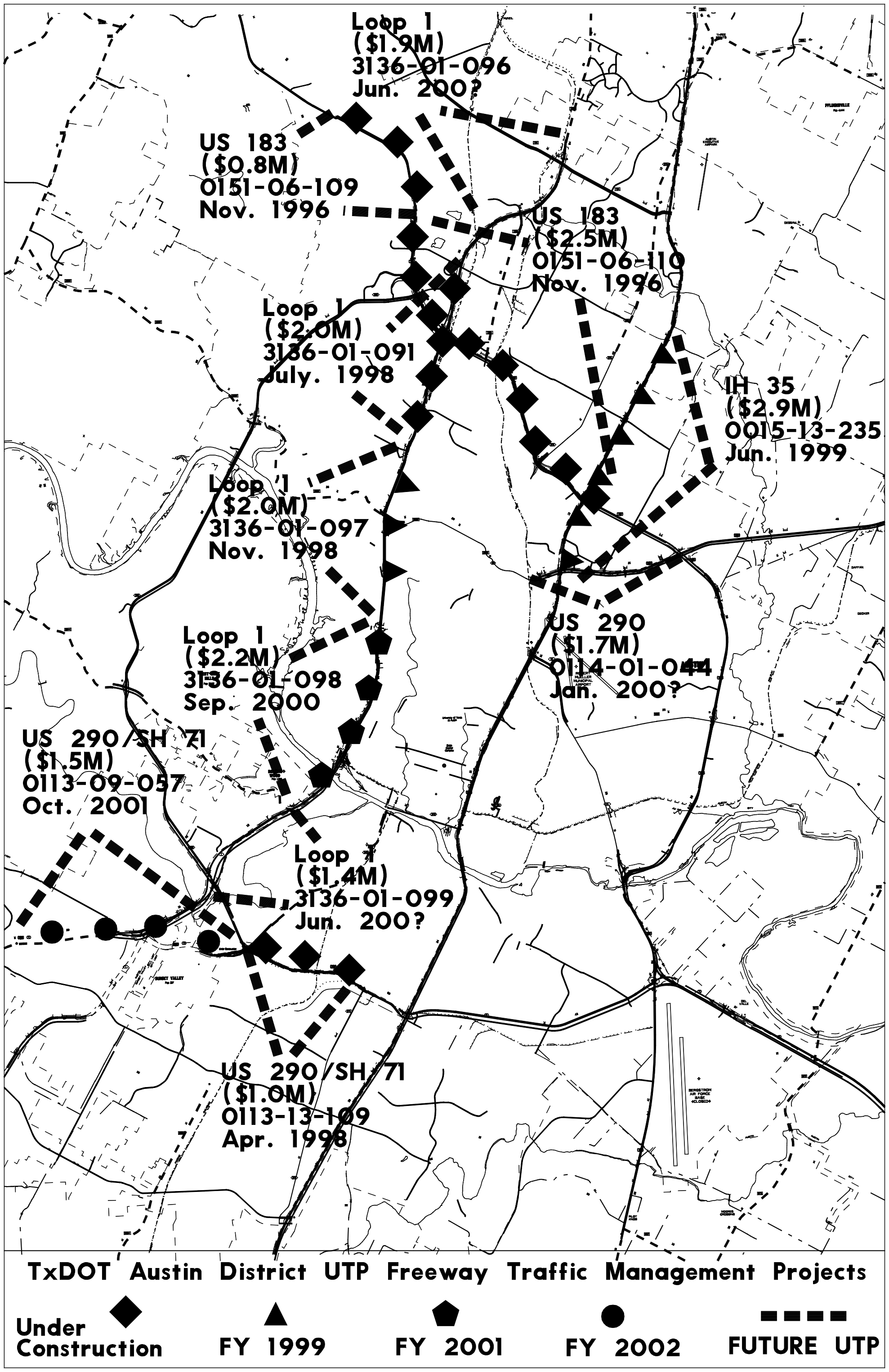

Figure VA-1_Austin Area FTM Projects

System Coverage

The Austin District has envisioned a freeway traffic management system to cover all expressways within the District boundary. Currently, existing expressways include IH 35, US 183, US 290, and LP 1 (Figure VA-1). These roadways are almost exclusively contained in the metropolitan planning organization (MPO), Austin Transportation Study (ATS), boundary. The ATS boundary encompasses the three counties of Williamson, Travis, and Hays. However, most of the expressway FTM corridors are contained only in Travis County (Table VA-1).

An important corridor, IH 35, bisects the ATS boundary. This corridor passes through San Antonio to the south, through Hays, Travis, and Williamson Counties to Dallas-Ft. Worth to the north. It is envisioned that freeway traffic management systems will be needed along this corridor as it passes through these heavily traveled counties.

System Design Operations/Maintenance Philosophies

Many advanced traffic management systems have struggled with operations and maintenance. Indeed, data indicates that while these advanced systems can cost millions to design and construct, maintenance and operations can cost much more over the life of the system.

Sy	Hwy	Project Limits	C	S	J	County	Letting FY Yr.	Mon	Mile Mkr. Beg.	+ Disp_B	End Mile End	+ Disp_E	Proj c.l. Lnth	mile c.l. C&D	XSt ea. SCS	mile c.l. FTM	Estimated Cost Construction	Estimated Cost Maintenance	E Add FTE	S SCU	T LCU	I CMS	M LCS	A CCTV	T Loop	E Ramp
IH	35	Subtotal for NHS Category 3D _ FTM Related				246								27.500	0	27.500	$20,625,000.00	$836,000.00	3.8500	3	110	28	110	69	1513	67
IH	35	Subtotal for NHS Category 3D _ FTM Related				227								27.954	0	27.954	$20,965,500.00	$849,801.60	3.9136	3	112	28	112	70	1537	54
IH	35	Subtotal for NHS Category 3D _ FTM Related				106								24.348	0	24.348	$18,261,000.00	$740,179.20	3.4087	2	97	24	97	61	1339	55
US	183	Subtotal for NHS Category 3D _ FTM Related				246								17.732	0	17.732	$13,299,000.00	$539,052.80	2.4825	2	71	18	71	44	975	8
US	183	Subtotal for NHS Category 3D _ FTM Related				227								26.829	0	26.829	$20,121,750.00	$815,601.60	3.7561	3	107	27	107	67	1476	110
US	290E	Subtotal for NHS Category 3D _ FTM Related				227								11.265	0	11.265	$8,448,750.00	$342,456.00	1.5771	1	45	11	45	28	620	32
US	290	Subtotal for NHS Category 3D _ FTM Related				227								15.073	0	13.653	$10,594,750.00	$415,051.20	1.9540	1	55	14	55	34	751	22
SH	71	Subtotal for NHS Category 3D _ FTM Related				227								15.080	0	16.500	$12,020,000.00	$501,600.00	2.2674	2	66	17	66	41	908	34
LP	1	Subtotal for NHS Category 3D _ FTM Related				246								1.300	0	1.300	$975,000.00	$39,520.00	0.1820	0	5	1	5	3	72	0
LP	1	Subtotal for NHS Category 3D _ FTM Related				227								25.542	0	25.542	$19,156,500.00	$776,476.80	3.5759	3	102	26	102	64	1405	194
SH	45	Subtotal for NHS Category 3D _ SCS Related				246								8.586	0	8.586	$6,439,500.00	$261,014.40	1.2020	1	34	9	34	21	472	0
SH	45	Subtotal for NHS Category 3D _ SCS Related				227								33.533	0	33.533	$25,149,750.00	$1,019,403.20	4.6946	3	134	34	134	84	1844	0
SH	130	Subtotal for NHS Category 3D _ SCS Related				246								16.000	0	16.000	$12,000,000.00	$486,400.00	2.2400	2	64	16	64	40	880	0
SH	130	Subtotal for NHS Category 3D _ SCS Related				227								18.500	0	19.000	$14,125,000.00	$577,600.00	2.6450	2	76	19	76	48	1045	0
		Subtotal for NHS Category 3D _ FTM Related				Var								192.623	0	192.623	$144,467,250.00	$5,855,739.20	26.9672	19	770	193	770	482	10594	576
		Subtotal for NHS Category 3D _ SCS Related				Var								76.619	0	77.119	$57,714,250.00	$2,344,417.60	10.7817	8	308	77	308	193	4242	0
		Subtotal for Central Control Center	914	0	100	227	2001	10					0.001	0.000	0	0.000	$8,000,000.00	$640,000.00	0.0000	0	0	0	0	0	0	0
		Total for NHS Category 3D Related												269.242	0	269.742	$210,181,500.00	$8,840,156.80	37.7489	27	1079	270	1079	674	14836	576

Table VA-1_Summary of Expressway FTM Corridor Projects

The driving force in the design of traffic management systems for the Austin District is to maximize needed traffic management efforts while minimizing the maintenance and operations cost. Some design decisions are made so as to reduce the personnel and equipment required for operations and maintenance. This philosophy may sometimes result in a higher one time cost for equipment and training, however, these are weighed against long term benefits.

The *Texas Highway Operations Manual* provides additional detailed information on system design and management considerations. This manual is maintained by the TxDOT Traffic Operations Division.

Incident management is historically a large portion of operations in a management center. Collecting data for planning purposes will also be a large focus of the system design.

Incidents are often typified by high lane occupancy (density), and low speeds. The impacts of these characteristics are multiplied as traffic volume increases. These are the parameters that the system will use to initially manage traffic. Volumes are also an important component in roadway planning. The ability to store this data provides the Department with a valuable planning tool.

The freeway traffic management system design initially concentrates on incident management. When an incident is reported to the operator, cameras would be used to verify and manage the response. Operators would coordinate the response with other agencies as needed, determine the necessary traffic control plan, and inform motorists if necessary. Initial components in the system include surveillance (detectors and cameras), communication (voice, data, and video), and control (signs, signals, gates, and radio). All of these components are controlled from a central site. Eventually, a combined communication and management center with other agencies is desirable in order to integrate the freeway traffic management system with regional public safety computer aided dispatch (CAD), traffic signal, and transit systems.

A conceptual incident scenario begins with the detection of an incident. An operator could be notified of a roadway incident from voice calls or from vehicle detectors which measure volume, occupancy, and speed. Typical detector data indicating an incident may be high detector occupancy coupled with low speed. Previous high volume data would lead an operator to assume a large problem was developing. Unfortunately, this data is very similar to congestion which does not represent an incident.

A historical database of detector data could be used to help determine if the detector data represents congestion or an actual roadway incident. This database would need to include lane and time of day information.

Incidents must be verified. Again, this could be accomplished by voice calls from observers at the scene. Closed circuit television (CCTV), however, provides another means of visually verifying a roadway incident remotely.

Once an incident has been detected and verified it should be managed. The freeway can be managed by informing motorists of the incident and possible action to be taken. Dynamic message signs (DMS), lane control signals (LCS), and highway advisory radio (HAR) are a proven effective means of informing motorists of roadway conditions. DMS can provide simple localized information and inform a motorist to tune to HAR for more detailed information. LCS can guide motorists to the appropriate lanes. HAR can provide more complex localized or area wide information.

It is important to note that this system is operational 24 hours a day. Human monitoring, however, will begin only on a part time basis during peak travel conditions as needed. As the system expands, so will the times of human monitoring.

Existing facilities at the TxDOT Austin District headquarters will be used to accommodate human monitoring. An interim control center has been established at the Austin District Traffic Signal Shop. It is envisioned that this facility can adequately support part-time human monitoring until the freeway traffic management system approaches 30 centerline miles. At this time, a larger facility specifically designed for advanced traffic management system management will be necessary.

Austin District staff are currently working with local county and city transportation, public safety, and emergency agencies on the possibility of operating from a centralized center. It is envisioned that a centralized facility could be constructed as the interim control center ends its useful life.

TxDOT Traffic Operations Division, Traffic Management, with the assistance of the Austin and El Paso Districts developed an *Operations Concept Document*. The document provides additional detail on how a standard Advanced Traffic Management System (ATMS) will be used in a Traffic Management Center (TMC) to support traffic and emergency operations.

System Architecture

Freeway traffic management systems designed by in-house TxDOT personnel function as an open standards, distributed processing systems. A distributed system offers the most flexibility for control of the system. The size of a central control facility can be reduced by implementing a distributed processing design. In a distributed processing system design, many devices needed to organize raw data can be located outside the central control facility. Simply moving raw data all the way to a central control site can be infrastructure intensive. In addition, if the central site fails, the system fails. A distributed processing system design can accommodate a central control center failure without allowing the entire system to fail. If any site acting as central control fails, another site can be easily and quickly configured as the central control.

TxDOT Traffic Operations Division, Traffic Management Section developed a document titled *Freeway Traffic Management System, Roadway to IVHS*. This document provides a technical discussion of the system architecture. Additional discussion of system architecture can be found in the document *Core Technology Architecture* maintained by the TxDOT Information Systems Division.

This distributed system architecture will take advantage of existing and emerging standards as they are developed. The system will also support the National ITS Architecture under the guidance of the FHWA.

System Integration

An open standards, distributed architecture will maximize the opportunity for integration with other systems inside and outside TxDOT. A freeway traffic management system should be designed to coordinate and communicate information to and from other systems for increased efficiency.

An enormous potential exists to integrate data within TxDOT, especially in the Austin District. Maintenance and construction activities affect freeway travel in the Austin District. Integrated freeway traffic management can support and provide additional information not currently available to the public, enabling these activities to take place more efficiently and safely.

Currently, Division, District, County, and City planning offices deploy technology to gather information on the transportation system. These technologies can be integrated into traffic management systems to provide seamless data collection for all offices. This could also lead to lower equipment maintenance costs.

A regional effort exists to rehabilitate and integrate several public safety and service systems in the Austin area. This effort is referred to as 9-1-1 RDMT (Figure VA-2). 9-1-1 RDMT includes regional initiatives in 9-1-1, trunked radio (R), computer aided dispatch (D), mobile data terminals (M), and intelligent transportation systems (T).

A centralized 9-1-1 RDMT operations facility shared with transportation, public safety, and emergency service agencies will be more successful if systems and data integration take place. All of these agencies are concerned with the condition of the transportation network. Centralized or not, integrated information is necessary to efficiently manage agency resources.

9-1-1 RDMT Participating Entities

- **City of Austin**
  - ***Police***
  - ***Fire***
  - ***EMS***
  - ***Office of Emergency Management***
  - ***Public Works - Traffic Signals***
- **Travis County**
  - ***Sheriff's Office***
  - ***Constable's Offices***
  - ***Emergency Services***
  - ***Office of Emergency Management***
  - ***17 Emergency Services Districts/ & Volunteer FDs***
- **TxDOT**
  - ***Freeway Traffic Management***
  - ***I.T.S.***
- **Capital METRO**
  - ***Operations***

Figure VA-2_9-1-1 RDMT Entities

Project	Funding	Source
9-1-1	$3.37m	CAPCO
Radio	$39.025M	Participating Entities COA Bond Authority
CAD/MDT	$8.3m	COA Participating Entities
Transportation Mgt.	$16.096m	TxDOT COA
GIS	$3.2m	CAPCO COA Travis County
Microwave	($3m)	PCS Vendors
Combined Center	$8.9m	Participating Entities

Figure VA-3_9-1-1 RDMT Funding

The TxDOT Austin District has funded a portion of some 9-1-1 RDMT initiatives (Figure VA-3). This includes a request for offer to integrate the City of Austin CAD system, as well as, other regional systems with the Advanced Traffic Management System (ATMS) being designed under the direction of the TxDOT Traffic Operations Division. ATMS will be used to manage the freeway traffic management system in the Austin District. TxDOT is also involved in funding a combined emergency communication and transportation management center with some of the 9-1-1 RDMT entities.

System Components and Functions

System components and functions can be divided into three groups. These groups are surveillance, communication, and control (SC&C). Hardware components for distributed processing of these functions can also be divided into three areas. These areas are field, communication, and management levels of the system.

Surveillance

Surveillance is the primary means of detecting incidents. Monitoring roadway conditions is only one way of detecting incidents. Monitoring 911 telephone calls and emergency services dispatching is also an effective means of detecting incidents.

Surveillance also includes monitoring and evaluating the system through reporting and analysis. Daily status, incident, alarm, and user ad hoc reports provide operators and managers with necessary information to effectively manage system components and functions.

Surveillance primarily involves detection. Vehicles are normally the subject of this detection. However, ice detection of the travel surface is also being considered for implementation in the Austin District.

Detectors

Generally, inductive loops are used in freeway traffic management systems due to their reliability and cost effectiveness. Other detector technologies such as video, sonic, infared, and radar detectors may be used in the future. Ideally, corridor wide data is needed to effectively provide integrated management along the freeway. Detectors are, therefore, placed on all lanes including freeway, frontage road, ramps, and connectors.

Freeway detectors are located at areas of anticipated congestion. One example of this is the merge area of an entrance ramp. Freeway detectors are also needed at areas of anticipated free flow, such as long tangent sections with a significant separation between ramps.

Some detector data about the conditions of the frontage road are needed. Vehicles may need to be diverted from the freeway to the frontage road to avoid an incident. Likewise, detector data may be needed to divert frontage road traffic to the freeway.

Speed is generally not a consideration on exit ramps. However, speed may be significant data on an entrance ramp or connection. Additionally, entrance ramps may be metered in the future. It would be ideal to integrate these initial loops into the future ramp metering system. Currently, fixed metering rates are believed to be the most effective. Speed may be a significant item for responsive gap based metering, if that technology improves in the future.

CCTV

Surveillance also involves verification and visual monitoring. Closed circuit television (CCTV) is used to accomplish this function.

Verification is needed along the freeway, as well as, frontage roads. Ideally, visual images along intersecting arterials should also be provided. Therefore, cameras are placed at intersections with arterial streets and visual gaps along the freeway are filled in with additional cameras. It is also desirable to overlap and stagger the placement of the cameras to provide comprehensive freeway and frontage road coverage.

Communication

Communications includes the transmission of voice, data, and video. Voice communications will be needed to minimize the number of maintenance and operations personnel. Data transmissions are how most of the surveillance information is relayed and controlled. Video transmission is needed for the CCTV system.

Voice

Voice communication is primarily provided to support maintenance personnel. Voice communications are provided at all roadway device enclosures. Many times it is necessary for maintenance personnel to speak with an operator at the control center to test various remote functions.

Data

Field hardware includes camera control units, dynamic message sign (DMS) controllers, AM transmitters, and local control units (LCUs). All but the LCU are proprietary units that currently do not share other functions. The LCU has been developed by the TxDOT Traffic Operations Division, Traffic Management Section and includes many functions. The LCU collects and distributes data for specific field devices. These devices include detectors, lane control signals (LCS), ramp meters, ramp gates, and dynamic signs. One LCU can accommodate 12 detector pairs, 24 single detectors, 6 lane control signals, 2 ramp meters, 2 ramp gates, and 4 dynamic signs.

Communications hardware includes dial-up and limited distance modems (LDMs), add/drop multiplexors (ADMs), and fiber optic transceivers. LDMs are used to distribute information to individual field devices. This information is multiplexed over fiber optic cable to the management level.

The management level hardware includes system control units (SCUs) and managerial workstations running software on a local area network. SCUs collect and process information from up to 64 LCUs over eight RS-232 channels. Workstations are used to control field equipment and manage information processed by the SCU.

Video

An important component of communications is the transmission of video images. Many agencies, as well as the public, are interested in images illustrating roadway conditions. Video images also provide critical information needed by emergency response agencies. These images help to ensure that the right resources are dispatched at the right time to the right place.

Control

Initial control functions include the use of closed circuit television (CCTV), dynamic message signs (DMSs), lane control signals (LCSs), traveler information station/highway advisory radio (TIS/HAR), ramp gates, and other roadside devices. All of these functions are necessary in the freeway traffic management system. DMSs are used to communicate short, simple pieces of information to motorists. LCSs are used to communicate the condition of travel lanes in the immediate vicinity. HAR is used to communicate longer, more complex information to the motorist.

Ramp meter signals, gates, and dynamic signs are used in conjunction to directly control the flow of vehicles entering the freeway. These devices will be utilized, as needed in the future, to enhance the initial control components.

These control functions are used to manage incidents. Many of these control functions could be automated through the use of simple software and hardware rules. In the future, an expert system could be developed to provide greater uniformity and assistance to the operator.

DMS

A dynamic message sign is a large sign in which messages can be changed dynamically. Normally large characters are used in accordance with the Texas Manual on Uniform Traffic Control Devices (TMUTCD).

Dynamic message signs (DMSs) are typically located to the side of the travel lanes in advance of driver decision points. These decision points may be major interchanges or detour points for incident management.

Generally, these signs can only convey short and simple information to the driver. Typically, these signs consist of 3 or 4 lines of text, 14 to 15 characters long.

LCS

A lane control signal (LCS) is a signal head mounted over a travel lane. Different messages are displayed on the LCS head to inform drivers of the condition of the lane ahead. The messages used by the LCS are defined in the Texas Manual on Uniform Traffic Control Devices (TMUTCD).

TIS/HAR

Traveler Information Station/Highway Advisory Radio is used to broadcast more detailed information to the driver. During an incident, TIS/HAR may be used to broadcast detour information. At other times, scheduled road closings and maintenance activities can be broadcast to the driver.

Communication Subsystem Design and Approach

The communication subsystem is a hybrid of a few well known standards. The interface for all data terminal equipment (DTE) and data communication equipment (DCE) is the Electronics Industries Association (EIA) Recommended Standard 232 (RS 232). All hardware whether at the field, communication, or management level conform to this standard.

Communication among field devices takes place over twisted wire pairs typically operating at speeds of 9,600 bits per second (9.6 kbps) or greater. Communications for these field devices are grouped or hubbed together at convenient locations, typically at highway overpasses.

Hub enclosures house the necessary communications equipment that are being hubbed. The hub enclosure is designed to accommodate LCUs and related hardware. An additional 19" equipment rack is sometimes provided for other necessary and future communications or control equipment. The enclosure may also accommodate environmental control equipment if necessary.

It is not cost effective to operate and maintain each field device on a twisted wire pair communication circuit to a control center. Therefore, communications at the hub are multiplexed. Multiplexing is way of applying technology to permit a communication circuit to carry more than one signal.

Deciding on what multiplexing technology to use is currently a question of economics and functionality. A digital signal level of 1 (DS1) or T1 (1.544 Mb/s) is a cost effective multiplex rate. T1 data rates and supporting equipment are reliable and widely available. Therefore, field data is typically multiplexed at a T1 rate to the control center.

Fiber optic transmission medium has been chosen because of reduced maintenance and operations cost. Optical fibers are not susceptible to electrical and environmental interference that plagues copper conductors. Fiber optics should be more cost effective to maintain because of its lower failure rate and longer life when compared to copper.

Another benefit of fiber optics involves video. An analog video signal requires a large bandwidth for transmission. Copper conductors can not efficiently transmit such a large bandwidth signal for significant distances required along roadway corridors. However, fiber optical cable can transmit a large bandwidth signal over long distances efficiently.

When video signals are transmitted in analog form over fiber optics, each camera normally utilizes a dedicated optical wavelength to transmit its signal over a single fiber. As the system grows, it is more efficient to multiplex several video signals on a single fiber. This can be accomplished by utilizing different optical wavelengths for each video signal on a single fiber.

Another economy of scale may be realized if the video signal is digitized as well. As previously discussed, data is already multiplexed in the field. This data is digital. If analog video signals are digitized they may be able to use the same equipment and technology as the data signals. A digital signal level of 3 (DS3) or T3 (44.736 Mb/s) currently represents an acceptable rate to transmit digital video signals. Multiplexing digital video signals at T1 and T3 over fiber optic cables is quite easily done over an optical carrier level 1 signal (OC-1) in a synchronous optical network (SONET). The electrical building block for SONET is equal to OC-1 and is called a synchronous transport signal level 1 (STS-1). The rate of an OC-1/STS-1 is 51.840 Mb/s.

There is another compelling reason to utilize the T1 and T3 rates described above. The State of Texas General Services Commission (GSC) provides telecommunication services for many State agencies. GSC owns fibers in a fiber optic network in the Austin area called the Greater Austin Area Telecommunications Network (GAATN). GSC operates their fibers on the network at SONET optical carrier levels 3, 12 and 48 signals (OC-3, OC-12, and OC-48). The City of Austin also owns fibers on the GAATN and utilizes SONET carrier levels. There is an opportunity to use this network for redundancy.

The management level of the freeway traffic management system operates on an Ethernet local area network (LAN). Workstations can easily be locally or remotely linked using existing reliable SONET technology (Figure VA-4).

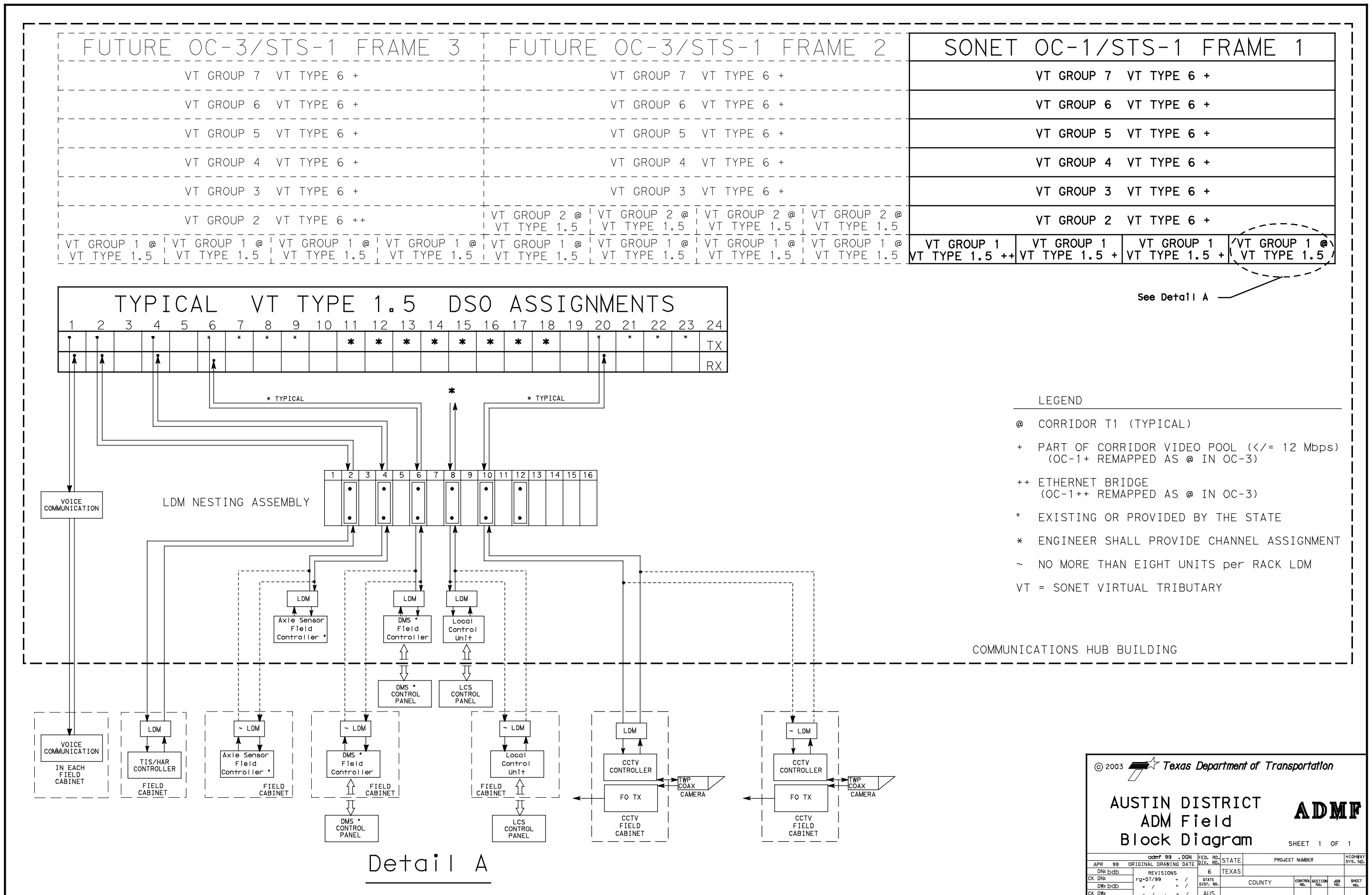

Figure VA-4_Austin District SONET

Traffic Operations Center Design Features

An existing building at the Austin District Headquarters is used as an interim control center. The location of this interim facility is strictly governed by convenience. A larger control center will be needed as the system expands.

An interim control center has been established at the Austin District Traffic Signal Shop. It is envisioned that this facility can adequately support part-time human monitoring until the freeway traffic management system approaches 30 centerline miles. At this time a larger facility specifically designed for freeway traffic management will be necessary.

The interim control center has amenities such as a restroom, sink, refrigerator, and microwave to support part-time staffing. Showers are located in a building nearby, but only accessible during regular business hours.

The interim control center is also located in close proximity to existing TxDOT maintenance and operation facilities. The freeway courtesy patrol is also headquartered in the District Signal Shop. Nearby is the area maintenance section responsible for the expressways in the initial system deployment. The District headquarters is also where public information is disseminated for the Austin District.

The interim center has raised floors and a video monitoring wall. Two workstations can be accommodated to manage traffic.

Austin District staff are currently working with local county and city transportation, public safety, and emergency service agencies on the possibility of operating from a centralized center. It is envisioned that a centralized facility could be constructed as the interim control center ends its useful life after about five years. Currently, TxDOT along with other 9-1-1RDMT partners have funded a consultant study to provide and conceptual design of a centralized center.

Project Phasing/Scheduling

Initial system coverage will concentrate on Austin expressways recently converted from conventional divided highways. These facilities offer cost effective opportunities to implement freeway traffic management. Much of the conduit and detection (C&D) infrastructure can be placed during roadway construction (Table VA-2 and Figure VA-5). Projects will be phased in order to construct a complete system loop around Austin (Figure VA-1). Projects associated with the 9-1-1 RDMT initiatives are phased in relation to schedules that can be accommodated by the participating agencies. The schedule for each initiative is somewhat independent of one another (Figure VA-6).

Sy	Hwy	Project Limits	C	S	J	County	Letting FY Yr.	Mon	Mile Mkr. Beg.	+ Disp_B	End Mile End	+ Disp_E	Proj c.l. Lnth	mile c.l. C&D	XSt ea. SCS	mile c.l. FTM	Estimated Cost Construction	Estimated Cost Maintenance	Add FTE E	S SCU	T LCU	I CMS	M LCS	A CCTV	T Loop	E Ramp
		Summary					1985							0.000	0	0.000	$0.00	$0.00	0.0000	0	0	0	0	0	0	0
		Summary					1986							0.000	0	0.000	$0.00	$0.00	0.0000	0	0	0	0	0	0	0
		Summary					1987							0.076	0	0.000	$19,000.00	$0.00	0.0023	0	0	0	0	0	0	0
		Summary					1988							0.000	0	0.000	$0.00	$0.00	0.0000	0	0	0	0	0	0	0
		Summary					1989							0.833	0	0.000	$208,250.00	$0.00	0.0250	0	0	0	0	0	0	0
		Summary					1990							7.777	0	0.000	$1,944,250.00	$0.00	0.2333	0	0	0	0	0	0	0
		Summary					1991							0.000	0	0.000	$0.00	$0.00	0.0000	0	0	0	0	0	0	0
		Summary					1992							4.469	0	0.000	$1,117,250.00	$0.00	0.1341	0	0	0	0	0	0	0
		Summary					1993							3.086	0	0.000	$771,500.00	$0.00	0.0926	0	0	0	0	0	0	0
		Summary					1994							0.398	0	0.000	$99,500.00	$0.00	0.0119	0	0	0	0	0	0	0
		Summary					1995							0.000	0	0.000	$0.00	$0.00	0.0000	0	0	0	0	0	0	0
		Summary					1996							1.639	0	8.207	$4,513,250.00	$249,492.80	0.9519	1	33	8	33	21	451	46
		Summary					1997							0.000	0	0.000	$0.00	$0.00	0.0000	0	0	0	0	0	0	0
		Summary					1998							3.197	0	5.744	$3,671,250.00	$174,617.60	0.7278	1	23	6	23	14	316	46
		Summary					1999							12.108	0	7.688	$6,871,000.00	$233,715.20	1.2089	1	31	8	31	19	423	34
		Summary					2000							3.434	0	3.434	$2,575,500.00	$104,393.60	0.4808	0	14	3	14	9	189	34
		Summary					2001							15.924	0	0.000	$11,981,000.00	$640,000.00	0.4777	0	0	0	0	0	0	0
		Summary					2002							26.295	0	3.855	$8,501,250.00	$117,192.00	1.2129	0	15	4	15	10	212	6
		Summary					2003							25.761	0	7.864	$10,372,250.00	$239,065.60	1.6379	1	31	8	31	20	433	74
		Summary					2004							21.851	0	20.400	$15,662,750.00	$620,160.00	2.8995	2	82	20	82	51	1122	30
		Summary					2005							6.373	0	39.082	$21,134,250.00	$1,188,092.80	4.4902	4	156	39	156	98	2150	80
		Summary					2006							25.478	0	15.636	$14,187,500.00	$475,334.40	2.4843	2	63	16	63	39	860	0
		Summary					2007							6.524	0	9.511	$6,386,500.00	$289,134.40	1.2419	1	38	10	38	24	523	46
		Summary					2008							18.871	0	37.995	$23,715,250.00	$1,155,048.00	4.7456	4	152	38	152	95	2090	29
		Summary					2009							17.091	0	22.241	$15,393,250.00	$676,126.40	2.9592	2	89	22	89	56	1223	41
		Summary					2010							10.595	0	21.642	$13,469,750.00	$657,916.80	2.6985	2	87	22	87	54	1190	35
		Summary					2011							31.262	0	7.462	$11,546,500.00	$226,844.80	1.7587	1	30	7	30	19	410	15
		Summary					2012							7.859	0	13.592	$8,760,750.00	$413,196.80	1.7309	1	54	14	54	34	748	21
		Summary					2013							6.025	0	6.025	$4,518,750.00	$183,160.00	0.8435	1	24	6	24	15	331	17
		Summary					2014							6.152	0	25.952	$14,514,000.00	$788,940.80	3.0393	3	104	26	104	65	1427	10
		Summary					2015							6.164	0	10.164	$6,623,000.00	$308,985.60	1.3030	1	41	10	41	25	559	8

|::

Note: All items are tentative and subject to change.

C&D cost data averaged from projects contracted through 11/96
Cost data from TxDOT Traffic Operations Division letter to Districts..., dated October 28, 1981

Term: C&D = Conduit and Detection System
SCS = Signal Coordination System
FTM = Freeway Traffic Management System
XSt = Number of Cross Streets
FTE = Full Time Equivalent

SCU = System Control Unit @ (SCS XSt x 0.5)+(FTM mile x 0.1
LCU = Local Control Unit @ (FTM mile x 4.0)
DMS = Dynamic Message Sign @ (FTM mile x 1.0)
LCS = Lane Control Signal @ (FTM mile x 4.0)
CCTV = Closed Circuit Television @ (FTM mile x 2.5)
Loop = Detection Device @ (SCS XSt x 36)+(FTM mile x 55)

Construction Costs

C&D Cost = $250,000/mile - includes ductbank, ground box, & loops
SCS Cost = $17,000/XSt - includes equipment, diagonistics
FTM Cost = $500,000/Mile - includes SCU, LCU, CMS, LCS, CCTV, ramp meter, & cabinets

Maintenance Costs

C&D Cost = $0/mile
SCS Cost = Construction Cost x 8.0%
FTM Cost = Construction Cost x 8.0%

Additional FTE

C&D FTE = 0.03/mile
SCS FTE = 0.02/XSt

Table VA-2_Schedule of FTM Projects

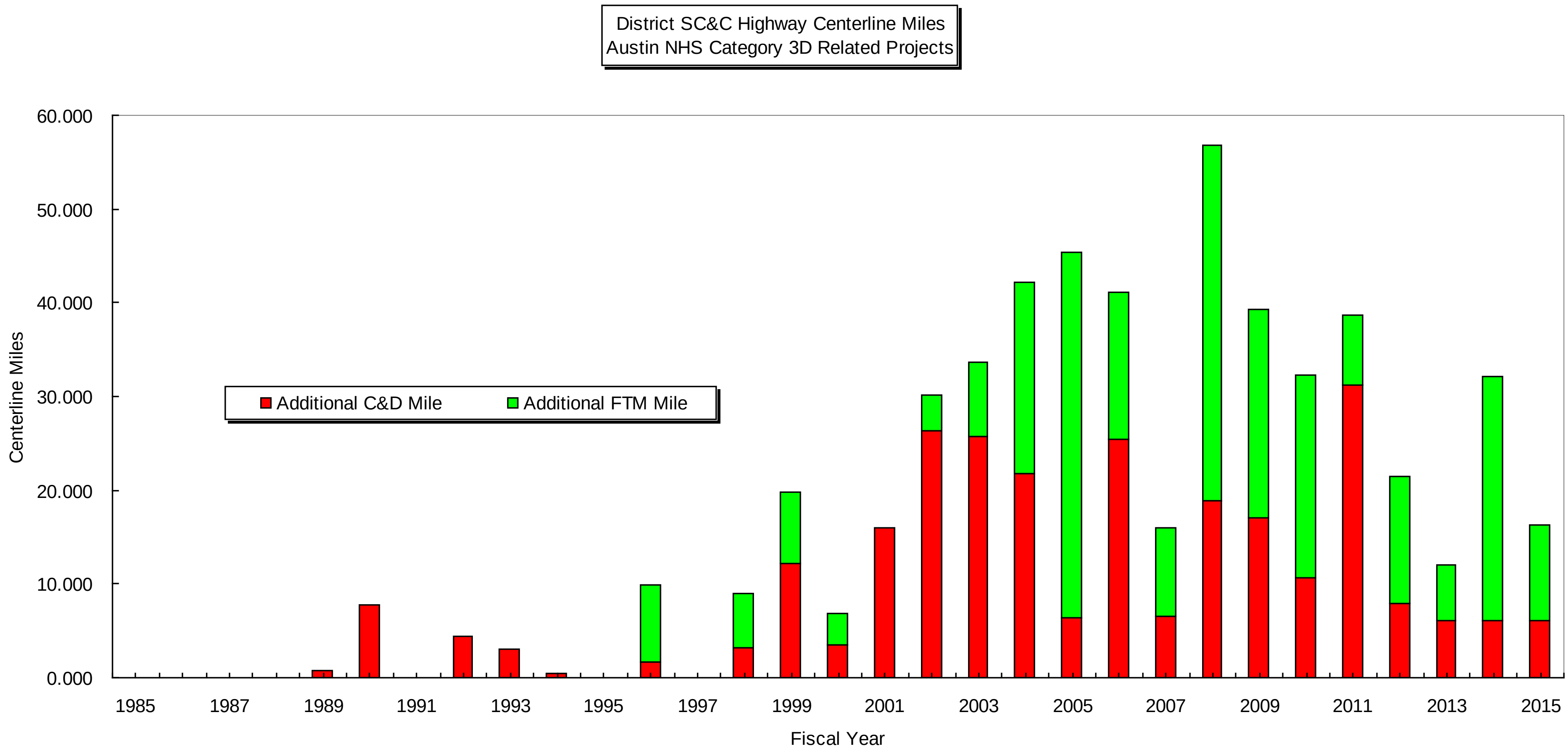

Figure VA-5_FTM Project Schedule Graph

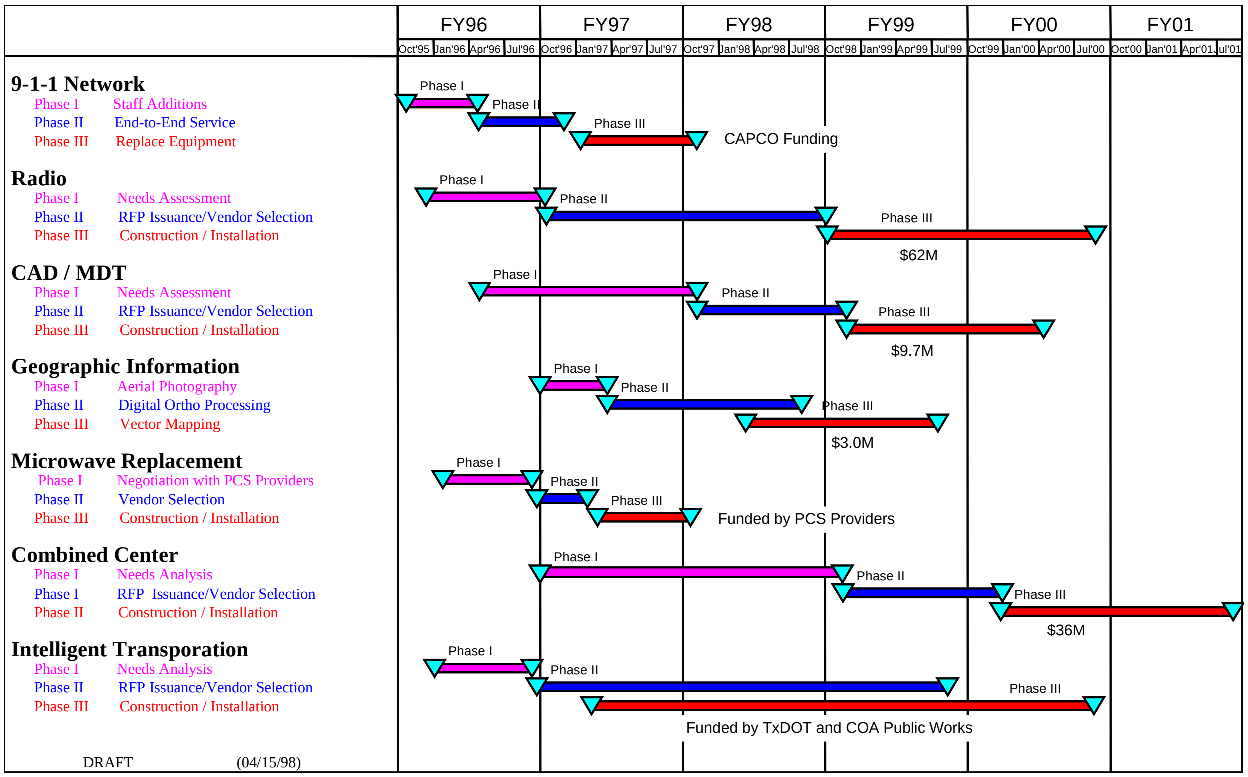

Figure VA-6_9-1-1 RDMT Timelines

Design Review

TxDOT has extensive experience with system components and communication subsystems described in this document for over twenty years. The system has proven its ability to manage traffic in other areas of the State such as Houston, Ft. Worth, and San Antonio.

It is envisioned that eventually projects would be reviewed by a multi-agency team. This team could represent the existing local traffic management team (TMT) or a working group of the Austin ITS Steering Committee developed with the *Austin Area-wide IVHS Plan*.

PROCUREMENT METHODS

TxDOT has traditionally utilized competitive procurement methods to construct highway improvements. The Engineer/Contractor method is usually used. Traffic management projects are typically procured as any other highway improvement. However, the maintenance of the system may utilize other competitive procurement methods. Uniform practices and procedures for procurement methods available to TxDOT are described in the *Manual of Procedures* maintained by the TxDOT General Services Division.

TxDOT procurement procedures will provide other alternate procurement methods when justified. This may need to be the case when experimental equipment or other entities are involved. For instance, the City of Austin is a significant stakeholder in the 9-1-1 RDMT combined center initiative. It is reasonable for the City of Austin to assume a lead role in the procurement of materials and services for this initiative.

Engineer/Contractor

This is the typical procurement method utilized by TxDOT for highway improvements, including traffic management systems. An engineer, either on staff or by consultant, prepares plans, specifications, and estimate (PS&E). The PS&E is reviewed and then advertised for bid. Usually a contract is awarded to the contractor submitting the lowest bid.

The schedule for review, advertising, and bidding follows established TxDOT procedure. The TxDOT *Design Division Operations and Procedures Manual* and the *PS&E Preparation Manual* contains additional detail on the PS&E process.

Funding is generally secured through one or a combination of TxDOT categories of funding. These categories are described in the Statewide Transportation Improvement Plan (STIP). The TxDOT categories include Federal, State, and local funding sources.

CONSTRUCTION MANAGEMENT PROCEDURES

The Austin District is divided into several areas, generally by county. There is an Area Engineer responsible for construction and maintenance activities in each area. Urban areas may have more than one Area Engineer depending on the location. Some design activities may also be completed by the Area Engineer's office.

The Area Engineer's office is familiar with managing large and complex construction projects. The Area Engineer's office can best coordinate construction with other projects in the immediate area of a traffic management project.

The design of a traffic management system project is usually managed out of the District headquarters. However, construction and some maintenance activities are managed from the Area Engineer's office. The headquarters design office may have limited involvement in the construction including submittal review and testing.

As in procurement, TxDOT has established construction management procedures for highway improvement projects. Either a formal or informal partnering process may be used in the management of construction activities. The partnering process identifies the division of responsibilities and conflict mitigation.

The *Area Engineers' and Inspectors' Contract Administration Handbook* along with *Standard Specifications for Construction of Highways, Streets and Bridges*, Standard Specification Items 1 through 9, further define construction management procedures including division of responsibilities, scheduling and mileposts, conflict mitigation, and coordination with other projects.

Although design and construction responsibilities reside in different TxDOT offices, the Austin District Transportation Operations has a history of close cooperation and active involvement with the construction office. It is also important to realize that projects with significant involvement with other agencies may mean that the other agency's construction procedures will be used. This may be case for the 9-1-1 RDMT combined center initiative. In these cases, TxDOT has traditionally utilized contract agreements which insure the involvement and consideration of TxDOT's interests. The TxDOT Austin District Transportation Operations office has enjoyed a close partnering relationship with other agencies in the past.

SYSTEM START-UP PLAN

TxDOT has developed a special specification for statewide use on projects governing testing, training, documentation, and warranty. Additional special specifications, as well as, the general notes for the project can be used to further define these requirements.

Testing, whether hardware or software, generally includes a design approval test, demonstration test, stand alone test, and system integration test. The specifications describe each of these tests including consequences of failure and partial acceptance, if any.

Transition

A majority of the software used in the Austin District Freeway Traffic Management System has been developed by TxDOT to integrate the management of devices. However, some devices are controlled by proprietary software until such time that they can be integrated into the TxDOT software system. In addition, vendor proprietary software is envisioned to remain an integral part of the overall system as a functioning back up. Should TxDOT's integrated software fail the vendor's software will be utilized to manage the system.

Media and Public Support

Each TxDOT District has a full time equivalent (FTE) assigned as a public information officer (PIO). The Austin District has already begun involving the PIO in planning access to traffic information by the media. In addition, daily coordination with the PIO is envisioned to update highway advisory radio reports.

OPERATIONS and MAINTENANCE PLAN

This document is mainly concerned with describing the technical aspects of the Austin District Freeway Traffic Management System. Vital to the success of this technical system are standard operations and maintenance procedures. These procedures identify how the system will be operated and maintained from day to day. The *Traffic Management Center Advanced Traffic Management System Standard Operations Concept* contains many of the concepts used to form the day to day operations procedures. An important role in supporting the operations of this system is the freeway courtesy patrol. The *Austin District Freeway Courtesy Patrol Standard Operating Procedures* describes the operations of this important freeway traffic management function. In addition to operations, procedures are also needed to determine how the operations will be evaluated and maintained.

Evaluation

Evaluation measures are important, but often, difficult to achieve. Some baseline data before the system is implemented is desired. However, this before data is often difficult to obtain. Surveillance technology needed to collect the before data is often installed along with the other components of the freeway traffic management system. Computer equipment, needed to efficiently process the data, and the communication system components, to transport the data, are often the last work completed on projects. However, once the initial system computer and communications equipment have been installed it may be possible to phase the work on the next project so as to collect some surveillance data prior to the rest of the freeway traffic management system becoming operational.

Projects in the Austin District include instructions to the Contractor explaining the intention to collect data for the purposes of evaluation. The Contractor is asked to phase work accordingly. The initial focus of the evaluation will be the accuracy of detectors. Detector data is the foundation of the system in the Austin District. Almost all other system functions depend on accurate detector data. Detector data is also the primary means of evaluating services supported by the system.

Evaluator

It is desirable to have a third party evaluate the system performance and user satisfaction. This may not be possible in all cases. TxDOT, whether Division or District, must also continuously evaluate the systems it is responsible for operating.

Method of Evaluation

The *Austin Area-wide IVHS Plan* discusses evaluation techniques for each of the ITS strategies identified in the plan. These techniques along with others developed by an evaluation team should be employed. It is desirable to have a comprehensive independent evaluation at least every 5 years.

Cost of Evaluation

The cost of the evaluation will depend on the complexity of the system and user services evaluated. The Austin and El Paso Districts have very similar systems developed by the Traffic Operations Division. It may be possible to pool resources and coordinate an evaluation satisfying all three stakeholders involved.

Maintenance Plan

TxDOT is ultimately responsible for maintaining the freeway traffic management system. Maintenance and operations have traditionally been a line item of HB 1 discussed earlier under State legislature. Maintenance may be outsourced when beneficial. The development of ATMS software under the direction of the TxDOT Traffic Operations Division has established ATMS software as the intellectual property of TxDOT. It is anticipated that ATMS software can be maintained under “work for hire” contracts in the future. TxDOT has a successful history of maintaining field hardware in the past. As in other areas, projects with significant involvement of other agencies may require a form of shared maintenance.

Maintenance Policies

The *Traffic Operations Manual*, *Signs and Markings Volume*, and *Traffic Signal Design and Application Volume* contain specific maintenance policies for equipment. These policies and procedures can be utilized for most devices.

Maintenance Management

TxDOT uses four different mainframe computer systems to track various information related to maintenance activity. The Maintenance Management Information System (MMIS) tracks specific maintenance work performed. The Salary and Labor Distribution system (SLD) tracks employee time. The Equipment Operations System (EOS) tracks equipment use. The Material Supply Management System (MSMS) tracks material use.

In addition, the Financial Information Management System (FIMS) tracks various financial information. The Minor Equipment System (MES) provides information about all aspects of minor equipment from requisition and purchase, through receipt, assignment to inventory, change in value, transfer, to retirement.

Spare Parts

Spare parts or units for most devices are currently obtained on construction projects at the rate of 10% of the contract amount. Additional spare equipment may be purchased following procurement guidelines. Spare equipment is entered into the MES.

Test Equipment

Test equipment is specified as needed on construction projects. Additional test equipment may be purchased by following procurement guidelines. This equipment also is entered into the MES.

Training

Training is generally specified along with the procurement of equipment and services. Training is provided as software and equipment are brought into the system. Training can also be obtained through the TxDOT Human Resources Division as needed to supplement training accomplished through procurement.

INSTITUTIONAL ARRANGEMENTS

The *Austin Area-wide IVHS Plan* identified and established an institutional framework for planning and selection of Intelligent Transportation Systems (ITS) in the Austin area. This same institutional framework can be utilized beyond the planning and selection process to encompass maintenance and operations.

An example of this arrangement can be seen in the development of a combined regional emergency and transportation communication center (9-1-1 RDMT). A working group of the ITS Steering Committee functions within another institutional framework specific to 9-1-1 RDMT.

The partners involved in 9-1-1 RDMT realize that institutional arrangements will need to be made to accommodate shared operations and maintenance. A 9-1-1 RDMT Finance Team Working Group has been established to formulate detailed goals and objectives for financing 9-1-1 RDMT operations and maintenance of initiatives. Separate working groups have been established for each 9-1-1 RDMT initiative to determine operation and maintenance needs.

Institution arrangements may also be necessary to expand the Freeway Courtesy Patrol in the future. This could be with vehicle vendors to supply patrol vehicles or other service and equipment vendors to sponsor courtesy patrol purchases.

PERSONNEL and BUDGET RESOURCES

Staffing Plan

The *Traffic Management Center Advanced Traffic Management System Operations Concept Document* identifies roles and responsibilities of staff needed to operate and maintain an advanced traffic management system (ATMS). The number of persons needed to fulfill the roles and responsibilities will vary depending on the size of the system, amount of maintenance contracted, and amount of resources that can be shared within a muti-agency center. A preliminary estimate of full time equivalent (FTE) persons needed is illustrated in Table VA-2 and Figure VA-9.

Shifts

Initially, the system may only be staffed by TxDOT during peak weekday periods. As the system expands, 24 hour staffing is desirable. TxDOT shifts may be eliminated depending on the ability to share resources with other agencies and the amount of automated tasks in the system.

Currently, the Freeway Courtesy Patrol operates exclusively along IH 35 during peak periods (6 a.m. - 9 a.m. and 4 p.m. - 6 p.m.) in two shifts. In between these times, two vehicles attempt additional patrols along US 183, US 290/ SH 71, LP 1, and LP 360. Additional patrols are needed to adequately operate on these facilities.

Contract Agreements

The use of contract operations staff is not currently anticipated. However, contract maintenance staff is under consideration. Contract staff may also be an option to expand the courtesy patrol.

Training

New staff utilizing TxDOT software and hardware may be trained on the job. Other avenues for training previously mentioned included training associated with equipment procurement and through the TxDOT Human Resources Division.

Budgetary Resources

TxDOT's budgetary resources are dependent on allocations from federal funds, a dedicated state motor fuel tax, and legislated general revenue. Federal funds are generally allocated on a formula basis approved by Congress. A bill authorizes these funds typically on a six year basis. This bill specifies funds in specific areas. Each area has specific requirements concerning eligibility and amount of matching participation. Each State submits a *Statewide Transportation Improvement Program* (STIP) indicating all projects including Federal assistance. This document is revised quarterly.

The Texas Legislature appropriates money for use by TxDOT arranged by strategies. The Texas Transportation Commission organizes all construction sources of funding into categories. The *Unified Transportation Program* (UTP) identifies the construction categories of funding approved by the Texas Transportation Commission. This document is updated each year.

Generally, budgetary resources may include design, construction, maintenance, and operations. Except for Interstate Highways, most federal assistance on projects is for 80% of the estimated construction cost. Federal assistance for maintenance and operations is currently limited and expenditures are currently 100% State funded.

Maintenance and operations budgetary allocations to district areas of the State are determined by TxDOT. Allocations are made on a fiscal year basis.

Annual Expenses

Annual maintenance and operations expenses are estimated at 8% of construction costs. As the system is installed and operated, these costs can be more accurately quantified

Graphs illustrating the data contained in Table VA-2 are shown in Figures VA-7, VA-8, and VA-9. The information illustrated is only an estimate of what is needed to accomplish a system build out by 2015. Significant additional funding and resources will be needed to achieve this goal.

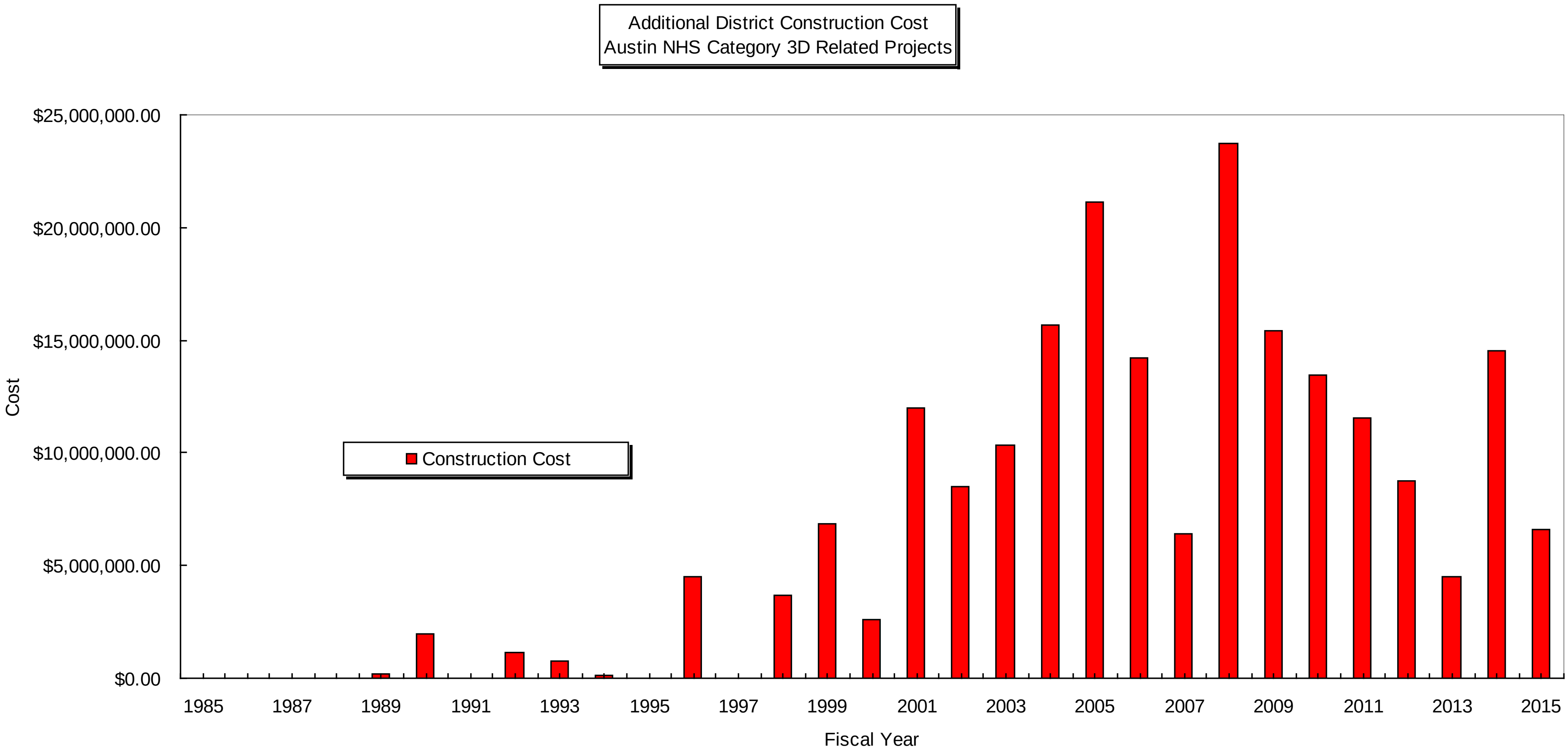

Figure VA-7_Estimated FTM Construction Cost

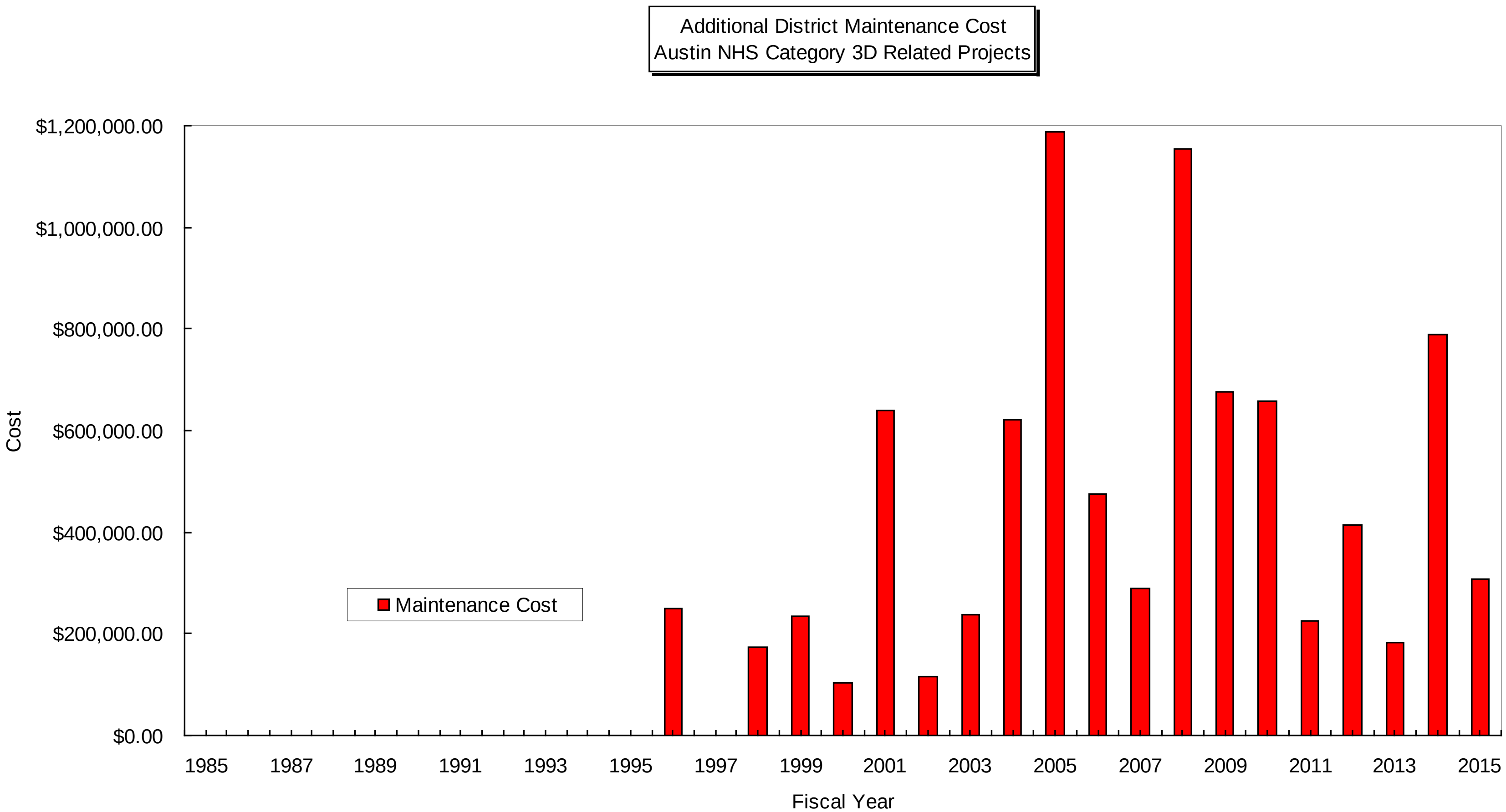

Figure VA-8_Estimated FTM Maintenance Cost

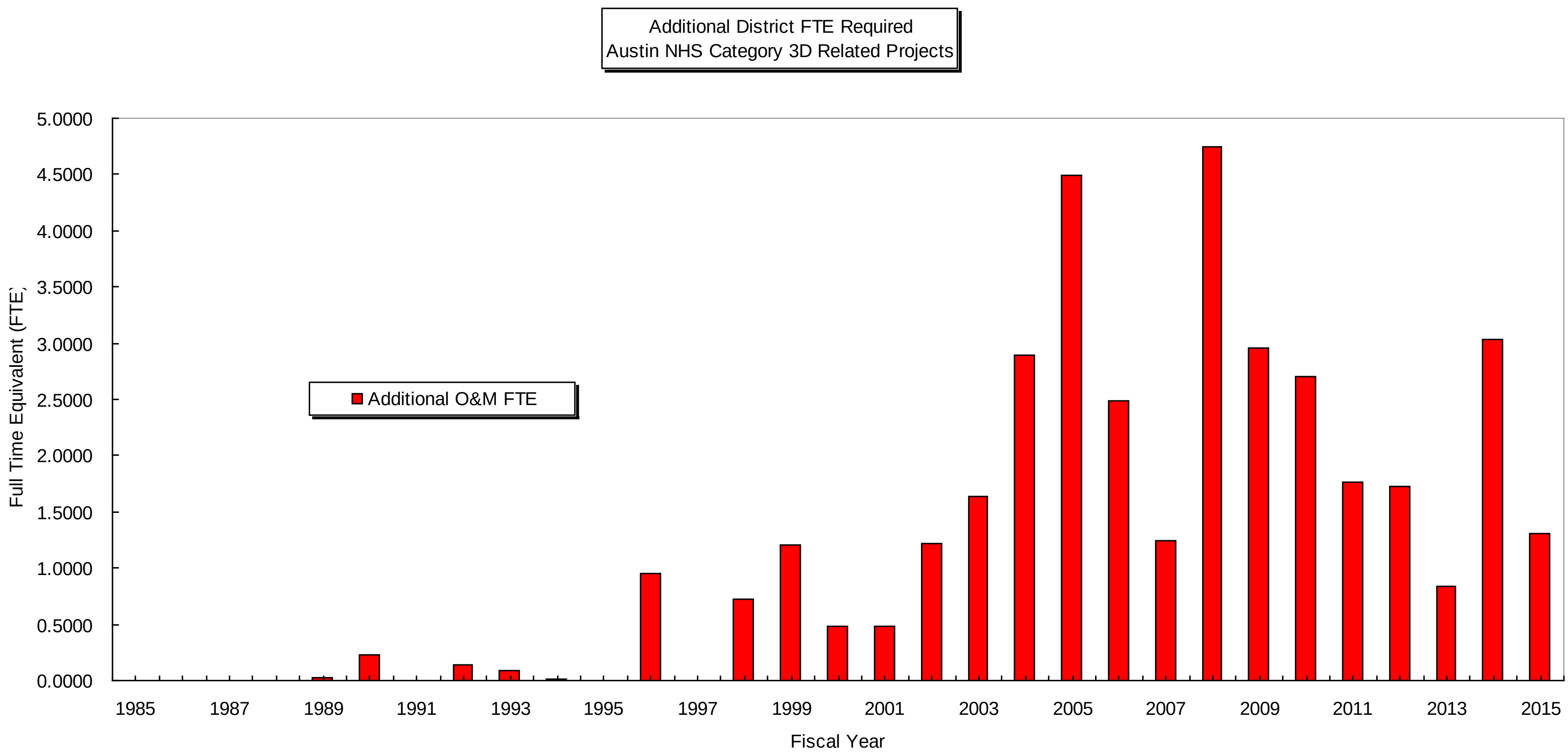

Figure VA-9_Estimated FTM FTEs

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IMPLEMENTATION PLAN

for the

TEXAS DEPARTMENT OF TRANSPORTATION

AUSTIN DISTRICT

FREEWAY TRAFFIC MANAGEMENT SYSTEM

Recommended for implementation:

William C. Garbade, P.E.
District Engineer
TxDOT Austin District

Carlos A. Lopez, P.E.
Director
TxDOT Traffic Operations Division

Charles W. Heald, P.E.
Executive Director
TxDOT

C.D. Reagan
Division Administrator
FHWA Texas Division

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APPENDIX VB

CITY OF AUSTIN

DEPARTMENT OF PUBLIC WORKS AND TRANSPORTATION INITIATIVE

ARTERIAL-STREET SURVEILLANCE AND INCIDENT MANAGEMENT SYSTEM

Table of Contents

List of Figures

INTRODUCTION

The ultimate objective of the City of Austin Arterial-Street Intelligent Transportation System (ITS) Plan is to define the role of arterial streets in the broader context of the Austin Area-Wide ITS Plan. These plans should compliment one another. The final product of the Arterial-Street ITS Plan are ITS deployment priorities. These priorities allow the City of Austin Transportation Division to focus resources (i.e., funding and personnel) on deploying the Arterial Street ITS Plan. At the same time, the Transportation Division will provide the necessary assistance to other transportation organizations planning, coordinating, and implementing ITS projects.

ORGANIZATION OF THE REPORT

The remaining Arterial-Street ITS Plan is organized into three sections. The first section identifies the guiding principles used to develop the Arterial-Street ITS Plan. Recommended ITS priorities for the City of Austin Transportation Division are identified in the second section. The final section provides an estimated deployment schedule.

GUIDING PRINCIPLES

The following principles were used to guide the development of the Arterial-Street ITS Plan. These principles were originally adapted from work performed by the Texas Transportation Institute for the Texas Department of Transportation (TxDOT)[1]. Although these principles were used to develop the Arterial-Street Plan, they should be reviewed periodically as Austin continues to plan and to deploy ITS elements.

- Clearly identifies, and preferably quantifies problems (problem driven)
- Illustrates how ITS recommendations will facilitate the movement of people, goods,

and/or services

! Strongly considers proven ITS strategies and technologies
! Involves maximum number of partners
! Minimizes costs
! Pursues compatibility with existing and future systems (open architecture)
! Supports expanded deployment (building block approach)
! Supports other transportation management/planning efforts
! Supports other community desires/priorities
! Maximizes operational efficiency and safety
! Fosters private sector participation

ARTERIAL-STREET ITS RECOMMENDATIONS

Enhanced Signal System

Definition

The signal system primarily consists of seven components: (1) central software, (2) central hardware, (3) communication medium, (4) local controller and hardware, (5) controller software, (6) detectors, and (7) database(s). These components require varying levels of enhancement in order to perform the functions/services described in the remaining recommendations. All of the remaining recommendations (video surveillance camera system, management center, traveler information, etc.) should be considered in the design of the enhanced signal system since they will influence the signal system design.

Benefits an Enhanced Signal System Begins to Provide

1. Reduced recurring and non-recurring congestion
2. Reduced emergency response times

3. Improved on-time transit performance
4. Benefits identified in subsequent recommendations

<u>Recommendations</u>

1. Organize a team whose members have a stake in the design of the signal system. This team would provide input to ensure their needs are met in designing the signal system. These organizations can also provide a source of funds for design and implementation. At a minimum, the City of Austin Transportation Division, Texas Department of Transportation, Capital Metropolitan Transportation Authority, public safety organizations, and Travis County should be represented on this team. Consideration should also be given to involving the University of Texas Center for Transportation Research (CTR) since they posses a wealth of knowledge about transportation operations. Although this team should assist with developing the request for proposals, it is essential that they be involved in defining the consultant's scope-of-work to ensure their needs are addressed.
2. Identify funding sources for design.
3. Develop a request for proposals (RFP) to hire a consultant to design an enhanced signal system. Request the Greater Austin Area Telecommunications Network (GAATN) staff to review the RFP. At a minimum, the enhanced signal system should provide the functions (1) described in the remaining recommendations and (2) identified by the Transportation Division staff during 1995. Those desired functions identified in 1995 were:
    a. Provide integration of signal control, preemption, cameras, dynamic lane control signs, changeable message signs, video from a mobile source, and school zone flashers which utilizes a distributive architecture to support a variety of communication mediums, performing multiple tasks simultaneously, and remote access,
    b. Provide traffic responsive capability,
    c. Provide real-time traffic volumes (turning movement and directional), speeds, travel times, and queue lengths,
    d. Continuously updates color coded maps to display problem areas,

e. Recommend streets which can accommodate diversion during congestion,

f. Enable emergency vehicle signal preemption and transit signal priority while maintaining signal coordination and identifying time, agency, and impact of preemption/priority,

g. Share real-time data between City, TxDOT, public safety, and Capital Metro, and

h. Perform diagnostics (e.g., loop and bulb failures).

4. Hire a consultant to design the enhanced signal system. The level of detail required in the design should be sufficient to initiate deployment once their design is complete. It may be desirable to retain the consultant should be retained to assist with implementing the design and remaining recommendations (e.g., selection of video image detection equipment). Retaining the consultant should be based on their ability to satisfy our expectations. An element of their final product should include an implementation schedule identifying (a) the order in which to implement the design and (b) when the functions described in the remaining recommendations come on-line. The design should be coordinated with the development of the regional management center discussed later in the text.
5. Identify funding sources for implementation.
6. Implement the design.

<u>Justification</u>

1. <u>System Design</u> To implement the remaining recommendations requires enhancing one or several signal system components. Designing these components independent of one another may lead to incompatibilities. Subsequent and unnecessary expenditures would then be required to overcome these incompatibilities. Therefore, it is recommended that all components of the signal system be considered in the design.

<u>Potential Partners with the Department of Public Works and Transportation</u>

Texas Department of Transportation

Capital Metropolitan Transportation Authority

Public Safety Organizations

Travis County

UT Center for Transportation Research

Issues/Questions

1. Are the desired functions identified by the City of Austin Transportation Division in 1995 still current?
2. How do we involve our customers (TxDOT, Capital Metro, public safety, etc.) in designing a signal system that can better meet all of our needs and the needs of the system?

Video Surveillance System

Definition

Video surveillance cameras are mounted above the roadway to visually evaluate traffic flow conditions. Cameras can be either fixed on a particular location or equipped with pan, tilt, and zoom capabilities. Black and white or color cameras are available. In the case of arterial streets, video cameras enable transportation managers: (1) to verify non-recurring congestion which ensures accurate traveler information is disseminated, (2) to monitor and evaluate problem locations and progression, (3) to make improvements, and (4) to evaluate how effective the improvements were. For example, in the City of Richardson, Texas, video cameras are used to monitor various problem intersections and freeway ramps, to conduct traffic studies, to observe special event traffic conditions, and in some cases, as a tool to showcase the city to prospective companies relocating to the area.

Benefits Video Surveillance Cameras Begin to Provide

1. Reduced recurring and non-recurring congestion
2. Freeway and arterial street integration
3. Improved staff productivity
4. Improved customer service

5. Improved public safety resource management
6. Improved traveler information

Recommendations

1. Include video surveillance cameras in the consultant's scope-of-work for designing the enhanced signal system. Video requirements should be discussed with the signal design team mentioned in the previous recommendation. The consultant should identify camera locations to maximize coverage (while minimizing the number of cameras required), type of cameras, central software to manage video images from City and TxDOT cameras (e.g., displaying multiple camera views) and to share video with other entities, and all equipment necessary for implementation. Considerations: (a) using the same video equipment specifications that TxDOT uses; (b) during implementation of the freeway traffic management system, TxDOT plans to place surveillance cameras at major arterials that intersect the freeway; (c) using GAATN for video transmission and sharing video among organizations, especially TxDOT and public safety; and (d) placing the cameras in locations where they could be used for video image detection (if desired in the future) to collect intersection (e.g., occupancy, volumes, turning movement counts, queue lengths) and link data (e.g., travel times, speeds).
2. Investigate amending the existing franchise agreement with Austin Cablevision once it expires to transmit video images over their coaxial cable. The advantages of using Austin Cablevision's existing coaxial cable include: (a) minimizing capital costs to install communication lines and (b) minimizing maintenance costs by negotiating the agreement (if possible) to have Austin Cablevision maintain the communication lines to transportation field equipment. The City of Richardson, Texas has included a provision in their agreement that allows them to transmit video over their local cable provider's coaxial cable. The City of Richardson is using the cable company's coaxial cable to transmit video images to their control center from field cameras.
3. Coordinate with public safety organizations. Ask 911 and public safety dispatchers which quality of video they require. At a minimum, ensure video meets the needs for

transportation management. Integrate video into emergency center design for public safety's use.

4. Include plans, specifications, and estimates for video surveillance system in the consultant's scope-of-work for the enhanced signal system design.
5. It may be desirable to retain the consultant for future work on an as needed basis.
6. Develop evaluation procedures for measuring effectiveness of video cameras.
7. Identify deployment funding sources (e.g., partners and federal and state solicitations).
8. Deploy video surveillance system pilot project.
9. Evaluate effectiveness of surveillance cameras and identify areas for improvement.
10. Decide whether to expand system. If the decision is favorable, initially focus at major signalized intersections. Continued expansion to minor signalized intersections and remote locations should be based on the needs of stakeholders and their ability to fund the expansion.
11. Periodically (e.g., annually) reevaluate effectiveness of video surveillance program to ensure the expectations of each organization are being met.

Justification

1. Traffic Flow Surveillance Surveillance is the required first step in improving the operation of a transportation system. Traffic flow improvements cannot effectively be made unless the current operating conditions are known. Video surveillance cameras enable traffic managers to monitor current traffic patterns (e.g., recurring congestion), thereby enabling them to make real-time improvements that keep traffic moving safely and efficiently. Video cameras supplement other surveillance methods, like inductive loops. Unlike loops, however, video cameras allow a traffic manager to begin to identify why a problem has occurred and to determine what actions to take. Video cameras should not be used for incident detection due to the strain and boredom placed on a person watching a video screen for extended periods.
2. System-Wide Transportation Management These video images should also be shared with the Texas Department of Transportation (TxDOT). As a systems approach to daily

transportation management evolves in Austin, decisions about freeway and arterial-street operations will begin to be made based on real-time information about both facilities, not only one. For global decisions to be made, information about freeways and arterial streets will need to be shared between those, TxDOT and the City of Austin, responsible for the operation of each facility. Arterial street video cameras can provide real-time traffic information to facilitate these global decisions. For example, arterial-street video cameras can provide information about current operating conditions to TxDOT and City of Austin staff making decisions about whether or not to divert traffic to a particular street when a freeway incident occurs.

3. Productivity Enhancements The City of Richardson has experienced staff productivity enhancements by using video cameras.[2] Their cameras provide immediate observation and response to unusual traffic conditions, which in the past involved long delays and the necessity to dispatch personnel to investigate the problem. After staff arrived at the problem scene and evaluated the situation, he or she would then contact the City of Richardson's Control Center for signal adjustments to remedy the problem. This process required several minutes of costly and unnecessary delay time which could be eliminated through the use of remotely located cameras. As the City of Austin and traffic volumes continue to grow, the frequency of dispatching staff to problem locations and the distance they have to travel will also grow. Video cameras can reduce the time spent traveling to problem locations. In addition, the cameras can be used for proactive problem identification before they are reported, thereby reducing the frequency of reported problems.
4. Improved Customer Service Video cameras can provide an immediate response to citizen complaints. For instance, when a citizen calls in a complaint about not enough green time, the transportation manager can immediately view the location and adjust the signal timing, if needed. This immediate response not only provides a quicker response to the citizen but also benefits the hundreds of travelers affected by the lack of green time.
5. Improved Public Safety Resource Management Video cameras can improve public safety resource management. Video images should be shared with public safety organizations--

emergency medical service (EMS), fire protection, and law enforcement. These images will allow public safety organizations to make more informed and quicker decisions about the resources (e.g., number of ambulances, hazardous materials unit, tow truck) needed at the scene of a roadway incident without waiting until a public safety unit arrives or relying solely on the information provided in a 911 call. Video cameras not only expedite the response to the injured, but also the restoration of roadway capacity (i.e., reducing the impacts of non-recurring congestion). Public safety dispatchers could convey information from the video images to emergency response personnel about what to expect at the scene. Eventually, the video image could be sent directly to the emergency unit's mobile data terminal. Sharing the video with public safety organizations ultimately benefits the people involved in and delayed by the roadway incident. Public safety agencies could also use the video cameras to assess their emergency response route (Is the route congested? Should another route be used?).

6. <u>Improved Traveler Information</u> The video images should also be provided to commercial traffic reporters, Capital Metro, commercial fleet operators, and the general public. Disseminating these video images via television, Internet, and/or kiosks enables informed trip decisions to be made about routes and departure times. Vehicle fleets, like Capital Metro and commercial delivery businesses, can use this information to avoid congested locations and thus improve the management of their fleets. For instance, travelers may choose to avoid certain arterial-street sections if they knew when and where it was congested and the magnitude of congestion. Subsequently, recurring and non-recurring congestion could be reduced.

<u>Potential Partners with the Department of Public Works and Transportation</u>

TxDOT

Public Safety--EMS, fire protection, and law enforcement

Capital Metro

Private Sector (e.g., commercial traffic reporters--TV and radio)

Issues/Questions

1. What video quality (e.g., full motion video, color) is required to satisfy stakeholder needs? What are the costs associated with varying degrees of video quality?
2. Which communication medium (e.g., fiber, coaxial cable, and/or twisted-wire pair) should be used to communicate with field equipment?
3. Are maintenance costs reduced by using one or two communication systems (e.g., fiber only or fiber and twisted wire pair)?
4. Can we use the same video equipment specified by TxDOT? Using the same equipment may facilitate sharing video images and maintenance equipment.
5. Level of involvement GAATN can provide to assist the consultant
6. Expandability--accommodate 100's of cameras
7. How to share video images with TxDOT, public safety, Capital Metro, commercial traffic reporters, other media entities, and the public

Management Center

Definition

A multi-agency management center is the core of an integrated traffic control system. A management center collects, analyzes, and disseminates real-time traveler information. In addition, coordinated decisions between separate transportation and public safety organizations are facilitated with daily contact required between those agencies housed in the same facility, a management center.

Benefits a Management Center Begins to Provide

1. Improved coordination between transportation and public safety organizations
2. Improved integration between freeways and arterials
3. Safer and more efficient transportation system for Austin

Recommendations

1. Coordinate the creation of a management center with TxDOT and public safety organizations. These efforts are already underway.
2. Proceed with the current implementation schedule--design center in FY 97 and build center in FY 98.

Justification

1. Integration As mentioned previously, as a systems approach to daily transportation management evolves in Austin, decisions about freeway and arterial-street operations will begin to be made based on real-time information about both facilities, not only one. Although the people do not need to be face-to-face to make these decision with high-speed communications systems available, like GAATN, cooperative decisions can be expedited. A heightened sense of a "TEAM" is formed when all agencies are in one location. Efforts are focused upon arriving at a unified response, not just what is best for each agency. Obstacles produced by the "them vs. us" syndrome are decreased as members become better acquainted with each agency's capabilities, resources, procedures, and personnel.
2. Cost Savings The equipment required to share data will likely be cheaper if the equipment (e.g., communication equipment) is only needed at one location instead of placing the same equipment at several locations. Task II report prepared by Wilbur Smith Associates estimated the communication equipment costs for a centralized center at approximately $1,527,200 and for a distributed centers at $432,500 per center. As the number of distributed centers increases so does the cost. Furthermore, a distributed approach requires additional backup equipment to support multiple sites instead of one.

Potential Partners with the Department of Public Works and Transportation

TxDOT
Capital Metropolitan Transportation Authority
Public Safety Organizations

Issues/Questions

1. Which functions should the Transportation Division perform in a center (e.g., signal operation, roadway maintenance, etc.)?

Traveler Information

Definition

A real-time traveler information system provides information for selecting the best departure times, routes, and transportation modes. Traveler information would be available for multiple travel modes: freeways, arterial streets, transit, bicycle routes, etc.

Benefits Traveler Information Begins to Provide

1. Reduced recurring and non-recurring congestion

Recommendations

1. Organize a team to oversee the implementation of the following traveler information elements. This team would guide the deployment of the traveler information system, coordinate with other projects, establish goals and objectives for each traveler information element, and develop evaluation procedures to measure the effectiveness of the system.
2. If needed, hire a consultant to design a regional traveler information system. Consider including this task as a phase in the design of the enhanced signal system design. The consultant would identify elements of the traveler information system and an implementation schedule.
3. Investigate contracting with a private sector entity, like SmartRoute Systems, Inc., to collect, manage, and disseminate real-time, multi-modal, transportation information. SmartRoute currently provides this service in the Boston and Cincinnati metropolitan areas. SmartRoute primarily provides this information to the public over the telephone. Even if a private sector provider of traveler information is not appropriate, consideration should still

be given to providing multi-modal transportation information over the telephone since a telephone is accessible to nearly everyone.

4. Investigate amending the franchise agreement with Austin Cablevision once it expires to provide an additional cable station for 24-hour traffic information.
5. Develop a method to collect real-time traffic flow data on arterial streets that can be provided in a format travelers can use to make informed trip decisions. A consultant may be able to assist with identifying the most appropriate method.
6. Investigate funding through the Federal Highway Administration (FHWA)--ITS Operational Test and Innovations Deserving Exploratory Analysis (IDEA) programs. The approach described below to collect and display arterial-street real-time data may qualify as an approach that has not been tried elsewhere. Therefore, the FHWA may provide a substantial portion of funding for the project.
7. Develop an Internet Home Page to display real-time traffic flow data. This same information could be disseminated through kiosks at major trip generators (e.g., office buildings, malls, airport) or a television station. The format of this information could be similar to the real-time traffic report maps available for Houston, Seattle, Los Angeles, Chicago, San Diego, and soon, San Antonio that illustrate freeway traffic conditions. Camera icons could also be located on the map for people to click on to see the latest image of traffic conditions at that location. The home page could also contain information about arterial-street construction zones, transit routes and maps, bike routes and maps, speed hump program, freeway traffic flow map, upcoming Urban Transportation Commission meeting times and agendas, and neighborhood meetings.

At this time, no locations are known that illustrate real-time conditions on arterial streets. The Home Page recommended here should initially provide access to real-time traffic conditions on a major arterial street. The real question with arterial streets is what information to collect that accurately reflects real-time traffic flow conditions. Houston uses transponders mounted on vehicles to measure travel times between successive points on the freeway. Knowing the distance between these points, travel time are converted to speeds to display. Most other freeway real-time traffic report maps use point speed measurements to represent the operating characteristics for freeway segments. These speeds are then used to determine the color of the freeway segments on the map. Typically, green is used for ideal conditions, while red is used for the most congested condition. Point speed measurements on arterial streets may not accurately reflect true traffic flow conditions. For instance, inductive loop speed measurements at a mid-block location away from a signal will likely be much higher than at the signal. A recommendation for overcoming this obstacle may be to compute volume-to-capacity (v/c) ratios for signalized intersection approaches. Each intersection approach could be displayed in different colors based on the v/c ratio. Another alternative is to display the entire intersection in a single color based on the level-of-service. Approach volumes should be measured at a point far enough upstream to avoid (a) queues stopped at the signal and (b) loosing vehicles to mid-block traffic generators. Volumes are easy to measure with existing technologies (e.g., video image detection or loops). Capacities could either be determined by measuring discharge volumes or estimating them based on green time, cycle length, and saturation flow rates.

Deploy real-time arterial-street data collection method on a selected arterial street. Surveillance cameras should be deployed on the arterial street to confirm the data being disseminated truly reflects real-time operating characteristics.

7. Investigate using Channel 6 as a transportation station during the peak drive times. Images from surveillance cameras and/or the arterial-street traffic map as described for the home page could be displayed. Capital Metro plans to use a television station to disseminate information to the public. A partnership with Capital Metro to provide multi-modal transportation information in one location should be explored.
8. Develop a traveler information kiosk pilot project. Partnerships should be formed between those agencies disseminating traveler information to lead the kiosk pilot project. The pilot project should focus around major activity centers. More travelers will be exposed to the

kiosks at major activity centers. Therefore, the kiosks may influence the trip decisions of a greater number of people.

9. Deploy traveler information system.
10. Develop evaluation procedures and deploy traveler information system. If possible, evaluate each element of the traveler information system independently to identify the most successful means of providing traveler information. Similarly, the entire traveler information should be evaluated to ensure goals and objectives are achieved.

<u>Justification</u>

1. <u>Improved Utilization of Existing Roadway Capacity</u> Traveler information has had an influence on trip decisions. For example, this influence was documented in Boston with *SmarTraveler,* an area-wide Traveler Advisory Telephone Service covering the metropolitan area. The following statistics[3] highlight the influence *SmarTraveler* had on the trip decisions of 2,000 users:
   a. 48% of the respondents reported the information they received during the particular call about which they were being questioned, had a direct influence on their travel decision-making.
      ! 28% reported making some kind of change in their travel behavior.
      ! 14% reported changing their departure time.
      ! 12% reported using a different route.
      ! 2% reported canceling the trip.
      ! 1% reported changing route and time.
      ! 20% indicated they used the information to choose between two or more relatively equal alternative routes
   b. Most of the remaining callers in some way used the information they received to verify that their preferred route would be viable.
   c. 8% reported that they contacted others to indicate that they would be delayed, based on the information they received.

By changing departure times and travel routes, travel demand is spread over time and the roadway network. Therefore, providing traveler information to the public in a useable, friendly format can lead to a more efficient use of the existing roadway capacity.

2. Initial Results of Houston's Freeway Real-Time Traffic Report Preliminary findings of Houston's real-time traffic map indicate that a peak in usage occurs prior to the traffic peaks. The assumption is that people are using the home page to make decisions before departing on their trip.

Potential Partners with the Department of Public Works and Transportation

Texas Department of Transportation

Capital Metropolitan Transportation Authority

University of Texas Center for Transportation Research

Federal Highway Administration

Video Image Detection Vendor

Issues/Questions

1. How can arterial-street operational characteristics be collected and displayed to travelers that reflect true real-time traffic flow conditions?
2. Are resources (i.e., manpower) available to keep static information on the home page current? When does static information become outdated?

Dynamic Lane Control Signs

Definition

Dynamic lane control signs change the designated movements permitted from a lane during either a signal cycle or peak period depending on the need. Mechanical and fiber optic signs are available.

Benefits Dynamic Lane Control Signs Begin to Provide

1. Reduces recurring congestion
2. Increased capacity to accommodate incident diverted traffic

Recommendations

1. Identify locations to apply dynamic lane control signs. Begin by having Transportation Division staff suggest locations since they are most familiar with traffic operations throughout Austin. Review turning movement counts (TMCs) and geometrics at the suggested locations and signalized intersections along the priority roadways established by the Austin ITS Steering Committee. Use the TMCs and geometrics to model traffic operations at candidate locations and to assess the benefits.
2. Develop evaluation procedures.
3. Deploy signs.
4. Evaluate effectiveness of signs.

Justification

1. Increased Capacity Based on the 1985 Highway Capacity Manual[4], increasing the number of left turn lanes with protected phasing from one to two lanes increases capacity by more than 93 percent for the left-turn movement. In addition, increasing the number of right-turn lanes with protected phasing from one to two lanes increases capacity by more than 76 percent. Providing additional turning movement capacity would also increase the capacity for other movements by reallocating green time that the turning movements no longer need.
2. Low Cost Improvement Where appropriate, dynamic lane control signs can provide a significant increase in intersection capacity at a low cost. Mechanical signs cost approximately $1000/sign while fiber optic signs cost approximately $2500/sign.

Issues/Questions

1. How are traffic regulations written for lane control signs that change during the day?

Advanced Traffic Controllers

Definition

Traditional traffic controllers perform the basic signal timing and logic functions at signalized intersections. Advanced transportation controllers, however, provide additional computing power that expands the functions (e.g., video surveillance, adaptive signal control) available at signalized intersections.

Benefits Advanced Traffic Controllers Begin to Provide

1. Increased flexibility to perform additional ITS functions
2. Self diagnostic capabilities
3. Reduced maintenance costs (One 2070 with all internal control units should provide a lower maintenance cost than a 170/AIB and all of its external hardware.)

Recommendations

1. Include the ability to use advanced traffic controllers in the enhanced signal system design.
2. Invite advanced traffic controller vendors to give presentations.
3. Prepare RFP to purchase advanced traffic controller(s) for a pilot project.
4. Select the controller(s) to test in a pilot project. Purchasing a limited number of controllers for a pilot project will likely increase the cost per controller when compared to purchasing several controllers at once. Therefore, if the Transportation Division staff is comfortable with the controller that they have selected, then a pilot project may not be necessary.
5. Develop evaluation procedures.
6. Deploy pilot project.
7. Evaluate pilot project. Identify issues associated with further use and deployment of advanced traffic controllers.
8. Decide whether to expand advanced traffic controllers to other signalized intersections.

Justification

1. Improved Customer Service The Transportation Division should deploy at least one advanced transportation controller. Advanced traffic controllers may be standard in urban areas across the country to perform ITS functions. Hands-on experience provides the opportunity to learn how the additional controller functions can be used to improve transportation services provided to our customers. Although their price may be high when compared to traditional equipment that performs only a limited number of their functions, these items will become more affordable as more are deployed.

Issues/Questions

1. Installing a single advanced traffic controller may not be possible. The existing traffic controllers may need to be replaced along an entire signalized corridor.

Video Image Detection

Definition

Video image detection systems detect vehicles by monitoring specific points in the video image of a traffic scene to determine changes between successive frames. Two different algorithms exist to process the video signal. The first algorithm monitors vehicles entering a predetermined area of the video image. This algorithm can provide volume and occupancy data. The second algorithm actually "tracks" the vehicle as it passes through the video image. Data provide by this algorithm include: volumes, occupancy, speeds, classification counts, and possibly travel times.

Benefits Video Image Detection Systems Begins to Provide

1. Reduced manpower requirements for collecting turning movement counts
2. Flexibility in construction areas for vehicle detection
3. No need to close travel lanes for installation and maintenance of inductive loops

Recommendations

1. Include the ability to perform video image detection in the enhanced signal system design.
2. Invite video image detection vendors to give presentations.
3. Prepare RFP to purchase video image detection system(s) for a pilot project.
4. Select the system(s) to test in a pilot project.
5. Develop evaluation procedures.
6. Deploy pilot project.
7. Evaluate pilot project. Identify issues associated with further use and deployment of video image detection systems. The evaluation should also include a comparison between loops and video image detection systems--performance, functionality, and cost--capital, maintenance, and operations (the cost to perform turning movement counts with loops and video image detection should also be compared). Currently, the FHWA is performing a detector comparison study which may provide these comparisons.
8. Decide whether to expand video image detection to other signalized intersections.

Justification

1. Improved Customer Service The Transportation Division should deploy at least one video image detection system. As with advanced traffic controllers, hands-on experience provides the opportunity to learn how video image detection can be used to improve transportation services to our customers. Although their price may be high when compared to traditional equipment that performs only a limited number of their functions, these items will become more affordable as more are deployed.

Issues/Questions

1. Effects on visibility during inclement weather and poor lighting
2. Image stabilization during windy conditions
3. Ability to use cameras for both detection and surveillance
4. How reliable is video image detection compared to other forms of detection?

5. Life-cycle costs compared to loops--are the functions and maintenance requirements of a video image detection system more desirable than loops? When is it more cost effective to use video image detection than loops?
6. Can video image detection provide link travel times?
7. Can detection zones be set in the field and at a central location?

Adaptive Signal Control

Definition

Adaptive signal control allows signal timing adjustments to be made based on real-time traffic demand sensed through vehicle detectors.

Benefits Adaptive Signal Control Begins to Provide

1. Reduced recurring and non-recurring congestion by implementing traffic signal timing plans to accommodate real-time traffic demand
2. Productivity enhancements for the City of Austin Transportation Division

Recommendations

1. Visit other areas using adaptive signal control to learn more about this signal timing approach and whether it is appropriate for Austin. Do not base decision on visit to one site using adaptive signal control.
2. Include adaptive signal control in the enhanced signal system design.
3. Investigate potential partnership with FHWA. The FHWA is currently developing an adaptive signal control system, "RT-TRACS"--"Real-Time TRaffic-Adaptive Control Systems." Eventually, RT-TRACS will need to be field tested. Why not test it in Austin? We would likely receive more consideration if we offered to share the cost of the field test. If Austin is chosen for the field test, it may change the following recommendations.
4. Select a pilot project location. An appropriate pilot project location would be one that experiences significant fluctuations in traffic volumes. Frontage roads experience

unpredictable volume changes when traffic diverts from the freeway during an incident. Adaptive signal control would allow the signal timing to adjust automatically to better accommodate the traffic demand. Since the City of Austin operates most of the frontage road signals on TxDOT's right-of-way, these two entities should form a partnership to deploy a pilot project. The pilot project should be deployed in the same area as TxDOT's freeway traffic management system. Arterial streets adjacent to special event centers also experience unpredictable volume changes when traffic is arriving and departing an event. Therefore, the signalized intersections around the Frank Erwin Center and the University of Texas football stadium may be ideal candidates for an adaptive signal control pilot project.

5. Design pilot project (e.g., detector locations).
6. Develop evaluation procedures.
7. Identify funding sources for pilot project.
8. Deploy pilot project.
9. Evaluate pilot project. Evaluation results should indicate whether to continue deployment.

<u>Justification</u>

1. <u>Reduced Recurring Congestion</u> Providing the most current signal timing plans minimizes delays incurred by motorists. For instance, Toronto's adaptive signal control system, SCOOT (Split, Cycle, and Offset Optimization Technique), during the peak periods, demonstrated a travel time savings ranging from six to 11 percent when compared to their current signal timing plans.[7] Current signal timing plans were those updated within the past five or more years. While the quality of these timings was not optimum, it was considered to be typical of the "best effort" that can be expected given the size of Toronto's signal network (1700 signals) and the current traffic engineering staff. Toronto's results indicate that there were overall improvements in on-street performance under SCOOT. That is not to say that SCOOT out-performs fixed timing plans for all locations, at all times, and under all circumstances, but rather it outperforms fixed timing plans under most of the circumstances studied.

2. <u>Productivity Enhancements</u> Adaptive signal control can reduce the need for additional manpower requirements to develop current signal timing plans. In Toronto, for example, an evaluation of their adaptive signal control program, SCOOT, found that six additional staff would be required to update existing fixed timing plans sufficiently to even come close to the level of on-street performance that SCOOT can provide within their demonstration network of 75 signals.[7] Less than one person was needed to for the same number of signals under SCOOT. The City of Austin typically collects turning movement counts (TMCs) on Tuesday, Wednesday, and Thursday for developing signal timing plans. If TMCs were only performed on these days, it would take a two-man data collection team roughly 3 years and 10 months to collect turning movement counts for the more than 600 signals the City of Austin currently maintains. Additional time is still required to develop and implement the signal timing plans. The need for additional manpower to developing signal timing plans could be significantly reduced by moving to an adaptive signal control system. As Austin continues to grow there will be a more frequent need to update signal timing plans to accommodate the corresponding growth in traffic volumes. Adaptive signal may reduce the need for additional signal timing manpower to keep pace with this growth. Delay and travel time savings may also be seen during the evenings and weekends.
3. <u>Additional Benefits Seen in Toronto, Ontario</u> In Toronto, Ontario[7], SCOOT was tested in three distinctively different signal environments: (1) 42 intersections within a central business district (CBD) grid network; (2) 20 intersections along a major limited access arterial street that operates parallel and as an alternate to a freeway; and (3) 13 intersections along a major unlimited access commercial arterial. Peak-period before and after studies revealed a six percent decrease in the CBD travel times, seven percent decrease on the parallel freeway route, and an 11 percent decrease on the arterial. Weekday evening before and after studies demonstrated a six percent reduction in travel times and a 21 percent reduction in stops. Weekend before and after studies resulted in a 15 percent reduction in travel times and a 34 percent reduction in stops. Vehicle delay decreased on average by 17 percent and ranged between a reduction of 6 percent and 26 percent for the three signal networks. During special events (Blue Jay's baseball game), vehicle stops and delays were

reduced by 58 percent and 61 percent, respectively. For the arterial, average overall intersection delay increased by 10 percent with a 22 percent decrease in stops. This increase was due to additional cross-street delays ranging from 25 percent to 35 percent Approximately five loops were installed per intersection. The SCOOT project began in July, 1990 with a capital cost of $1,225,000 (Canadian dollars, approx. $1,000,000 US). Annual fuel and travel time savings equalled $1,164,000. Annual maintenance and operations costs increased by approximately $50,000 (primarily due to increased maintenance requirements for more than 350 system loops required by SCOOT). Based on these figures, the payback period would be just over a year. A comprehensive benefit and cost analysis over 10-years indicated a benefit-to-cost ratio of over 8.0.

Potential Partners with the Department of Public Works and Transportation

Texas Department of Transportation

Travis County

FHWA

Issues/Questions

1. Is adaptive signal control appropriate for Austin?
2. Where should adaptive signal control be used? Time-of-day plans may be adequate in some locations.
3. How does adaptive signal control effect emissions?
4. What is the driver's perception of adaptive signal control?

Incident Management Program

Definition

Arterial-street incident management provides the ability to detect, verify, respond, and remove arterial-street incidents while actively managing the signal timing and disseminating information to motorists to avoid delays caused by incidents. These abilities, or functions, ensure aid to those injured arrives as soon as possible and the impact of the incident on the transportation system is minimized.

<u>Benefits Arterial-Street Incident Management Begins to Provide</u>

1. Reduced emergency response times
2. Reduced non-recurring congestion
3. Improved customer service
4. Reduced roadway incident detection times

<u>Recommendations</u>

1. Coordinate freeway incident management efforts with TxDOT. When traffic is diverted away from a freeway incident it will likely be diverted to the nearest arterial street. Signal timing can be adjusted on these arterial street to better accommodate diverted traffic. Since the City of Austin operates the signals on parallel freeway routes (e.g., frontage roads), it is imperative that the City of Austin partners with TxDOT to implement the most efficient response to freeway incidents.
2. A consultant may be needed to assist with developing an approach for arterial-street incident detection.
3. Establish an incident management team to coordinate the development, deployment, and evaluation of an arterial-street incident management plan. At a minimum, the City of Austin Transportation Division, Texas Department of Transportation, and public safety organizations should be represented on the team. A couple of tasks for the team would be (a) to identify issues with notifying transportation managers about roadway incidents and (b) to establish a method of notification.
4. Develop arterial-street incident management program: (a) to detect, verify, respond, and remove roadway incidents; (b) to manage traffic during incidents; and (c) to disseminate traveler information. Initially, focus on arterial streets with video cameras. Video cameras are necessary for incident verification. In addition, ensure public safety staff are aware of

transportation resources available to them to reduce their work load and facilitate the movement of traffic approaching the scene of an incident (e.g., the police do not have to direct traffic when the signal timing can be adjusted to accommodate traffic).

5. Develop evaluation procedures for measuring the effectiveness of an arterial-street incident management program. Involve public safety organizations.
6. Involve public safety organizations in video system design. This approach will begin to develop the foundation for the partnerships necessary for incident management between public safety and transportation organizations. It will also ensure they have access to the quality of video images that they need.
7. Deploy arterial-street incident management program.
8. Use traveler information recommendations to disseminate information to public about incidents.
9. Evaluate arterial-street incident management program to identify areas for improvement.

Justification

1. Improved Customer Service At this time, incident detection typically occurs through 911 calls. 911 calls enable public safety organizations to detect incidents, but not transportation managers who operate the signals. If traffic managers knew when and where roadway incidents occurred, signal timings could be adjusted to better accommodate the traffic impacted by the incident thereby reducing non-recurring congestion. Traffic management also benefits public safety organizations by reducing (a) the need for law enforcement to direct traffic (signal timings could be automatically adjusted to accommodate demand) and (b) the amount of traffic approaching the incident scene through disseminating traveler information. Therefore, transportation managers need to be informed about roadway incidents in order to provide the best service to the traveling public and public safety organizations.
2. Reduced Roadway Incident Detection Times Reduced roadway incident detection times benefit both public safety organizations and transportation managers. The sooner public safety organization are aware of a roadway incident, the sooner they can begin to dispatch

the appropriate response to aid the injured. At the same time, the sooner transportation managers are aware of a roadway incident, the sooner they can formulate a response to manage affected traffic. Measuring traffic flow characteristics (e.g., speeds, volumes, occupancies, travel times) and comparing those to time-of-day thresholds may provide a quicker detection time than 911 calls. This approach is currently used in cities like San Antonio to detect freeway incidents, but has not been applied to arterial streets. Another approach to potentially reduce detection times is to have the existing fleet of public service vehicles with two-way radios serve as "eyes" in the field to report incidents. Any of these approaches may reduce detection times which ultimately benefits those involved and affected by the incident.

3. Improved Response Times In San Antonio, the average response time for police to arrive at a roadway incident, following notification of an incident, averages 18 minutes.[5] More time is consumed as the officer determines the need for EMS, tow trucks, hazardous materials clean-up resources, and other support personnel. The average response time can be reduced, after incident notification, by using video surveillance cameras to determine the resources needed to assist the injured and clean-up the debris to restore traffic flow. These cameras can also be used by traffic managers to verify the incident and to ensure timely and accurate incident information is disseminated to the public.

Potential Partners with the Department of Public Works and Transportation

Public safety organizations

Texas Department of Transportation

Issues/Questions

1. How to involve transportation managers in the existing process used by public safety organizations to detect incidents through 911 calls and their units in the field. 911 and police dispatchers indicated that their work load during an emergency does not allow them to contact transportation organizations about roadway incidents.

2. Which approach to pursue for arterial-street incident detection (e.g., loops, video image detection, radar, public service fleets with two-way radios)?
3. How do we develop a partnership with public safety organizations and make them aware of our resources that can assist them? How do we ensure new officers are aware of the transportation resources available to them?
4. How do we disseminate traveler information?
5. Staffing requirements to ensure a response is implemented when public safety notifies traffic management personnel.

Signal Preemption

Definition

Signal preemption results in the signal indication turning green for an emergency vehicle responding to an emergency. Once the vehicle passes through the intersection, the signal returns to its normal routine. Currently, Austin uses 3M's opticom priority control system for signal preemption in a few locations (e.g., Ben White Boulevard, Parmer east of MoPac). Emitters, mounted on emergency vehicles, transmit an infrared signal when responding to an emergency. The infrared signal is recognized by detectors typically mounted on signal mastarms.

Benefits Signal Preemption Begins to Provide

1. Reduced emergency response times
2. Reduced emergency vehicle accident rates
3. Reduced public safety capital and operating costs

Recommendations

1. Incorporate emergency vehicle signal preemption into the enhanced signal system design.
2. Approach the University of Texas to perform an evaluation (possibly through a graduate class) of the proposed central business district (CBD) signal preemption system.

3. Develop evaluation procedures to measure effectiveness of signal preemption system proposed for downtown. EMS and Fire have databases that could assist with the evaluation. The evaluation should also consider whether another form of signal preemption may be more appropriate. For instance, if all emergency vehicles are tracked by global positioning system (GPS) units, their location and emergency status could be linked to the signal system. When a vehicle is responding to an emergency the signal system would know and automatically adjust the signal timing to ensure the vehicle receives a green indication in time to pass through the intersection. A GPS/automatic vehicle location (AVL) system may reduce maintenance costs since field equipment would not be deployed at the intersection. A GPS/AVL system may address line-of-sight issues with the opticom system (e.g., if an emergency vehicle turns a corner, the adjacent signal may not have time to turn green before the emergency vehicle arrives).
4. Deploy signal preemption system in the CBD.
5. Evaluate system.
6. Identify methods that minimize the impact of signal preemption.
7. Make decision to expand system. If decision is to expand, pursue following approach.
8. Identify priority locations. Discuss with emergency organizations to identify priority locations.
9. Develop evaluation procedures.
10. Deploy system.
11. Evaluate system effectiveness periodically (e.g., annually)..

Justification

1. Reduced Emergency Response Times Studies in Houston and Denver have realized a 20 percent average improvement in emergency response times with a signal preemption system in place.[6]
2. Reduced Emergency Vehicle Accident Rates A 12-year study in a major metropolitan area reported that the signal preemption system reduced emergency vehicle accident rates by 70.8 percent at signalized intersections.[6]

Issues/Questions

1. What is the impact on the traffic stream?
2. What is the most appropriate form of signal preemption in the long term?

Transit Signal Priority

Definition

In its simplest definition, transit signal priority provides additional green time to transit vehicles at signalized intersections. The conditions that need to be met for a transit vehicle to receive this green time depends on the criteria established by those who operate the signals and transit vehicles. Some examples of those conditions include:

1. green time is extended every time a transit vehicle approaches a signalized intersection,
2. green time is extended only when the bus is behind schedule and arrives during a certain period of the signal cycle (This approach is currently used in a pilot project in Austin.), and
3. additional green time is provided to the transit vehicle based on the number of passengers (i.e., the bus is weighted more heavily than a vehicle with only a driver).

Benefits Transit Signal Priority Begins to Provide

1. Improved on-time transit performance which leads to improved customer service
2. Reduced recurring congestion by travelers switching to transit

Recommendations

1. Review the findings from the University of Texas CTR's study of the Transit Signal Priority Pilot Project on Lamar Boulevard to decide whether or not to expand the existing priority system.
2. Integrate smart buses into the design of the enhanced signal system. The City of Austin Transportation Division should work closely with Capital Metro. This integration should

allow priority to be provided to all transit vehicles (buses and light rail vehicles) based on the number of passengers aboard. This approach should minimize people delay. The impact that this approach has on progression would need to be considered.

3. Identify potential funding through the FHWA and the Federal Transit Administration.
4. Develop evaluation procedures to assess impacts of passenger weighted signal timing system. People-delay will likely decrease.
5. Deploy pilot study. The City of Austin Transportation Division and Capital Metro should mutually agree on the pilot study location.
6. Evaluate pilot study.
7. Decide on expansion.

Justification

1. CTR's Findings CTR's findings will explain the benefits and limitations seen within the existing approach used for transit signal priority along the Lamar Boulevard Pilot Project. These findings may suggest another approach to transit signal priority.
2. Passenger Weighted Transit Signal Priority Why should a bus with 30 passengers be treated equally as one automobile with one passenger? Providing more green time to transit vehicles based on the number of passengers may reduce existing transit travel times. Reducing their travel times may make transit a more attractive mode of transportation than the automobile to certain travelers. Attracting people away from their automobiles and into transit vehicles, maximizes the use of existing roadway capacity which in turn reduces recurring congestion, emissions, fuel consumption, and driver frustration. Maximizing existing roadway capacity also prolongs the need for expansion. Therefore, if the travel time savings provided by passenger weighted transit signal priority attracts people to transit who use to drive their automobiles, benefits will be seen throughout the transportation system.

   Although existing technologies may require equal treatment between loaded buses and automobiles, technologies will provide these capabilities in the future. At a minimum, for this type of transit signal priority to occur, information about the bus' location and number of passengers will need to be incorporated into the signal timing logic. Systems already exist that provide automatic vehicle location and automatic passenger counting. It is unknown whether integrating this information with the signal system has been performed previously.

Potential Partners with the Department of Public works and Transportation

Capital Metro

FHWA/Federal Transit Administration

Issues/Questions

1. What impact does extending the green time for Lamar Boulevard buses have on cross-street buses and automobiles?
2. How beneficial is the existing approach to transit signal priority for buses involved in the Lamar Boulevard pilot project?
3. Does the signal system need to provide adaptive signal control in order to adjust the signal timing based on the weighted passenger value of a bus? The signal system would need to respond to the number of passengers on a transit vehicle. Successive transit vehicles will likely differ in the amount of passengers that they are transporting.
4. How is data from Capital Metro's Smart Bus System integrated into the signal system?
5. When is a bus far enough behind schedule to require signal priority? Should the transit scheduled be altered if the bus is consistently behind schedule?
6. Does passenger weighted signal timing increase ridership?

Arterial-Street Travel Time Measurement

Definition

Arterial-street travel time measurement permits the collection of travel times on each link (at a minimum, signal-to-signal) of an arterial street.

Benefits Arterial-Street Travel Time Measurements Begin to Provide

1. Reduced emergency response times
2. Improved traveler information and reduced recurring and non-recurring congestion
3. Improved incident detection (potentially)
4. Productivity enhancements within the Transportation Division and commercial fleets

Recommendations

1. Meet with CTR to identify most feasible method to collect arterial-street travel time information.
2. Meet with public safety organizations to ensure they can use travel time information. Coordinate with the existing CAD/MDT (computer aided dispatch/mobile data terminal) team to ensure travel time data can be incorporated into their design.
3. Incorporate arterial-street travel time measurements into the design of the enhanced signal system.
4. Select site for pilot project and design pilot project (e.g., detector locations).
5. Develop evaluation procedures to ensure the utilization of real-time travel time measurements are beneficial to the users.
6. Identify funding sources for pilot project.
7. Deploy arterial-street travel time data collection pilot study.
8. Evaluate arterial-street travel time data collection system and decide whether or not to expand.

Justification

1. Reduced Emergency Response Times The ability to collect real-time travel time data between arterial-street signalized intersections can be used by public safety organizations to determine the shortest travel time route to an emergency. Travel time information may also assist Fire and EMS staff with planning the location of new stations to meet their response time goals.

2. Improved Traveler Information Travel time data can be provided to travelers to make informed travel decisions about routes and departure times, ultimately avoiding the impacts of recurring and non-recurring congestion. This information could be provided through real-time traffic report maps like those used in Houston, Chicago, and Los Angeles. This information could also be provided over the phone similar to what is done in Chicago. Mode decisions can also be made if travel time data is available for comparisons between competing transportation modes (e.g., light rail transit and automobiles). Eventually, travel time information could be linked to in-vehicle navigation systems, like those currently used in San Jose, San Francisco, and Miami (real-time traffic information is not incorporated into the navigational systems used in these areas), to direct motorists along the shortest travel time path to their destination. Real-time travel time information was used in identifying the shortest travel time route for test vehicles in the completed TravTek Project in Orlando and the current ADVANCE Project in Chicago.
3. Improved Incident Detection Measuring real-time travel times may provide a means of incident detection. The sooner a roadway incident is detected the sooner emergency resources can be dispatched and traffic delays can be reduced.
4. Productivity Enhancements--Transportation Division Two programs within the Transportation Division require travel time studies to be performed. The first program, Congestion Demand Management, conducts annual travel time studies to monitor changes in roadway congestion. The other program, signal timing, performs before and after travel time studies to evaluate the effectiveness of signal timing improvements. If real-time travel time data was available, the time required to collect this data would be eliminated.
5. Productivity Enhancements--Commercial Fleets Travel time information could also be input into the process used to develop delivery schedules. In addition, travel time information would be critical to those companies who provide just-in-time deliveries.

Potential Partners with the Department of Public Works and Transportation

Public safety organizations

Commercial fleet operators

Issues/Questions

1. Identify an accurate method to collect arterial-street travel times, possibilities include:
    a. mid-block (i.e., system) loops
    b. high mounted video image detection cameras
    c. automatic vehicle identification
    d. ?
2. Will public safety organizations be able to use this information?

Reversible Lanes

Definition

Two-way arterial streets, particularly those in urban areas that serve commuter traffic, can experience much greater peak-hour traffic volumes in one direction than in the other. Reversible lane systems involve designating one or more lanes for one-way movement during part of the day and in the opposite direction during another part of the day. The purpose of reversible lanes is to provide an extra lane or lanes for use by the dominant flow of traffic. Providing an additional lane or lanes results in increased capacity in the peak direction without widening the roadway. In addition, reversible lanes may also be appropriate around special event facilities that require moving a considerable amount of traffic to and from the event.

Benefits Reversible Lanes Begin to Provide

1. Reduced recurring congestion

Recommendations

1. The ability to control reversible lane equipment should be included in the enhanced signal system design.
2. Identify locations for reversible lanes. The following process is suggested for identifying locations:

a. Review directional traffic volumes for the priority roadways established by the Austin ITS Steering Committee to identify potential locations for reversible lanes. Roadways with evenly split directional volumes during the peak periods are probably not candidates for reversible lanes.

b. Ask the Transportation Division staff to identify candidate locations for reversible lanes since they are most familiar with the transportation system

c. Inventory roadway geometrics.

d. Collect turning movement volumes at candidate locations for several days to determine peak conditions for modeling reversible lanes. Conservative traffic volume counts may produce unrealistically optimistic modeling results.

3. Model candidate locations with and without reversible lanes. Modeling (a) identifies whether or not the reversible lanes are feasible or where further analysis may be needed and (b) allows a comparison between with and without scenarios to measure the effectiveness of reversible lanes.
4. Select pilot project locations.
5. Design pilot project (e.g., sign locations).
6. Develop evaluation procedures.
7. Develop consensus among the public to implement reversible lanes.
8. Educate the public about how reversible lanes operate and the signing used to indicate which direction traffic is permitted to flow.
9. Implement reversible lanes.
10. Evaluate pilot project to decide whether or not their use should be continued.
11. Disseminate findings to decision makers and the public.

Justification

1. Increased Capacity Reversible lanes provide a method to increase capacity without widening the existing roadway. Increased capacity can reduce the impact of recurring congestion.

Potential Partners with the Department of Public Works and Transportation

Texas Department of Transportation

Issues/Questions

1. Public support
2. Safety--ensuring motorists know which direction traffic is flowing in the reversible lanes
3. Impact on off-peak direction
4. Operational problems where reversible lanes terminate
5. Method of designating lanes to be reversed and the direction of flow--Three general methods are used: (a) special traffic signals suspended over each lane; (b) permanent signs advising motorist of the changes in traffic flow and the hours it is in effect; and (c) physical barriers (e.g., traffic cones, movable barriers).

TENTATIVE DEPLOYMENT SCHEDULE

Below is a tentative deployment schedule developed by the City of Austin Transportation Division (refer to **Table VB-1**). The schedule reflects the approximate time to begin planning, designing, deploying pilot projects, and continuing with deployment (if pilot study is successful), operations, and maintenance. The recommended projects will likely change as new technologies and strategies emerge and as opportunities arise. One element of the consultant's scope-of-work for the enhanced signal system design should be a finalized implementation schedule identifying the order in which each recommendation should be deployed.

Table VB-1. City of Austin Tentative ITS Deployment Schedule

No.	Recommendation	1996				1997				1998				1999				2000				2001				2002			
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
1	Enhanced Signal System	plan		design				deploy/operate/maintain 6																					
2	Video Surveillance Camera System	plan		design				deploy pilot				e	deploy/operate/maintain 6																
3	Management Center	plan			design				construct				operate					e		operate/maintain 6									
4	Traveler Information	plan		design					deploy pilot				e	deploy/operate/maintain 6															
5	Dynamic Lane Control Signs			plan		d		e	deploy/operate/maintain 6																				
6	Advanced Traffic Controllers	plan		design				deploy pilot				e	deploy/operate/maintain 6																
7	Video Image Detection	plan		design				deploy pilot				e	deploy/operate/maintain 6																
8	Adaptive Signal Control	plan		design				deploy pilot				e	deploy/operate/maintain 6																
9	Arterial-Street Incident Mgmt. Prg.	plan		design									deploy pilot					e		deploy/op./maintain 6									
10	Signal Preemption			deploy CBD				e	deploy/operate/maintain 6																				
11	Transit Signal Priority	plan		design				deploy pilot				e	deploy/operate/maintain 6																
12	Arterial-Street Travel Time Measurement	plan		design					deploy pilot				e	deploy/operate/maintain 6															
13	Reversible Lanes																				plan		design			dp	e	d/o/m	

Note: e = evaluate, d = design, dp = deploy pilot, o = operate, m = maintain

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